AMENDED DESIGN/BUILD AGREEMENT

NIAGARA TUNNEL FACILITY PROJECT

December 1, 2008

Between

ONTARIO POWER GENERATION INC.

and

STRABAG INC.

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AMENDED DESIGN/BUILD AGREEMENT

This Agreement is made as of December 1, 2008 (the "**Effective Date**"), between

ONTARIO POWER GENERATION INC., a corporation existing under the laws of Ontario ("**OPG**" or "**Owner**"),

and

STRABAG INC., a corporation existing under the laws of Ontario (the "**Contractor**").

RECITALS

(A) OPG owns the Sir Adam Beck generating stations 1 and 2 and the pump generating stations (the "**Sir Adam Beck Generating Complex**") located in Niagara Falls, Ontario.

(B) OPG originally retained the Contractor to perform the Work in connection with the Tunnel Facility Project for a fixed price and according to an agreed contract schedule pursuant to the Design/Build Agreement between the Parties dated August 18, 2005 as amended by: (i) Amendment 1, dated March 15, 2006; (ii) Amendment 2, dated July 5, 2006; (iii) Amendment 3, dated October 10, 2007; (iv) Amendment 4, dated November 7, 2007; and (v) Amendment 5, dated September 25, 2008 (the "**Original Agreement**").

(C) The Original Agreement was assigned by Strabag AG to Strabag Inc. on August 15, 2005.

(D) A dispute arose between the parties with regard to the existence of differing subsurface conditions (DSCs) under the Original Agreement. The Parties referred this dispute to the dispute review board (the "**Dispute Review Board**") under the Original Agreement and sought the recommendation of the Dispute Review Board. While the Parties have not reached an agreement on the existence of the DSCs, following the recommendation of the Dispute Review Board, the Parties entered into discussions and agreed to a Principles of Agreement (the "**Principles of Agreement**") dated November 11, 2008 in which the Parties agreed to a settlement to all issues, claims and actions related to the DSC claim submitted to the Dispute Review Board.

(E) As part of the settlement set out in the Principles of Agreement, OPG agreed to make a one-time payment to the Contractor (the "Settlement Payment") for cost over-runs incurred prior to the Effective Date and the Parties agreed to amend the Original Agreement to reflect an open book Target Cost contract for the remainder of the Work. The Parties wish to set out such open book Target Cost contract in this Agreement.

(F) The Parties have agreed on an optimized alignment which has been reflected in Project Change Directive-031 and the Parties have agreed to amend the Original Agreement as part of this Agreement by including the applicable revised concept drawing in Appendix 1.1(h) to give effect to such optimized alignment.

(G) All the terms between the Parties respecting the Project are set out in this Agreement.

For value received, the Parties agree as follows.

SECTION 1. INTERPRETATION

1.1 Definitions

In this Agreement, the following terms have the respective meanings set out below.

(A) **Actual Cost** means $302,198,485.22 (subject to adjustment to reflect the final amount of the Settlement Payment in accordance with Section 2.1(j)) for Work prior to the Effective Date, plus the cumulative amount of Allowed Cost from and after the Effective Date, and net of (i) the proceeds realized by the Contractor on the sale or other disposition of the TBM, TBM Accessories and any other materials, equipment or vehicles procured by the Contractor for the Work and (ii) any insurance proceeds received by the Contractor under any insurance policy carried hereunder in respect of Allowed Costs. For greater clarity, insurance proceeds received by OPG in respect of Disallowed Costs shall be paid by OPG to the Contractor.

(a) **Agreement** means this design/build agreement, including any recitals, schedules, Appendices and Final Submittals, as amended or restated from time to time by an Amendment.

(AA) **Allowed Cost** means each cost that is not a Disallowed Cost and is incurred by the Contractor in the performance of the Work, including the actual cost invoiced to the Contractor by Subcontractors pursuant to the agreement between the Contractor and the Subcontractor (including amounts paid by the Contractor to settle claims of Subcontractors in accordance with Section 2.14(c)). For greater clarity and notwithstanding anything to the contrary in this Agreement, all costs of the Contractor incurred in the performance of the Work are Allowed Costs, including adjustments for gains or losses for foreign exchange on costs and revenues, plus hedging costs to which OPG has agreed, unless they are expressed to be Disallowed Costs and wherever in this Agreement a matter is expressed to be the responsibility or at the risk of the Contractor the costs of such matter shall be Allowed Costs, unless they are expressed to be Disallowed Costs.

(b) **Amendment** means a written amendment agreement signed by the Parties, in the form of document, attached as Appendix 1.1(b), or in the form of a Project Change Directive deemed to be an amendment pursuant to Section 5.1(d), which makes any change to this Agreement.

(c) **Applicable Laws**, in respect of any Person, property, transaction or event, means all applicable laws, statutes, regulations, treaties, judgments and decrees applicable to that Person, property, transaction or event at the applicable time and, whether or not having the force of law, all applicable Approvals, requirements, requests, directives, rules, guidelines, codes, standards, instructions, circulars,

manuals, and policies of any Governmental Authority having or purporting to have authority over that Person, property, transaction or event at the applicable time.

(d) **Application for Payment** means the application for payment delivered by the Contractor to OPG's Designated Delegate in accordance with Section 7.2, accompanied by completed forms of the documents set out in Appendix 1.1(d) or Appendix 7.14(a), as applicable.

(e) **Approvals** means any permits, licences, consents, approvals, clearances, orders, ordinances, registrations, filings or other authorizations respecting the Work or Tunnel Facility Project as may be required from any applicable Governmental Authorities or by this Agreement and, for greater certainty, includes the Environmental Assessment and the Environmental Assessment Approval, and all approvals, programs, plans, procedures and clearances required thereunder.

(f) **Business Day** means any day other than a Saturday, Sunday, New Year's Day, Family Day, Good Friday, Easter Monday, Victoria Day, Canada Day, Civic Holiday, Labour Day, Thanksgiving Day, Christmas Day and Boxing Day. Each Business Day will end at 5:00 p.m. on that day.

(F) **Change in Law** is defined in Section 5.3.

(g) **Community Impact Agreement** means the agreement made December 22, 1993 between The Corporation of the Regional Municipality of Niagara, the Corporation of the Town of Niagara-on-the-Lake, the Corporation of the City of Niagara Falls and Ontario Hydro.

(h) **Concept Drawings** means the drawings provided to the Contractor by OPG and listed in Appendix 1.1(h).

(i) **Confidential Information** is defined in Section 2.17(a).

(j) **Contract Price** means:

(1) if Actual Cost is greater than Target Cost:
Actual Cost less the Cost Performance Disincentive; and

(2) if Actual Cost is less than Target Cost:
Actual Cost plus the Cost Performance Incentive

in each case plus or minus the other incentives or disincentives payable under Sections 8.1, 8.2, 8.3, 8.4, 8.7 or 8.8 and plus the Overhead Recovery Fee.

(k) **Contract Schedule** means Appendix 1.1(k) which sets out the numbers of days and/or the dates to achieve certain milestones, including the Substantial Completion Date, as amended and/or restated from time to time in accordance with an Amendment.

(l) **Contractor's Personnel** means all personnel, including the Contractor's representative and the site manager, used by the Contractor or assisting the Contractor in the performance of the Work, including any personnel, staff, labour, employees, shareholders, directors, officers, partners, members, representatives, agents, consultants, experts and any other workers, of the Contractor or a Subcontractor, any Subcontractor who is an individual, and any other Person for whom the Contractor or any Subcontractor is responsible.

(m) **Contractor's Proposal Documents** means the Preliminary Design and Construction Approach, the Outline Specifications, the GBR, the Draft Drawings, the Draft Specifications for the TBM, the Outline Environmental Management Plan, the Outline Quality Assurance/Quality Control Program, the Preliminary Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the Preliminary INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the on-Site total monthly trade labour hours set out in Appendix 1.1(hhh), the Acknowledgment of Labour Requirements Clause and the list of Key Personnel, all as appended to this Agreement and provided by the Contractor to OPG in response to OPG's request for proposals for performance of the Work (which may or may not have been amended through negotiations between the Parties prior to being incorporated into this Agreement).

(M) **Cost Performance Disincentive** is defined in Section 8.4A.

(MM) **Cost Performance Incentive** is defined in Section 8.4B.

(n) **Defective** means:

(1) any part of the Work or Tunnel Facility Project that is defective in whole or in part, is inoperative, fails in any way to perform to specification or meet design tolerances because of any defect or does not comply with this Agreement, including any failure to comply with any requirement of the Owner's Mandatory Requirements or any Final Submittal, reference standard, inspection, test or Approval required for the Work or otherwise referred to in this Agreement, including whether or not the non-compliance is the result of defective Work (including design, workmanship and installation); or

(2) any part of the Goods or Tunnel Facility Project that was damaged on or before the Final Completion Date (but excluding damage that was caused by OPG and occurred after Substantial Completion to a part of the Tunnel Facility Project for which OPG was responsible at the time the damage occurred).

(N) **Dispute** is defined in Section 11.1.

(o) **Disallowance Advisory** means a notice in the form attached as Appendix 1.1(o).

(O) **Disallowed Cost** means any cost in the categories set out in below:

(1) any cost arising from, or incurred as a result of:

(i) the wilful misconduct of the Contractor, a Subcontractor or any member of the Contractor's Personnel; or

(ii) the failure by the Contractor, a Subcontractor or any member of the Contractor's Personnel to exercise the degree of care that would be reasonably expected of a TBM tunnelling contractor on a substantially similar project and under similar contractual arrangements. Included in the foregoing standard is an acknowledgement by the Parties that certain unplanned downtime, inefficiency, repairs, replacement, lost time and other consequences of mistakes are anticipated to occur on the Project and by agreement have been included in the Target Cost and shall be Allowed Costs; or

(iii) any act or omission of the Contractor, a Subcontractor or any member of the Contractor's Personnel which in the opinion of OPG, acting reasonably, would constitute a failure of the Contractor or any member of the Contractor's Personnel to meet the standard set out in subsection (ii) and for which OPG has provided a Disallowance Advisory prior to such act or omission.

Notwithstanding the foregoing, no costs shall be considered Disallowed Cost under subsection (i), (ii) or (iii) above unless OPG has provided the Contractor with a Disallowed Cost Notice notifying the Contractor of an instance of wilful misconduct or of conduct that falls below the standard in subsection (ii) or of an act or omission that contravenes a Disallowance Advisory immediately upon OPG having knowledge of the relevant conduct, but in any event no later than five (5) Business Days of the date that OPG has knowledge of the relevant conduct or within six (6) months after such conduct occurred, whichever is earlier. In addition, any cost in subsection (ii) will only be a Disallowed Cost if such cost is greater than $75,000 per occurrence. For greater clarity with respect to subsection (iii) above, the Contractor will have the right to dispute in accordance with Section 11.1 whether OPG acted reasonably in its determination whether the Contractor, a Subcontractor or Contractor's Personnel met the standard in subsection (ii);

(2) business development costs incurred by the Contractor, unless solely related to the Work or the Tunnel Facility Project and approved in advance by OPG;

(3) costs which cannot be reasonably justified by the Contractor's accounts and records;

(4) costs to vacate liens filed by the Contractor or by any Subcontractor due to Contractor's non-payment of amounts payable under a contract between the Contractor and Subcontractor, other than amounts disputed in good faith, unless such non-payment was approved in advance by OPG;

(5) head office costs: meaning non-project related costs of any kind from affiliated companies or parent or other inter-company charges or costs (excluding affiliated company charges or costs approved by OPG in advance for Work incorporated into the Project). For greater clarity, such excluded costs include costs for executive and operations management, planning, administration, treasury, human resources, tax planning and administration, benefits and administration, legal services, real estate services, accounting and financial reporting, auditing, cash management, information systems, training, safety policies and administration, risk management and corporate insurance policies and insurance administration, marketing and business development;

(6) income taxes & withholding taxes;

(7) tax equalization costs;

(8) costs of social events where the costs have not been mutually agreed by the Parties;

(9) costs of the Contractor's staff not shown as being directly subordinate to the Contractor's site project manager on the Organizational Chart in Appendix 2.2(a);

(10) travel and relocation costs for the Contractor's staff exceeding current limits as set by the Contractor's policy provided to OPG under Section 2.8(a);

(11) accommodation costs for the Contractor's staff exceeding the amounts set by the Contractor's 2009 policy provided to OPG under Section 2.8(a) where such excess is more than the applicable inflation rate;

(12) legal costs incurred by the Contractor for any claims, actions or proceedings against or negotiations with OPG, subject to any ruling by an arbitrator under Section 11.2;

(13) costs arising from the failure of the Contractor to comply with its obligations in Section 2.14(e), provided that costs incurred as a result of grievances filed against the Contractor will only be Disallowed Costs where the Contractor has accepted the position asserted in the grievance (not including settlements unless the Contractor expressly accepts the

position asserted) or where the grievance is upheld when the matter is finally determined by the Labour Relations Board (Ontario);

(14) costs arising from a breach of Applicable Law by the Contractor or any Subcontractor or any person for whom the Contractor or any Subcontractor is at law responsible, including any fines or charges arising from a breach of Applicable Law;

(15) interest costs, except as permitted under Sections 7.3(b) and 7.3B(5);

(16) any costs in respect of any indemnity in favour of any member of OPG Group payable by the Contractor under this Agreement;

(17) any costs in respect of liability to Third Parties, including any legal costs in connection with any Third Party liability claims;

(18) any disallowed deductibles under Section 4.3(f); and

(19) any item specified in this Agreement to be a Disallowed Cost in Sections 2.4(f)(4); 2.8(f) 2.9(c); 2.14(i); 2.16(e); 2.20(g)(4); 4.2; 9.1(a)(2); 9.3; 9.4(a); 9.4(c); 9.7(b) and 9.8(b).

(p) **INTENTIONALLY DELETED**.

(P) **Disallowed Cost Notice** means a form of specific notice of a Disallowed Cost using the form attached in Appendix 1.1(P).

(q) **INTENTIONALLY DELETED**.

(r) **Preliminary Design and Construction Approach** means the design and construction approach prepared by the Contractor and set out in Appendix 1.1(r).

(s) **Draft Drawings** means the 30% complete drawings prepared by the Contractor and listed in Appendix 1.1(s).

(t) **Draft Specifications for the TBM** means the specifications prepared by the Contractor and set out in Appendix 1.1(t).

(u) **Drawings** means the drawings to be provided by the Contractor in accordance with this Agreement.

(U) **Effective Date** means December 1, 2008.

(v) **Environmental Assessment** (or **EA**) means the Niagara River Hydroelectric Development Environmental Assessment dated March 1991, including the update of July 13, 1992, and the amendment of June 3, 1993, all as approved by the Environmental Assessment Approval.

(w) **Environmental Assessment Approval** (or **EA Approval**) means the environmental assessment approval, dated October 14, 1998, approved by Order in Council Number 2283/98.

(x) **INTENTIONALLY DELETED**.

(y) **Final Completion Date** means the day which is the later of:

(1) the day on which OPG accepts the Work as being entirely finished under Section 7.10(a);

(2) the day on which the Contractor has delivered to OPG the Maintenance Bond described in Section 4.1(f);

(3) the day on which the Contractor, subject to the maximum disincentive set out in Section 8.5, has paid to OPG all amounts owing to OPG pursuant to Sections 8.1, 8.3 and 8.4A; and

(4) the day on which the Actual Costs relating to the Work are known.

(z) **Final Submittal** is defined in Section 2.8(g). For greater clarity, any Final Submittals submitted under the Original Agreement continue as Final Submittals hereunder as of the Effective Date.

(aa) **Flow Verification Test** means the test and procedures described in Appendix 1.1(aa).

(bb) **Geotechnical Baseline Report** (**GBR**) means the geotechnical baseline report included in the Original Agreement and replaced as of the Effective Date with the GR.

(BB) **Geotechnical Report (GR)** means the Geotechnical Report attached as Appendix 5.4.

(cc) **Goods** means any goods, materials, instruments, devices, articles, supplies, equipment, machinery, structures and assemblies, or components of any of them, including the TBM, delivered or required to be delivered to the Site, to OPG or to such place or Person as OPG may direct, under this Agreement, whether or not incorporated into the Project.

(dd) **Governmental Authority** means any domestic or foreign government, including, any federal, provincial, state, territorial, municipal or local government, and any government established court, agency, tribunal, commission or other authority exercising or purporting to exercise executive, legislative, judicial, regulatory or administrative functions respecting government.

(ee) **Guaranteed Flow Amount** (or **GFA**) means 500 cubic meters per second (m^3/s) at the reference hydraulic head and the reference elevation of energy grade line defined in Appendix 1.1(aa).

(ff) **Hazardous Material** means any substance, material, solid, liquid or gas, waste (including "subject waste", as defined in Regulation 347 under the *Environmental Protection Act* (Ontario)) exposure to which is prohibited, limited or regulated by any Applicable Law or the Contractor's environmental management plan.

(gg) **INCW** means the International Niagara Control Works Structure.

(hh) **INCW Part Project** means the portion of the Work that is described in Appendix 1.1(sss), Section 3.1(h) under the heading "INCW Part Project Area" and on the Concept Drawings as the "INCW Part Project Area".

(ii) **INCW Part Project Area** means the area defined on the Concept Drawings.

(jj) **INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan** is defined in Section 2.20(d).

(kk) **INTENTIONALLY DELETED**.

(KK) **Insurable Event** is defined in Section 5.1A(d).

(ll) **Interim Completion Fee** is defined in Section 8.7.

(LL) **Lien** means any:

(1) lien, charge, attachment, security interest, mortgage, hypothec, claim, deemed trust or other encumbrance, whether fixed or floating, including any lien arising in respect of the *Construction Lien Act* (Ontario);

(2) pledge or hypothecation; or

(3) deposit arrangement, priority, conditional sale agreement or other title retention agreement, equipment trust, capital lease or other security arrangement of any kind,

respecting any property, whether real, personal or mixed, tangible or intangible.

(mm) **Losses** means all claims, demands, costs, penalties, expenses, liabilities, injuries, fines, losses and damages (including all fees and charges of engineers, architects, accountants, lawyers and other professionals and experts (in each case on a dollar for dollar full indemnification basis) and all court, arbitration and other dispute, mediation or resolution costs and charges), whether incurred through settlement or otherwise, together with interest at the rate equivalent to the prevailing Bank of Canada Prime Lending Rate plus 2% annually, compounded monthly, and

calculated from the date that the Losses were suffered or incurred, in each case whether arising before or after the termination of this Agreement.

(nn) **INTENTIONALLY DELETED**.

(NN) **Major Risk Event** means an event listed on Appendix 5.3C.

(NNN) **Major Subcontractor** means a Subcontractor where the value of all contracts with such Subcontractor exceeds $100,000 in the aggregate amount.

(oo) **Notice** means any notice, approval, demand, direction, instruction, consent, designation, request, document, instrument, certificate or other communication required or permitted to be given under this Agreement.

(OO) **Notice of Informal Resolution** means a notice in the form attached as Appendix 11.1(b).

(pp) **OPG Group** means OPG, each of OPG's wholly-owned subsidiaries and each of OPG's and each such subsidiary's shareholders, directors, officers, employees, representatives, agents and advisors, including OPG's Representative and OPG's Designated Delegates, but, for greater certainty, excluding the Contractor, each Subcontractor and each of the Contractor's and each Subcontractor's shareholders, directors, officers, partners, members, employees, representatives, agents, advisors, the Contractor's Personnel and any other Person for whom the Contractor or any Subcontractor is responsible at law.

(PP) **OPG Caused Event** is defined in Section 5.4.

(qq) **OPG's Designated Delegates** means Persons, who may or may not be employees of OPG, who have been designated, from time to time, in writing by OPG's Representative, in a Notice in the form of document attached as Appendix 1.1(qq) as delegates of OPG, within a specified scope and limits of authority, by OPG's Representative or are otherwise named as OPG's delegates in this Agreement.

(rr) **OPG's Representative** means the individual designated in writing by OPG from time to time to act as OPG's representative for all purposes in dealings with the Contractor under this Agreement.

(ss) **Outlet Canal Facility** means the outlet canal and the immediately adjacent 50 metres length of diversion tunnel.

(SS) **Outline Environmental Management Plan** means the plan prepared by the Contractor and set out in Appendix 2.5(a)(3).

(tt) **Outline Quality Assurance/Quality Control Program** means the outline of the quality assurance and quality control program prepared by the Contractor and set out in Appendix 2.12(c)(2).

(uu) **Outline Specifications** means the specifications prepared by the Contractor and set out in Appendix 1.1(uu).

(UU) **Overhead Recovery Fee** means 5% of Actual Costs incurred on or after the Effective Date. For greater certainty, the Overhead Recovery Fee shall apply only to the Actual Costs incurred by the Contractor on or after the Effective Date but does not apply to the $302,198,485.22 (subject to adjustment to reflect the final amount of the Settlement Payment in accordance with Section 2.1(j)) payable in respect of the pre-Effective Date period. For the purposes of the calculation of the Overhead Recovery Fee, Actual Costs shall not be reduced by the proceeds realized by the Contractor on the sale or other disposition of the TBM, TBM Accessories and other materials, equipment or vehicles procured by the Contractor for the Work or the proceeds of insurance.

(vv) **Owner's Mandatory Requirements** means OPG's minimum mandatory requirements for the Work set out in Appendix 1.1(vv), as amended or restated by an Amendment from time to time.

(ww) **Party (or Parties)** means OPG and/or the Contractor together with their respective successors and permitted assigns.

(xx) **Performance LC(s)** is defined in Section 4.1(d).

(yy) **Performance Test Water Flow Amount** (or **PTWFA**) means the water flow amount determined by the water flow performance test performed in accordance with the Flow Verification Test.

(YY) **Person** means any individual, sole proprietorship, partnership, corporation or company, with or without share capital, trust, foundation, joint venture, Governmental Authority or any other incorporated or unincorporated entity or association of any nature.

(zz) **Pre-Effective Date Loss** is defined in Section 2.1(j).

(ZZ) **Preliminary Design and Construction Approach** means the design and construction approach prepared by the Contractor and set out in Appendix 1.1(r).

(aaa) **Preliminary INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan** means the preliminary project specific site safety, security, public safety and emergency response plan prepared by the Contractor for the INCW Part Project and set out in Appendix 2.20(d).

(bbb) **INTENTIONALLY DELETED**.

(ccc) **Preliminary Project Specific Site Safety**, **Security, Public Safety and Emergency Response Plan** means the preliminary project specific site safety, security, public safety and emergency plan prepared by the Contractor and set out in Appendix 2.4(d).

(ddd) **INTENTIONALLY DELETED**.

(eee) **Professional** means a licensed professional, including engineers and architects, duly licensed in Ontario, and designated by the Contractor, to provide, in whole or in part, any of the Professional Services.

(fff) **Professional Services** means all the services in respect of this Agreement, including respecting documents, designs, drawings (including as built drawings), diagrams, illustrations, schedules, performance charts, brochures, specifications, plans, progress photographs, reports, manuals (including operating and maintenance manuals), information, data or other deliverables, models or samples whether in a written, graphic, physical, electronic or other format provided, or required to be provided, by the Contractor to OPG under this Agreement, that are:

(1) required under Applicable Laws or any Approvals to be provided by a Professional;

(2) required by this Agreement to be provided by a Professional;

(3) provided by a Professional retained by the Contractor, including by the Contractor's Personnel, to the extent services provided by such Professional are within such Professional's professional capacity; or

(4) necessary for performance of the Work.

(ggg) **Project** means all of the planning, approvals, design and construction elements contemplated for the diversion tunnel and associated works of which the Tunnel Facility Project forms a part.

(hhh) **Project Change Directive** means a written directive or consent signed by OPG's Representative, in the form of document attached as Appendix 1.1(hhh).

(iii) **Project Change Notice** means a written notice signed by the Contractor, in the form of the document attached as Appendix 1.1(iii).

(jjj) **Project Specific Site Safety, Security, Public Safety and Emergency Response Plan** is defined in Section 2.4(d).

(kkk) **INTENTIONALLY DELETED**.

(KKK) **Released Claims** is defined in Section 2.1(h).

(lll) **Schedule Performance Disincentive** is defined in Section 8.1.

(LLL) **Schedule Performance Incentive** is defined in Section 8.2.

(mmm) **Settlement Payment** is defined in Recital E;

(MMM) **Site** means (a) the areas identified in the Concept Drawings (including the INCW Part Project Area), and (b) all the subsurface areas where Work is performed.

(nnn) **Specifications** means the specifications to be provided by the Contractor in accordance with this Agreement.

(ooo) **Subcontractor** means a Person (including the Person's successors and permitted assigns) who supplies Work under an agreement with the Contractor, another Subcontractor or a combination of the Contractor and another Subcontractor.

(ppp) **Submittal** means:

(1) a document, design, drawing (including as built drawings), diagram, illustration, schedule, performance chart, brochure, specification, plan, progress photograph, report or manual (including operating and maintenance manuals);

(2) information, data or other deliverable; or

(3) model or sample,

whether in a written, graphic, physical, electronic or other format, prepared by or for the Contractor which illustrates details of a portion of the Work or is otherwise required by this Agreement, or is reasonably requested by OPG, and is to be submitted by the Contractor to OPG, or as OPG directs, under this Agreement.

(qqq) **Submittal Schedule** means the schedule of Submittals referred to in Section 2.8(a) as finalized by the Contractor and submitted to OPG's Representative in accordance with Section 2.8(a), as amended from time to time in accordance with an Amendment.

(rrr) **Substantial Completion** is defined in Section 7.9(a).

(RRR) **Substantial Completion Fee** is defined in Section 8.8.

(sss) **Summary of Work** means the summary of the Work set out in Appendix 1.1(sss).

(ttt) **Start Date** means September 1, 2005.

(TTT) **Target Cost** means the amount indicated as the "Target Cost" on Appendix 1.1(TTT), as adjusted from time to time hereunder. For greater clarity, the Target Cost excludes the Overhead Recovery Fee, the Interim Completion Fee, the Substantial Completion Fee, and any other incentives or disincentives under Section 8, but includes the administration fee payable by OPG under Section 9.1(a)(2).

(UUU) **Target Cost Baseline Items** are defined in Appendix 1.1(UUU).

(uuu) **Tax** means all present and future taxes, surtaxes, duties, levies, imposts, rates, fees, premiums, assessments, withholdings, dues and other charges of any nature imposed by any Governmental Authority (including income, capital, gross receipts, consumption, sales, use, transfer, goods and services or other value-added, excise, customs or other import, anti-dumping, countervail, net worth, alternative or add-on minimum, windfall profits, stamp, registration, franchise, payroll, employment insurance, Canada Pension Plan, workers' compensation, health, education, school, business, property, local improvement, environmental, development and occupation taxes) together with all fines, interest, penalties in respect thereof, or in lieu of or for non-collection thereof.

(vvv) **TBM** means the tunnel boring machine used for performing the Work.

(www) **TBM Accessories** is defined in Section 2.10(a).

(xxx) **TBM Completion Date** means the date on which all of the Work to be performed by the TBM to complete the Tunnel Facility Project has been completed in accordance with the requirements of this Agreement.

(XXX) **Third Party** means a Person that is not OPG, a director, officer or employee of OPG, a subsidiary of OPG, OPG's Representative or one of OPG's Designated Delegates;

(yyy) **INTENTIONALLY DELETED**.

(zzz) **INTENTIONALLY DELETED**.

(aaaa) **INTENTIONALLY DELETED**.

(bbbb) **INTENTIONALLY DELETED**.

(cccc) **INTENTIONALLY DELETED**.

(dddd) **INTENTIONALLY DELETED**.

(eeee) **Tunnel Facility Project** means the portion of the Project which the Contractor is responsible for under this Agreement, and includes the INCW Part Project.

(ffff) **Warranty Period** is defined in Section 9.8(a).

(FFFF) **Warranty Work** is defined in Section 9.1(a)(2).

(gggg) **Work** means providing to OPG entirely finished and fully functional tunnel diversion facilities and all associated and related facilities necessary to divert the GFA, over a distance of approximately 10.2 km from the upper Niagara River to the Sir Adam Beck Generating Complex. The Work includes providing the Goods, and a facility that is designed and constructed in accordance with, and that is fit for the purposes intended by, this Agreement, whether express or implied,

including those components described in the Summary of Work attached as Appendix 1.1(sss).

(hhhh) **INTENTIONALLY DELETED**.

(iiii) **INTENTIONALLY DELETED**.

1.2 Headings and Table of Contents

The division of this Agreement into sections, the insertion of headings and the provision of a table of contents are for convenience of reference only and are not to affect the construction or interpretation of this Agreement.

1.3 Expanded Definitions

Unless otherwise specified, words importing the singular include the plural and vice versa and words importing gender include all genders. The term "**including**" means "including without limitation", and the terms "**include**", "**includes**" and "**included**" have similar meanings. The term "**will**" means "**shall**". Any reference in this Agreement to any other agreement, is deemed to include a reference to that other agreement, as amended or restated from time to time. When words that have a well-known technical, construction industry or trade meaning are used in this Agreement to describe any Work, such words will be interpreted in accordance with that meaning.

1.4 Time of Day

Unless otherwise specified, references to time of day or date mean the local time or date in Niagara Falls, Ontario. When any period of time is referred to in this Agreement by days, it will be computed to exclude the first and include the last day of such period. A day is 24 hours measured from midnight to the next midnight.

1.5 Business Days

If under this Agreement any payment or calculation is to be made on or as of a day which is not a Business Day, that payment or calculation is to be made on or as of the next day that is a Business Day.

1.6 Governing Law

This Agreement and each of the documents contemplated by this Agreement are governed by, and are to be construed and interpreted in accordance with, the laws of Ontario and the laws of Canada applicable in Ontario. No Party will oppose the enforcement against it in any other jurisdiction of any judgment or order duly obtained from an Ontario court arising out of or made in connection with any arbitration conducted pursuant to Section 11.2. A Party may effect service of summons or any other legal process that may be served in any action, suit or other proceeding by delivering any such process to another Party in accordance with Section 14.4. Nothing in this Section 1.6 will affect the rights of a Party to serve legal process in any other manner permitted by law.

1.7 Conflict

If there is a conflict between any term in one part of this Agreement and any term in another part of this Agreement, the relevant term in the part of this Agreement or other document listed first in this Section 1.7 is to prevail:

(a) Amendments, excluding any part of an Amendment that applies to an Appendix;

(b) this Agreement, excluding the Appendices and Final Submittals;

(c) the Owner's Mandatory Requirements;

(d) the Geotechnical Report;

(e) Amendments to Appendix 5.3C (Major Risk Table);

(f) Appendix 5.3C (Major Risk Table);

(g) Amendments to any other Appendix (for greater clarity, an Amendment to any Appendix other than Appendices 1.1(vv), 5.3C, 5.4 and the Contractor's Proposal Documents);

(h) any other Appendix (for greater clarity, any Appendix other than Appendices 1.1(vv), 5.3C, 5.4 and the Contractor's Proposal Documents);

(i) Final Submittals, as amended or restated; and

(j) Contractor's Proposal Documents.

1.8 Severability

If any term of this Agreement is or becomes illegal, invalid or unenforceable, the illegality, invalidity or unenforceability of that term will not affect the legality, validity or enforceability of the remaining terms of this Agreement and the Parties will, if necessary, amend this Agreement to accomplish the intent of the Parties as originally set out in this Agreement to the maximum extent allowed by Applicable Laws.

1.9 Time

All references in this Agreement to time are intended by the Parties to be the actual time designated without the application of any principles of equity.

1.10 Statutory and Technical References

Each reference to a statute in this Agreement is deemed to be a reference to that statute, and to the regulations made under that statute, all as amended or re-enacted from time to time. Each reference, whether express or implied, to a standard, specification, manual or code of any technical organization or Governmental Authority is deemed to be a reference to that standard, specification, manual or code as amended or re-published from time to time.

1.11 Entire Agreement

This Agreement constitutes the entire agreement between the Parties regarding the subject matter and, except for any Amendment or Project Change Directive, supersedes all other agreements, negotiations, discussions, undertakings, representations, warranties and understandings, whether written or verbal, including any OPG invitation to submit design-build proposals, any Contractor proposal and any amendments or restatements of any such request. Specifically, except as expressly provided in this Agreement, OPG has not made any representations or warranties whatsoever respecting the Tunnel Facility Project, the Project or this Agreement, including any minimum or maximum hours of employment or respecting any information previously provided to the Contractor, physical conditions, labour conditions or scheduling, including subsurface conditions.

1.12 Appendices

The following Appendices are attached to and form part of this Agreement.

Appendix		**Description**
Appendix 1.1(b)	—	Amendment Form
Appendix 1.1(d)	—	Payment Related Documents
Appendix 1.1(h)	—	Concept Drawings
Appendix 1.1(j)	—	INTENTIONALLY DELETED
Appendix 1.1(k)	—	Contract Schedule
Appendix 1.1(o)	—	Disallowance Advisory
Appendix 1.1(P)	—	Disallowed Cost Notice
Appendix 1.1(r)	—	Preliminary Design and Construction Approach
Appendix 1.1(s)	—	Draft Drawings
Appendix 1.1(t)	—	Draft Specifications for the TBM
Appendix 1.1(aa)	—	Flow Verification Test
Appendix 1.1(nn)	—	INTENTIONALLY DELETED
Appendix 1.1(qq)	—	OPG's Delegation Notice
Appendix 1.1(uu)	—	Outline Specifications
Appendix 1.1(vv)	—	Owner's Mandatory Requirements
Appendix 1.1(hhh)	—	Project Change Directive Form
Appendix 1.1(iii)	—	Project Change Notice
Appendix 1.1(sss)	—	Summary of Work
Appendix 1.1(TTT)	—	Target Cost

Appendix		**Description**
Appendix 1.1(UUU)	—	Target Cost Baseline Items
Appendix 1.1(hhhh)	—	INTENTIONALLY DELETED
Appendix 2.2(a)	—	Organizational Chart
Appendix 2.2(b)	—	Scope of Authority for Contractor's Delegates
Appendix 2.4(c)	—	Contractor's Safety Program
Appendix 2.4(d)	—	Preliminary Project Specific Site Safety, Security, Public Safety and Emergency Response Plan
Appendix 2.4(g)	—	Elements of the Project Specific Site Security, Public Safety and Emergency Response Plan
Appendix 2.4(m)	—	Designated Substances Present at Site
Appendix 2.5(a)(3)	—	Outline Environmental Management Plan
Appendix 2.5(b)	—	Environmental Notice
Appendix 2.7(a)(3)	—	INTENTIONALLY DELETED
Appendix 2.8(a)	—	Submittal Requirements
Appendix 2.9(c)	—	Notice of Error in the Contractor's Proposal Documents or the Final Submittals
Appendix 2.12(c)(2)	—	Outline Quality Assurance/Quality Control Program
Appendix 2.12(c)(4)	—	Non-Conformance Notice
Appendix 2.13(f)	—	Non-Compliance Notice
Appendix 2.14(c)	—	INTENTIONALLY DELETED
Appendix 2.14(e)	—	Labour Obligations
Appendix 2.14(f)	—	INTENTIONALLY DELETED
Appendix 2.18	—	Conflict of Interest Declaration
Appendix 2.20(d)	—	Preliminary INCW Part Project Specific Safety, Security, Public Safety and Emergency Response Plan
Appendix 2.20(o)	—	Designated Substances Present at INCW Part Project Area
Appendix 4.1(a)	—	INTENTIONALLY DELETED
Appendix 4.1(b)	—	INTENTIONALLY DELETED
Appendix 4.1(d)	—	Letter of Credit
Appendix 4.1(e)	—	Indemnity Agreement
Appendix 4.1(f)	—	Maintenance Bond

Appendix		Description
Appendix 5.3	—	Notice of Change in Applicable Law
Appendix 5.3B	—	Notice of Force Majeure Event
Appendix 5.3C	—	Major Risk Table
Appendix 5.4	—	Geotechnical Report
Appendix 5.9(a)	—	Dispute Notice
Appendix 7.1	—	INTENTIONALLY DELETED
Appendix 7.2	—	INTENTIONALLY DELETED
Appendix 7.3(a)	—	INTENTIONALLY DELETED
Appendix 7.3(b)	—	Retail Sales Tax Exemption
Appendix 7.9(a)	—	Notice of Ready for Use
Appendix 7.9(a)(8)	—	Affidavit of Design Professional
Appendix 7.9(b)	—	Substantial Completion Confirmation Form
Appendix 7.10	—	Final Completion Form
Appendix 7.13(b)	—	INTENTIONALLY DELETED
Appendix 7.14(a)	—	Final Payment Related Documents
Appendix 7.14(b)	—	Final Payment Form
Appendix 9.4(a)	—	Work Not To Be Covered Without Prior Written Consent Of OPG
Appendix 10.7	—	Breach Form
Appendix 11.1(a)	—	INTENTIONALLY DELETED
Appendix 11.1(b)	—	Notice of Informal Resolution

SECTION 2. CONTRACTOR'S OBLIGATIONS

2.1 Intent and Initial Actions

(a) **General.** The Contractor will, safely and diligently, perform and complete the Work in an organized and timely manner and in accordance with this Agreement and, to the extent not inconsistent with this Agreement, good industry practices. The Contractor will ensure that all Work is performed in accordance with and complies with the Owner's Mandatory Requirements, the Contractor's Proposal Documents, Final Submittals, Applicable Law and the other terms of this Agreement.

(b) **Bargain.** This Agreement contains certain allocations of risk which reflect an informed and voluntary allocation of risk between OPG and the Contractor. This allocation represents a material part of this Agreement.

(c) **Intent.** The Contractor will provide all work, services and goods of any kind (which are deemed to be part of the Work), whether or not specifically required under this Agreement, which are evidently necessary, usually provided by prevailing custom or trade usage, or can be reasonably implied for the proper performance of the Work and the safe and proper operation of the Tunnel Facility Project.

(d) **Acknowledgement.** The Contractor acknowledges that OPG may, from time to time, have representatives present on Site or at off site locations where Goods are being manufactured or fabricated, to monitor performance of the Work and compliance with this Agreement.

(e) **Representations Regarding the Tunnel Facility Project.** The Contractor represents and warrants to OPG that the Contractor:

(1) is, and will, throughout the term of this Agreement, be sufficiently experienced and properly qualified, licensed, equipped, organized and financed (assuming receipt of payments made by OPG in accordance with Section 7 of this Agreement) to perform, or cause to be performed, the Work;

(2) has engaged and will engage only Subcontractors that are competent, properly qualified, licensed, equipped, organized and financed, and has made appropriate enquiries and exercised appropriate due diligence to confirm the competence, qualification, licensing, organization and financing of the Subcontractors;

(3) has examined and has satisfied itself in respect of all matters respecting the Work and Tunnel Facility Project, including:

(A) all necessary information respecting the risks, contingencies and other circumstances which may affect the Contract Schedule, Target Cost, the Work or the Tunnel Facility Project;

(B) the nature, location and physical conditions of the Site, including, surface conditions and the location of all above and below surface buildings, utilities, structures, pipes, conduits and works except the existing tunnel routes and except to the extent such matters are addressed in the GR;

(C) working and storage space, access, transportation, delivery and construction facilities;

(D) the general and local conditions, particularly those bearing upon labour, transportation, delivery, roads and uncertainties of weather;

(E) all Applicable Laws, including any restrictions on hours of work, and any required Approvals; and

(F) the goods, equipment and facilities needed to perform the Work.

(4) has satisfied itself that it can perform and entirely finish the Work in accordance with the Contract Schedule;

(5) has prepared the Contractor's Proposal Documents in accordance with the degree of care and skill used by leading members of the professional engineering profession practicing in Canada and the United States for a similar type of project, in accordance with all Applicable Laws and engineering practices and industry standards and specifications as they apply to tunnel projects and in a manner that complies with the Owner's Mandatory Requirements (including any requirements relating to the Environmental Assessment);

(6) having done all things necessary to inform itself, is not aware of any error or omission in the Owner's Mandatory Requirements, or elsewhere in this Agreement or any inconsistency between the Owner's Mandatory Requirements and this Agreement, between this Agreement and the Appendices, or between Appendices (and if an error, omission or inconsistency is subsequently discovered, will promptly provide a Notice to OPG of such error, omission or inconsistency);

(7) has reviewed the Owner's Mandatory Requirements and is satisfied, based upon those requirements and the Contractor's investigations and analyses, that upon performing the Work the water flow from the tunnel following the completion of the Tunnel Facility Project will meet the Guaranteed Flow Amount;

(8) has carefully studied all reports of explorations and tests of surface and subsurface conditions at or contiguous to the Site and all drawings of physical conditions in or relating to existing surface or subsurface structures at or contiguous to the Site which have been identified or made available by OPG;

(9) is aware of the general nature of work to be performed by OPG and others at the Site that relates to the Work;

(10) has disclosed in writing to OPG the names of each of the Contractor's Personnel who will be performing Work at the Site continuously, who is a former OPG employee and who received a severance package from OPG, is receiving pension payments from OPG or is receiving a non-working pension bridge from OPG or is on a paid leave of absence from OPG;

(11) is not aware of any legal action instituted, threatened or pending against the Contractor that could have a material adverse effect on its ability to perform its obligations under this Agreement; and

(12) has provided to OPG true, complete and accurate records of its costs.

(f) **Financial Information.** The Contractor authorizes OPG to make credit enquiries about the Contractor or any of its affiliates from time to time and to receive and exchange credit information from credit reporting agencies or other Persons with which the Contractor or any of its affiliates has or may expect to have financial dealings. The Contractor has provided OPG with the Contractor's audited financial statements for the last three financial years. Such financial statements have been prepared in accordance with the requirements of the Austrian Commercial Code, consistently applied. Such financial statements fairly reflect the consolidated financial position and results of operations of the Contractor as at the dates and for the periods set out in such statements. The Contractor will provide OPG with its audited financial statements and unaudited quarterly consolidated financial statements promptly after each such statement becomes available. The Contractor will also provide OPG with any other financial information respecting the Contractor or any of its affiliates that OPG may reasonably request to assist OPG in its ongoing evaluation of the value of the indemnifications and other rights provided to OPG by the Contractor under this Agreement.

(g) **Information Waiver.** The Contractor acknowledges that the Target Cost was determined on the basis that some or all of the information provided by OPG may contain errors, omissions or inaccuracies and that the Contractor waives any claim arising therefrom unless the error, omission or inaccuracy was the result of negligence on the part of OPG or Persons providing services to OPG, provided that nothing in this Section 2.1(g) is intended to affect the operation of Appendix 5.3C.

(h) **Release.** The Contractor acknowledges and agrees that, in consideration of the receipt from OPG of the Settlement Payment for cost overruns incurred prior to the Effective Date, it has released, acquitted and forever discharged each member of the OPG Group from any and all actions, causes of action, claims, proceedings, costs, expenses, damages or demands of any kind whatsoever, known or unknown and whether pursuant to statute, tort, contract or otherwise, arising prior to the Effective Date, including any claim which the Contractor had or may have had, or may have in the future against any member of the OPG Group and including further:

(1) all claims referred to or described in the claims submitted by Strabag Inc. to OPG by Document Transmittal DT-0685-R00 Proposal for Optimised Alignment & Revised Schedule dated February 4, 2008 and by Document Transmittal DT-0836-R00 Proposal for Agreement on Contract Resolution

Related to Differing Subsurface Conditions and Optimised Alignment dated October 6, 2008;

(2) all claims arising from or in relation to Project Change Notices 010, 011, 012, 013, 016, 017, 018, 021, 023, 024 and 025, and Project Change Directives 023 and 031, and

(3) any other claims in relation to additional costs for excavation in the Queenston Formation, or changes to the TBM or any claim related to the Work as of the Effective Date; subject to the clarification set forth in paragraph (b) below.

(collectively, the "**Released Claims**").

For greater clarity,

(a) The Contractor shall have no claim against any member of the OPG Group in respect of Work conducted prior to the Effective Date; and

(b) the Contractor shall be entitled to be paid, in accordance with this Agreement in respect of Work conducted on or after the Effective Date. In addition, Subcontractors' claims (that would otherwise be Released Claims) arising prior to the Effective Date for Work performed after the Effective Date are Allowed Costs, subject to Section 2.14(c), to the extent applicable to any settlement.

(i) **Other Projects.** In the event that the Contractor enters into a contract or contracts for another project or other projects, its overhead costs will be apportioned equitably between the Tunnel Facility Project and such other project or projects.

(j) **Pro-Ration of Settlement Payment.** The final Settlement Payment will be 4/9ths of the amount of cost over-runs (the "**Pre-Effective Date Loss**") up to $40,000,000 incurred by the Contractor in respect of Work performed prior to the Effective Date, as agreed to by the Parties. If the amount of cost over-runs as finally determined is less than $90,000,000, the Contractor will pay the difference between $40,000,000 and 4/9ths of the Pre-Effective Date Loss as finally determined and this amount shall be credited to OPG in the next applicable Application for Payment after the Pre-Effective Date Loss is determined. The Parties will use good faith and best efforts to resolve the amount of the final Settlement Payment. If the Parties are unable to agree to the amount of the final Settlement Payment within 90 days of the date of execution of this Agreement, each Party may refer the matter to the Steering Committee to resolve under Section 11.1 by delivering a Notice of Informal Resolution. Notwithstanding any term in this Agreement, if the Steering Committee is unable to agree to the amount of the final Settlement Payment within 30 days of the date of receipt of the Notice of Informal Resolution, the Steering Committee will refer the dispute

to a third party arbitrator or mediator selected mutually by the Steering Committee for a binding resolution.

2.2 Tunnel Facility Project Organization

(a) **Personnel.** Appendix 2.2(a) sets out an organizational chart identifying some of the Contractor's Personnel by name, title and contact information. At OPG's request, the Contractor will provide OPG with résumés for any such personnel indicating his or her qualifications for the performance of the Work. The names on the chart that are followed by an asterisk are considered key personnel. The Contractor will not remove any such key personnel from the performance of the Work, or materially reduce the responsibilities respecting the performance of the Work unless:

(1) OPG's Representative consents in advance in writing to such removal or reduction; or

(2) any such key personnel leave the employ of the Contractor (and all its affiliates) or the applicable Subcontractor (and all its affiliates), the Contractor delivers a Notice to OPG regarding such departure.

The Contractor will replace any such key personnel with an individual who is at least equally qualified and experienced, and will update Appendix 2.2(a) to reflect such changes from time to time or at any time on request by OPG. The Contractor will obtain OPG's consent in advance in writing to any individual who replaces any such key personnel. The names on the chart that are followed by a (1) are to be interviewed by OPG and OPG has the right to approve such Person prior to such Person being involved in any material way in performing the Work.

(b) **Site Manager.** The Contractor will keep on the Site at all times during the performance of Work on Site a competent and efficient resident site manager.

(1) The Contractor will not replace this site manager unless the Contractor delivers a Notice to OPG's Representative at least 25 days before the replacement and OPG's Representative consents in writing to such replacement.

(2) This site manager will be the Contractor's representative at the Site and will have authority to act on behalf of the Contractor.

(3) The site manager may delegate duties to superintendents, health and safety supervisors, account managers, records managers and other Persons designated by name and shown on Appendix 2.2(a) or as otherwise approved in writing by OPG.

(4) The site manager will specify in writing, in the form of document attached as Appendix 2.2(b), the scope and the limits of authority of each of his or her designated delegates.

(5) Any changes to or revocation of any delegations will also be specified by the site manager in writing to OPG's Representative in the form of document attached as Appendix 2.2(b).

(6) All Notices delivered to the site manager, or, in OPG's sole and absolute discretion, to his or her designated delegates (provided that the notice relates to a matter within the designated delegate's scope of authority), by OPG will be as binding on the Contractor as if given to the Contractor under Section 14.4.

(7) OPG may rely on any written instructions, directions or approvals provided by the site manager or his or her designated delegates (provided that such instructions, directions or approvals are within the designated delegate's scope of authority).

(8) OPG's determination as to whether or not a matter is within the scope of authority of a designated delegate of the Contractor's representative will be conclusive, so long as OPG has acted in good faith and does not have actual notice that the matter is not within the designated delegate's scope of authority.

(9) The Contractor will take all reasonable steps to ensure that the site manager and all designated delegates are accessible to OPG during the performance of the Work (including outside of normal working hours in cases of emergencies) and are available to render any necessary decisions or instructions promptly to avoid delays to the Contract Schedule.

(c) **Tunnel Design Engineer.** The Contractor will ensure that a senior tunnel design engineer, with full knowledge of the Tunnel Facility Project, is present on Site on a continuous basis when reasonably required by the progress of the Work, as agreed by the Parties, or when requested by OPG. The tunnel design engineer is subject to acceptance by OPG before being deployed to the Site.

(d) **Site Presence of Designers.** The Contractor will ensure that appropriate designer representatives are made available on-Site for meetings and other critical activities as required by the progress of the Work whenever such presence is requested by OPG.

2.3 Kick-Off and Subsequent Meetings

(a) **Kick-Off Meeting.** Within 10 Business Days after the Start Date, OPG's Representative will arrange a kick-off meeting. The Contractor will ensure attendance by its authorized representatives and any representatives of Subcontractors, including senior management, as required by OPG. At this meeting the Parties will discuss safety and environmental protection programs (including those of Subcontractors) and requirements, the hazards associated with the Work, labour matters, design concepts, schedules (including the schedules to

be developed pursuant to Section 2.7), procedures for handling Submittals, communication protocols, procedures for processing each Application for Payment, delivery procedures for the Site, records maintenance, Site security, OPG's review of Site conditions and any other matter raised by a Party.

(b) **Meetings.** In addition to the kick-off meeting, the Contractor will schedule, attend and conduct such other project readiness, pre-construction, design review, construction, pre-job mark up (including resolution of jurisdictional issues), hazard review, site co-ordination, weekly (or as otherwise required by OPG) progress review meetings and other meetings as requested by OPG or are otherwise desirable, including any meetings required by the Contractor's Proposal Documents or the Final Submittals. The Contractor will include in the agenda of any such meeting any issue requested by OPG. Progress review meetings will usually focus on safety, environmental matters, labour requirements, procedures, progress, clarifications of the requirements of this Agreement and scheduling (including interfaces between Persons providing services at the generating station). The Contractor will ensure that all Subcontractors and other Persons requested by OPG will attend these meetings. The Contractor will ensure that each representative of the Contractor and any Subcontractor attending meetings will be qualified and authorized to act on behalf of the Party each represents. The Contractor will provide the space for the meeting. Unless OPG otherwise requests regarding a particular meeting, OPG will prepare and distribute minutes of each meeting within 5 Business Days.

2.3A Co-operation

(a) **Co-operation on Costs.** The Parties shall co-operate with each other in the discharge of their respective obligations, including working together to optimize designs, means and methods under this Agreement, with the aim of minimizing Actual Costs consistent with the completion of the Project and the Work in accordance with this Agreement. For greater clarity, OPG's co-operation in optimizing designs, means and methods shall not have the effect of transferring any responsibility for such designs, means and methods, which responsibility will remain that of the Contractor.

(b) **Co-operation on Construction Risks.** The Parties will co-operate with each other and closely collaborate on the monitoring of construction risks.

(c) **Disclosure.** The Parties shall deal fairly, openly and in good faith with each other. Subject to Section 2.17, each Party shall disclose information which the other might reasonably need in order to exercise its rights and to perform its obligations under this Agreement. The Parties shall work together in a manner consistent with their respective obligations under this Agreement to resolve or mitigate any issues relating to the Project.

(d) **Records.** As of the Effective Date, the Contractor shall provide and maintain records as required and shall provide and maintain a robust, multiple user access,

computer based cost control and accounting system operated and maintained by suitably qualified and experienced personnel to the satisfaction of OPG's Representative to enable the Contractor to carry out effective control with respect to all payments made or due to be made in accordance with the Agreement. The cost control system shall facilitate comparison between the relevant elements of the Actual Cost and the Target Cost including any changes resulting from Project Change Directives.

Unless otherwise agreed, the Contractor shall at intervals of not more than one calendar month or as OPG may otherwise direct, provide to OPG cost control reports. In addition, OPG's Representative shall have continuous password protected read-only access to the Contractor's cost control and accounting system.

Notwithstanding the foregoing, OPG reserves the right to carry out an audit of the Contractor's financial records at such period that OPG may deem reasonable.

(e) **Inspection and Audits.**

(1) The Contractor will ensure that it and its Major Subcontractors retain records and documents, including proper time sheets, accounts and invoices, necessary for OPG to verify the nature and quality of the Work and the accuracy of invoices for Actual Costs issued by the Contractor hereunder for Work provided (collectively, the "**Records**"). Timesheets will identify the provider of the Work, the Work provided, the location of the Work, the relevant period of time the Work was provided and the hours incurred. The Contractor will and will cause its Major Subcontractors to maintain the Records for two (2) years following Final Completion and such Records will be available, upon reasonable notice by the OPG, for review and inspection by the OPG or its designates. The Contractor and any Major Subcontractor will provide copies of Records to OPG upon request at the expense of OPG. Notwithstanding the foregoing, OPG shall have no right to audit arms length fixed priced subcontracts, subcontracts entered into before the Effective Date, the purchase order for design of the restoration carrier given to BAYSTAG GmbH on January 9th, 2009 or any additional purchase orders with BAYSTAG GmbH or other affiliates of the Contractor approved in advance by OPG; however, in such cases OPG may review invoices for compliance with the subcontract at the Contractor's premises.

(2) Upon 10 days' written notice, OPG will be entitled, at its expense, to audit Records and to have access to the Contractor's facilities or any Major Subcontractors from which Work is performed in order to verify:

(A) the accuracy of charges invoiced;

(B) that the amount invoiced are based on Actual Costs;

(C) that the Contractor has paid its Major Subcontractors consistent with its obligations under this Agreement; and

(D) that the Work is being provided in accordance with this Agreement and that the Contractor has complied with all covenants of the Contractor in this Agreement.

The Contractor will provide, and will cause its Major Subcontractors to provide, appropriate facilities at its or their premises for any audit. OPG will use commercially reasonable efforts to ensure that these rights do not unduly interfere with the Contractor's ability to perform the Work or to provide services to other clients. The Contractor will cause each Major Subcontractor to allow OPG access, if required by the OPG, and the right to audit all records, data, purchase orders, invoices and receipts during business hours as may be necessary to verify compliance of the Contractor with all covenants of the Contractor in this Agreement and of the Major Subcontractor with all covenants of such Major Subcontractor in the agreement between such Major Subcontractor and the Contractor. The Contractor will correct or remedy, and will cause any Major Subcontractor to correct or remedy, any errors or discrepancies identified during the OPG's audit. If the results of an audit demonstrate that the Actual Costs do not meet the requirements of the subcontract or this Agreement, as applicable, the Actual Costs will be reduced accordingly and the Contractor shall repay OPG the amount found to be in excess of the amounts that should have been charged under this Agreement**.**

2.4 Safety - General

(a) **Primary Goal.** Safety of the Contractor's Personnel, individuals at or near the Site and the public is of paramount concern to OPG. In the performance of the Work, the Contractor will not in any manner endanger the safety of, or unlawfully interfere with other Persons on or off the Site, including the public.

(b) **Constructor.** The Contractor will be the "Constructor" in respect of the Work for the purposes of the *Occupational Health and Safety Act* (Ontario). The "Constructor" will submit the required notice of project and registration form to the applicable Governmental Authority. The Contractor will have complete and sole responsibility for all health and safety matters regarding the Tunnel Facility Project. The Contractor is not required to ask OPG for any input or recommendations (and OPG may not require the Contractor to take any specified actions) respecting any health or safety matter regarding the Tunnel Facility Project. OPG will not provide to the Contractor any personnel, equipment or services. Notwithstanding any term in this Section 2.4(b), OPG may at any time on delivery of a Notice to the Contractor, assume the role of the "Constructor".

(c) **Compliance.** The Contractor will perform all the Work in accordance with:

(1) all Applicable Laws and applicable collective agreements;

(2) and to the extent not inconsistent with Section 2.4(c)(1), the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, as described in Section 2.4(d);

(3) and to the extent not inconsistent with Sections 2.4(c)(1) and 2.4(c)(2), the Contractor's safety program (a copy of which is attached as Appendix 2.4(c)), as amended from time to time;

(4) and to the extent not inconsistent with Sections 2.4(c)(1), 2.4(c)(2) and 2.4(c)(3), the very best of practices respecting health and safety and in a manner that recognizes and minimizes the risks to workers, other individuals and property.

The Contractor will forward to OPG, without delay, any changes to its safety program made during the course of performing the Work. OPG will monitor the compliance of the Contractor and Subcontractors with these requirements through periodic audits from time to time during the course of the performance of the Work. The Contractor will forward to OPG, without delay, any change to the Council Amendment to Draft #7 (CAD-7) rating of the Contractor or to any Subcontractor performing Work at the Site.

(d) **Project Specific Site Safety, Security, Public Safety and Emergency Response Plan.** The Contractor has performed a safety hazard analysis to identify all significant safety hazards in respect of the Work. Based on this analysis and the Preliminary Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the Contractor will prepare, in accordance with the standards described in Section 2.8(b) and the procedures described in Section 2.8(c), a detailed project specific site safety plan (the plan, as amended from time to time, the "**Project Specific Site Safety, Security, Public Safety and Emergency Response Plan**") which will document how the Contractor will address all significant safety hazards including the methodology for safe work planning and will include provision for the regular and systematic review and audit of the plan elements by the Contractor to determine whether the Project Specific Safety, Security, Public Safety and Emergency Response Plan requires modification to more appropriately and effectively address all safety hazards associated with the Work. The Contractor will provide for the communication of the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to all workers performing Work on the Site and all Subcontractors. The Contractor will submit the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to OPG within 30 days after the Start Date and such plan will be deemed to form part of this Agreement. The Project Specific Site Safety, Security, Public Safety and Emergency Response Plan will be implemented by the Contractor. To the extent the Contractor's review and audit of the Project Specific Site Safety,

Security, Public Safety and Emergency Response Plan reveals that the Project Specific Safety, Security, Public Safety and Emergency Response Plan requires modification to more appropriately and effectively address all safety hazards associated with the Work, the Contractor will modify the Project Specific Safety, Security, Public Safety and Emergency Response Plan within 5 days after such review and audit. The Contractor will submit to OPG the results of its regular review and audit of the Project Specific Safety, Security, Public Safety and Emergency Response Plan, including modifications thereto, within 10 days after each review and audit. OPG may monitor the compliance of the Contractor and Subcontractors with the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan through periodic audits from time to time during the course of the performance of the Work.

(e) **Safety Representative.** The Contractor will provide a qualified and experienced full time health and safety representative for the Site. The Contractor will make this representative's sole obligation the training of the Contractor's Personnel in safety, prevention of accidents and the maintaining, reviewing and revising of safety precautions and programs. The Contractor will form a joint health and safety committee that will include representatives of the Contractor and the trades.

(f) **Safety Precautions and Remedies.**

(1) **Protection.** The Contractor will be solely responsible for initiating, maintaining, reviewing, revising and supervising all safety precautions and programs in respect of the Work. The Contractor will take all necessary precautions (including ensuring that all of the Contractor's Personnel are equipped with, and use, all safeguards and personal protective equipment necessary for the performance of the Work) for the safety of, and will provide the necessary protection to prevent damage, injury or loss resulting from the performance of the Work to:

(A) each Person who is on the Site or who may otherwise be affected by the performance of the Work, including the Contractor's Personnel and members of the public;

(B) any of the Goods, whether in storage on or off Site;

(C) the Tunnel Facility Project; and

(D) any other property on, under, over or near the Site, whether belonging to OPG or to any other Person, including buildings and other structures, facilities, fences, gates, pavements, roadways, sidewalks, walks, vegetation, utilities and underground facilities that are not designated for removal and disposal in the course of performing the Work.

(2) **Lock-Out Provisions.** The Contractor will perform all Work under applicable lock-out procedures stipulated in the *Occupational Health and*

Safety Act (Ontario) ensuring that equipment being worked on is safely isolated and de-energized.

(3) **Notification of Owners.** The Contractor will promptly deliver a Notice to OPG's Representative as the Contractor becomes aware of, and indicating the identity of, each utility, owner of underground facilities and owner of property (excluding OPG and its subsidiaries) on, under, over or near the Site that may be affected by the Work and how each such utility or owner may be affected. OPG will deliver a Notice to the Contractor confirming the identity of each such Person and the Contractor will, at OPG's direction, deal with or co-operate with OPG in dealing with settling all issues respecting the performance of the Work, including the protection, removal, relocation or replacement of the property of any such Person.

(4) **Repair of Damage.** To the extent that any Third Party, such as a utility, owner of underground facilities or owner of property (excluding OPG and its subsidiaries) on, under, over or near the Site suffers or incurs any Losses to any property caused by the Contractor or a Subcontractor, the Contractor will remedy such Losses in a timely manner as a Disallowed Cost. The Contractor will indemnify and hold harmless each member of the OPG Group, from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by a Third Party in connection with Losses suffered or incurred to any property of such Third Party caused by the Contractor or a Subcontractor.

(g) **Site Security, Public Safety and Emergency Response.** The Contractor has performed a security, public safety and emergency response analysis to identify all public safety hazards associated with the Site and the Work and to identify all potential means of unauthorized access to the Site. Based on this analysis and the Preliminary Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the Contractor will prepare, in accordance with the standards described in Section 2.8(b) and the procedures described in Section 2.8(c), a project specific site security, public safety and emergency response plan. Such plan, as amended from time to time will be included in the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan and will document, among other things, how the Contractor will address all significant public safety hazards and prevent unauthorized access to the Site, the matters described in Appendix 2.4(g) and will include provision for the regular and systematic review and audit of the plan elements to determine whether the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan requires modification. The Contractor will provide for the communication of the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to all workers performing Work on the Site and all Subcontractors. The Contractor will submit the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to OPG within 30 days after the Start Date and such plan will be deemed to form part of this Agreement. The Project Specific Site Safety, Security,

Public Safety and Emergency Response Plan will be implemented by the Contractor. To the extent the Contractor's review and audit of the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan reveals that the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan requires modification to more appropriately and effectively address all public safety hazards associated with the Site and the Work and/or all potential means of unauthorized access to the Site, the Contractor will modify the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan within 5 days after such review and audit. The Contractor will submit to OPG the results of its regular review and audit of the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, including modifications thereto, within 10 days after each review and audit. OPG may monitor the compliance of the Contractor and Subcontractors with the Project Specific Site Safety, Security, Public Safety and Emergency Response Plan through periodic audits from time to time during the course of the performance of the Work.

(h) **Safety Reports.** During the performance of the Work, the Contractor will provide OPG's Representative with:

(1) a verbal report immediately of any serious incident requiring off-site medical attention or near miss incidents which do or could have resulted in the death of, or serious injury to, a worker or other Person on or off the Site or an incident which has resulted in the death of or serious injury to a worker or other Person on or off the Site;

(2) within 24 hours of an accident, construction occurrence or incident report, a copy of all accident, construction occurrence and incident reports which the Contractor, any Subcontractor, or OPG is required to submit in respect of the Work under the *Occupational Health and Safety Act* (Ontario) or the *Workplace Safety and Insurance Act, 1997* (Ontario);

(3) within 24 hours, Notice of any visits by the Ministry of Labour and copies of any reports, orders to comply, charges, stop work orders, and notices of compliance under the *Occupational Health and Safety Act* (Ontario) or other Applicable Laws;

(4) a copy of the minutes of each meeting of the joint health and safety committee; and

(5) a monthly report within ten days of each month's end with safety statistics for the Contractor and all Subcontractors performing Work at the Site. The Contractor will include in this report, with a brief description of each incident and injury:

(A) the number of injuries resulting in a worker requiring medical aid;

(B) the number of near miss incidents which could have resulted in the death of, or serious injury to, a worker;

(C) the number of injuries resulting in a worker's absence from one or more complete shifts;

(D) the time each worker takes off from work for each injury;

(E) the number of Ministry of Labour orders to comply; and

(F) the total number of person hours worked by the Contractor's Personnel at the Site broken down between the Contractor and each Subcontractor.

(i) **Stop Work Orders.** Where an order to comply, stop work order or any similar order or notice respecting the Work is issued by the Construction Health and Safety Branch of the Ontario Ministry of Labour or any other Governmental Authority, such order or notice will not be grounds for any change to the Contract Schedule or Target Cost to the extent that the underlying circumstances were caused by or were attributable to the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii). To the extent OPG or another member of the OPG Group was immediately and directly responsible for causing the underlying circumstances giving rise to such order or notice, this situation will be deemed to constitute an OPG Caused Event for the purposes of Section 5.4(a). The Contractor will promptly deliver to OPG's Representative a copy of any such order or notice.

(j) **Emergencies.** In emergencies affecting the safety or protection of individuals, the Work or Tunnel Facility Project or property on, under, over or near the Site, the Contractor, without the express consent of OPG, will take reasonable actions to prevent or minimize all threatened or actual damage, injury and loss.

(k) **Requirement to Leave.** In the case of an emergency requiring the Contractor to leave the Site at the direction of OPG, the Contractor will put all equipment in a safe state in accordance with the *Occupational Health and Safety Act* (Ontario) and leave the Site in an orderly fashion pending further instructions from OPG's Representative.

(l) **Hazard Communication Programs.** The Contractor will co-ordinate all exchanges of material safety data sheets and other hazard communication information related to the Work required to be made available to, or exchanged between or among, Persons at the Site.

(m) **Designated Substances and Other Hazardous Materials.**

(1) The Contractor is solely responsible for any "designated substances" (as defined under the *Occupational Health and Safety Act* (Ontario)) brought onto the Site by it, and shall fully remove any remaining amounts prior to or upon completion of the Work. The Contractor shall also ensure that in

no event will designated substances be incorporated into the permanent facilities.

(2) Any other potentially hazardous materials or substances to which OPG personnel may be exposed during operation and maintenance of the facility must be in conformance with OPG's HAZMAT approved material list.

(3) The Contractor acknowledges that prior to execution of this Agreement, OPG provided the Contractor with a list of designated substances present at the Site (a copy of which is attached as Appendix 2.4(m)), as required pursuant to the *Occupational Health and Safety Act* (Ontario). OPG is not aware of any other designated substances at the Site.

(n) **Indemnity Relating to Safety.** To the extent that the circumstances giving rise to a charge or fine pursuant to legislation applicable to worker health and safety, including the *Occupational Health and Safety Act* (Ontario) or its Regulations were caused or contributed to, in whole or in part, by the Contractor's negligence or wilful misconduct, the Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and from and against all claims, demands, actions, suits or any other proceedings for Losses made against any member of the OPG Group in connection with such charge or fine.

(o) **General.** The provisions of this Section 2.4 shall not apply with respect to that portion of the Work required for the INCW Part Project and carried out in the INCW Part Project Area. For greater certainty, the provisions set out in Section 2.20 shall apply to the portion of the Work required for the INCW Part Project and carried out in the INCW Part Project Area. In addition, references to Subcontractors in this Section 2.4 apply only to Subcontractors providing services at the Site.

2.5 Environment

(a) **Compliance and Protection.** In addition to the Contractor's obligation to comply with all Applicable Laws, the Contractor will perform the Work in a manner that:

(1) protects health and the environment;

(2) complies with the requirements of the Environmental Assessment, the Environmental Assessment Approval, the Approvals held or to be obtained by OPG in relation to the Project, the Community Impact Agreement, and the Approvals held or to be obtained by Contractor in relation to the Project;

(3) complies with the Outline Environmental Management Plan attached as Appendix 2.5(a)(3);

(4) complies with the Contractor's environmental management plan, which plan will be based on the Outline Environmental Management Plan, which shall be submitted as a Submittal within 60 days after the Start Date;

(5) complies with the plans, which shall be submitted to OPG as Submittals, as required by OPG to comply with the Environmental Assessment, the Environmental Assessment Approval or required by the Owner's Mandatory Requirements;

(6) adequately anticipates, protects and plans for impacts to the environment, including spills, erosion and sedimentation, waste disposal and the use, storage and disposal of hazardous materials; and

(7) uses all commercially reasonable efforts to reduce, reuse or recycle non-hazardous waste.

(b) **Notices.** The Contractor will immediately provide OPG's Representative with Notice in the form attached as Appendix 2.5(b):

(1) of any changes to its environmental management plan made during the course of performing the Work for OPG's review and prior approval;

(2) of any discharge, spill, release, emission, deposit or leak of:

(A) fuels, oils, hydraulic fluid, herbicides; or

(B) any substance whether solid, liquid, gas, odour, heat, sound, vibration or radiation or any combination thereof, exposure to which is prohibited, limited or regulated by any Applicable Law, or the Contractor's environmental management plan,

that occur at or near the Site or that occur with the Goods or materials owned or controlled by the Contractor or a Subcontractor; and

(3) upon receipt of any order, directive, notice or other communication whatsoever received from any Governmental Authority respecting any substance whether solid, liquid, gas, odour, heat, sound, vibration or radiation or any combination thereof, exposure to which is prohibited, limited or regulated by any Applicable Law, together with a copy of such order, directive, notice or other communication.

(c) **Disposal.** The Contractor is responsible for the transport, receipt, inspection, use, storage and disposal of all hazardous and non-hazardous substances, materials, solids, liquids and gases that are brought on to the Site or created at the Site during performance of the Work. Without limiting the generality of the foregoing, the disposal of any excavated material produced in the performance of the Work will be carried out in accordance with:

(1) Applicable Laws;

(2) to the extent not inconsistent with Section 2.5(c)(1), the Contractor's environmental management plan as approved by OPG, and as amended in accordance with Section 2.5(b)(1); and

(3) any order, directive, notice or other communication whatsoever received from any Governmental Authority, subject to direction by OPG's Representative following notification in accordance with Section 2.5(b).

(d) **Discharges and Spills.** The Contractor will, to the satisfaction of all applicable Governmental Authorities and OPG, in a timely manner, prevent all discharges, spills, releases, emissions, deposits or leaks contrary to:

(1) Applicable Laws; and

(2) to the extent not inconsistent with Section 2.5(d)(1), the Contractor's environmental management plan as approved by OPG, and as amended in accordance with Section 2.5(b)(1);

and clean up, dispose of and otherwise comply with all requirements of:

(3) Applicable Laws;

(4) to the extent not inconsistent with Section 2.5(d)(3), the Contractor's environmental management plan as approved by OPG, and as amended in accordance with Section 2.5(b)(1); and

(5) any order, directive, notice or other communication whatsoever received from any Governmental Authority, subject to direction by OPG's Representative following notification in Section 2.5(b);

respecting all discharges, spills, releases, emissions, deposits or leaks of any substances, materials, solids, liquids, gases or wastes whatsoever that are caused by the Contractor and that occur at or near the Site or that occur with materials owned or controlled by the Contractor.

(e) **Disposal of Hazardous Material.** Unless otherwise specifically provided for in this Agreement, the Contractor may not dispose of any Hazardous Material on, under, over or near any property owned, leased or licensed by OPG or any of its subsidiaries or in which OPG or any of its subsidiaries has an interest, in whole or in part, including the Site.

(f) **Remedy for Breach.** The Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person in respect

of any breach by the Contractor of any of its obligations under Sections 2.5(a) to 2.5(e) inclusive to the extent that the circumstances giving rise to the claim, demand, action, suit or proceeding were caused or attributable to the wilful misconduct of the Contractor, a Subcontractor or any member of the Contractor's Personnel or the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii).

(g) **General.** References to Subcontractors in this Section 2.5 apply only to Subcontractors providing services at the Site.

2.6 Applicable Laws and Approvals

(a) **Applicable Laws.** The Contractor will comply with all Applicable Laws and all applicable standards, specifications, manuals or codes of any technical organization or Governmental Authority and, to the extent not inconsistent with Applicable Laws or applicable standards, specifications, manuals or codes of any technical organization or Governmental Authority, good industry practices, in respect of the Work. Without limiting the generality of the foregoing, the TBM will comply with all Applicable Laws and all applicable standards, specifications, manuals or codes of any technical organization or Governmental Authority. OPG will not be responsible for ensuring the Contractor's compliance with any Applicable Laws, or applicable standards, specifications, manuals or codes of any technical organization or Governmental Authority or good industry practices. Except as expressly set out in this Agreement, the Contractor will submit, and provide a copy to OPG of, all notices, requests, documents, instruments and certificates to all applicable Governmental Authorities as may be required in respect of the Work including, for greater certainty, any applications or other submissions in respect of Approvals. Notwithstanding any reference in the Contractor's Proposal Documents to DIN or other international standards when an applicable Canadian standard exists (such as CSA), the Contractor agrees to abide by the Canadian standard.

(b) **Approvals.** Except as set out in Sections 3.1(e) and 3.1(f), the Contractor will obtain and pay all the expenses in connection with all Approvals required to carry out the Work in compliance with Applicable Laws as an Allowed Cost, including those Approvals to be issued in the name of OPG, in a timely manner in order to meet the Contract Schedule. For greater clarity, the identification of required Approvals shall be the responsibility of the Contractor. The Contractor will provide technical criteria, written descriptions and design data required for obtaining all such Approvals. OPG will support the Contractor as and when the Contractor requests to obtain such Approvals in order to meet the common objective of obtaining the Approvals within the expected time periods. To the extent an Approval is to be issued in the name of OPG, the Contractor will obtain OPG's prior written approval to all terms and conditions of such Approval. The Contractor will pay all fees and other charges respecting all such Approvals obtained by the Contractor as an Allowed Cost. The Contractor and the Subcontractors will comply with the terms and conditions of all Approvals. The

Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person arising as a result of the failure of the Contractor to comply with the terms and conditions of any Approval issued in the name of OPG. The Contractor will provide a copy to OPG of all Approvals.

(c) **OPG Code of Conduct.** The Contractor will not take any action that would cause any member of the OPG Group to breach an obligation set out in OPG's code of business conduct, as amended from time to time.

2.7 Schedules

(a) **Development of Schedules.** The Contractor will complete and submit to OPG's Representative as a Submittal the following document within the following time period:

(1) within 30 days after signing the Agreement, a detailed contract schedule indicating the dates for starting and entirely finishing each component of the Work (including the INCW Part Project), including a reference to each milestone set out in the Contract Schedule so that this contract schedule incorporates, and integrates with, the Contract.

(2) OPG will review this contract schedule within 10 Business Days after receipt thereof and provide the Contractor with a Notice setting out any comments thereon. The Contractor will then have 5 Business Days from the receipt of such Notice to respond to OPG's comments and make any necessary amendments to the contract schedule.

(b) **Initially Acceptable Schedules.** Any review, comment, acceptance, rejection or failure to review, comment, accept or reject by OPG of the Contract Schedule, in whole or in part, will not:

(1) impose on OPG responsibility for the sequencing, scheduling or progress of the Work;

(2) be deemed to confirm that any schedule is a reasonable plan for performing the Work in accordance with the detailed contract schedule;

(3) affect or change the Contractor's obligation to perform the Work in accordance with this Agreement; or

(4) otherwise have the effect of transferring any obligation under this Agreement from the Contractor to OPG or otherwise have the effect of amending this Agreement.

(c) **Adherence to Schedules.** The Contractor will adhere to the Contract Schedule. The Contractor will provide OPG with a monthly progress schedule (including earned value reporting), setting out the status and progress of the Work and any deviations or anticipated deviations from the Contract Schedule. To the extent that the Contract Schedule has not been, or is anticipated not to be, satisfied, the Contractor will indicate the total number of days set aside for contingencies that will be used and will provide OPG with satisfactory assurances, including, recovery plans, involving all necessary additional resources, acceptable to OPG, that the Contract Schedule will be restored. There will be no changes to the Contract Schedule except as provided by Section 5 of this Agreement.

(d) **Daily Record.** The Contractor will maintain a detailed daily record of the progress of the Work, the number of personnel of all categories at the Site, the Goods delivered to the Site and all such other items deemed necessary to record.

(e) **Continuing the Work.** Notwithstanding any term in this Agreement, the Contractor will not stop or delay the performance of Work, in whole or in part, on account of any Dispute or pending resolution of any such Dispute between the Contractor and OPG or between the Contractor and any other Person and will continue to perform the Work in a timely manner and continue to adhere to the Contract Schedule, except to the extent, if any, expressly directed to do so by OPG in a Project Change Directive, provided that the Contractor may suspend the performance of the Work, if OPG has not paid the amounts required under Section 7.3(b) within 30 days of the date OPG is required to make payment under Section 7.3(b).

2.8 Submittals

(a) **Submission of Submittals.** The Contractor agrees to provide each Submittal described in Appendix 2.8(a), in addition to other Submittals as required pursuant to this Agreement all in accordance with the requirements set out in Appendix 2.8(a). The Contractor agrees to provide each Submittal to OPG (as set out in the Submittal Schedule) in a timely manner and orderly sequence and in accordance with the Submittal Schedule, so as not to cause any delay in the Work. Unless otherwise authorized by OPG's Representative, all Submittals will comply with Appendix 2.8(a).

(b) **Submittals Prepared by Professionals.** The Contractor will prepare the Submittals required to be prepared by a Professional, including the Drawings and Specifications as more fully described in Appendix 2.8(a), in accordance with the degree of care and skill used by leading members of the professional engineering profession practicing in Canada and the United States for a similar type of project, in accordance with all Applicable Laws and engineering practices and industry standards and specifications as they apply to tunnel projects and in a manner that complies with the Owner's Mandatory Requirements (including any requirements relating to the Environmental Assessment and EA Approval) and the Contractor's Proposal Documents.

(c) **Review of Submittals.** The Contractor will review and approve all Submittals before submission to OPG. The Contractor's review and approval of each Submittal will be indicated by stamp, seal (if applicable), date and a signature of a responsible and qualified Person. Any Submittals not stamped, sealed (if applicable), signed, dated and identified may be returned to the Contractor without being examined and will be considered not to have been submitted. By this review and approval, the Contractor will be deemed to represent to OPG that it has diligently determined and verified all necessary requirements including field measurements, field construction criteria, materials, catalogue numbers and similar data and has checked and coordinated all Submittals with the requirements of the Contractor's Proposal Documents and the remainder of this Agreement and that OPG can and will rely upon this deemed representation. Together with any Submittal, the Contractor will notify OPG's Representative of, and clearly show or describe, any deviation of that Submittal from any requirement under this Agreement.

(d) **Return of Submittals.** OPG's Representative will return Submittals to the Contractor marked "Reviewed as Submitted", "Revise as Noted - Do not Resubmit", "Revise and Resubmit" or "Review not Required". However, if OPG, acting reasonably, determines that a Submittal is not suitable for review and does not meet the basic requirements for such Submittal, the Submittal will be returned to the Contractor and the time period for review of such Submittal by OPG pursuant to the Submittal Schedule will be deemed not to have commenced.

(e) **Non-Compliance.** The Contractor will respond, in a timely manner, to queries from OPG's Representative respecting its review of the Submittals and provide, in a timely manner, all such other documentation and information requested by OPG's Representative to finish its review of the Submittals. Where any Submittal delivered by the Contractor deviates from the requirements of this Agreement, OPG's Representative may require the Contractor to conform that Submittal to the requirements of this Agreement. Unless otherwise directed by OPG's Representative, the Contractor will promptly, and in any event within the time period required by the Contract Schedule, correct all items in a Submittal, whether or not raised by OPG's Representative, which do not conform to the requirements of this Agreement. The Contractor will then return to OPG's Representative the required number of corrected copies of the Submittal clearly identifying any revisions to the Submittal and such Submittal will continue to be subject to this Section 2.8(e) until there is no requirement to resubmit. The Contractor will be responsible for recovering any time lost in the review process by reason of error or defect in the Submittals and, in any event, the Contractor will maintain the dates set out in the Contract Schedule. If the Parties dispute the conformity of a Submittal and it is subsequently determined by the Parties or through dispute resolution under Section 11 that the Submittal was in conformity with the Agreement, any delay attributable to such dispute will be treated as a delay caused by OPG pursuant to Section 5.4(a).

(f) **Work Before Review by OPG.** Where a Submittal is required by this Agreement including the Submittal Schedule and Work relating to that Submittal is performed before OPG's Representative has completed its review of the Submittal (including any required revisions to the Submittal), any costs incurred to correct the Work inconsistent with the Final Submittal will be a Disallowed Cost.

(g) **Effect of Review.** Notwithstanding any term of this Agreement, if OPG reviews, comments on, accepts or rejects or fails to review, comment on, accept or reject any Submittal or any item in a Submittal, any such action or failure to act:

(1) will not have the effect of transferring any obligation under this Agreement from the Contractor to OPG or otherwise have the effect of amending this Agreement; and

(2) will not affect or change in any way,

(A) the Contractor's obligation to entirely finish the Work, or

(B) the Contractor's responsibility for any error or omission in any Submittal or any deviation in a Submittal from the requirements of this Agreement, unless in each case OPG's Representative gives express written acceptance of the error, omission or deviation.

Review of Submittals by OPG's Representative will be for conformity to the Contractor's Proposal Documents, the Owner's Mandatory Requirements and this Agreement and for general arrangement only. In addition, any such review will generally not extend to means, methods, techniques, sequences or procedures of construction or to related safety precautions or programs, other than for compliance with this Agreement (for example, with respect to the INCW Part Project), and will not indicate OPG's approval of such item or OPG's acceptance or approval of the assembly in which the item in the Submittal functions. Once a Submittal is reviewed by OPG's Representative and no longer requires revision, or once a Submittal is submitted where such Submittal does not require OPG's review, such Submittal will become a "**Final Submittal**" and will be deemed to be incorporated into this Agreement.

(h) **Manuals.** All manuals will be in sufficient detail for OPG to operate, maintain, commission, refurbish, replace and alter the Tunnel Facility Project.

2.9 Professional Services

(a) **Provision.** The Contractor will provide all the Professional Services necessary or desirable to perform the Work, including all design required for a tunnel that delivers the Guaranteed Flow Amount. The Contractor will ensure that all Work is designed in accordance with Applicable Laws.

(b) **Standard of Care.** The Contractor will provide all the Professional Services necessary or desirable to entirely finish the Work and Tunnel Facility Project. The standard of care used for all the Professional Services provided under this Agreement will be the degree of care and skill used by leading members of the profession practicing in Canada and the United States for a similar type project and in accordance with all Applicable Laws, prudent practices and professional practices and industry standards and specifications as they apply to tunnel projects.

(c) **Error in Contractor's Proposal Documents or Final Submittals.** The Contractor will promptly provide Notice, in the form of document attached as Appendix 2.9(c), to OPG's Representative of any error, deficiency, defect, inconsistency, discrepancy, omission or deviation from the requirements of this Agreement or the Owner's Mandatory Requirements in the Contractor's Proposal Documents or the Final Submittals of which the Contractor becomes aware. After the Contractor provides OPG's Representative with all information reasonably requested by it, OPG's Representative will discuss the error, deficiency (excluding those related to health and/or safety, except for the INCW Part Project), defect, inconsistency, discrepancy, omission or deviation and provide a prompt direction to the Contractor resolving the issue by way of a Project Change Directive. If the Contractor's Proposal Documents or the Final Submittals, or any portion of them, are found to be in error, deficient, defective, inconsistent, incomplete or deviate from the requirements of this Agreement or the Owner's Mandatory Requirements in any way, the Contractor will perform, having regard to the terms of this Agreement and prudent practices, any corrective work to remedy the erroneous, deficient, defective, inconsistent or incomplete part of the Contractor's Proposal Documents or the Final Submittals and take any other remedial action with respect to the Work arising in respect of such error, deficiency, defect, inconsistency, discrepancy, omission or deviation, unless the error, deficiency, defect, inconsistency, discrepancy, omission or deviation in the Contractor's Proposal Documents or the Final Submittals is as a result of an error in the Owner's Mandatory Requirements. All Work performed after the Contractor became aware of the error, deficiency, defect, inconsistency, discrepancy, omission or deviation from the requirements of this Agreement will be a Disallowed Cost until OPG's Representative accepts the Contractor's recommendation as to how to reconcile or fix the error, deficiency, defect, inconsistency, discrepancy, omission or deviation. If the Contractor fails to provide Notice to OPG's Representative as required under this Section 2.9(c) respecting any such error, deficiency, defect, inconsistency, discrepancy, omission or deviation, the Contractor's costs resulting from such error, deficiency, defect, inconsistency, discrepancy, omission or deviation will be Disallowed Costs.

2.10 Tunnel Boring Machine

(a) **Transfer of Title to OPG.** Notwithstanding any other provision of this Agreement, the Contractor hereby transfers to OPG all of the Contractor's right,

title and interest in and to the TBM, all trailing gear and tunnel transportation systems (collectively, the "**TBM Accessories**") and any right, title or interest in and to the TBM and the TBM Accessories that it may acquire hereafter, free and clear of all Liens. The transfer of title to the TBM and TBM Accessories shall in no way detract from the Contractor's obligations in Section 2.12(a). The Contractor will have available to it a spare main bearing that can be available for shipment within 10 days and can be delivered to the Site within 60 days of a breakdown of the TBM main bearing. OPG may also direct the Contractor to acquire a spare main bearing and transfer title to OPG by issuing a Project Change Directive. In the event OPG issues such a Project Change Directive, the Contractor shall deliver the spare main bearing to the Site or to the Robbins factory in Ohio USA, as OPG may direct in a Project Change Directive, within a period of time as may be agreed by the Parties acting reasonably, as an Allowed Cost and with an adjustment to the Target Cost for acquisition, delivery, and maintenance.

(b) **License to Contractor.** OPG hereby grants the Contractor a license to the use of the TBM and the TBM Accessories for all purposes that the Contractor deems necessary to perform the Work and complete the Tunnel Facility Project, which license will terminate on the TBM Completion Date.

(c) **Maintenance and Repair.** The Contractor shall be responsible for the maintenance, repair and refurbishment of the TBM and the TBM Accessories.

(d) **Transfer of Title to Contractor.** On the earlier of:

(1) the TBM Completion Date; and

(2) the date for transfer set out in a written Notice from OPG to the Contractor which written Notice states that OPG will be transferring, conveying and assigning the TBM and the TBM Accessories to the Contractor,

OPG will be deemed to have transferred, conveyed and assigned to the Contractor all of OPG's right, title and interest in the TBM and the TBM Accessories. For greater certainty, all costs, charges, liabilities or expenses related to or incurred in connection with decommissioning or dismantling the TBM and the TBM Accessories shall be Allowed Costs.

(e) **Assignment Agreement.** The Contractor will enter into an assignment agreement in form and substance satisfactory to OPG, acting reasonably, which will assign to OPG, as security for the performance of the obligations of the Contractor hereunder, all rights, benefits and entitlements under any agreement with a Subcontractor relating to the TBM and the TBM Accessories (the "**TBM Agreement(s)**") and will obtain any consents from third parties necessary in connection with such assignment.

(f) **Creditors of the Contractor.** The Contractor will require any creditor of the Contractor having or purporting to have any Lien respecting the TBM and the

TBM Accessories to enter into an acknowledgement, in form and substance satisfactory to OPG, acting reasonably, which will acknowledge OPG's interest in the TBM and the TBM Accessories.

(g) **Further Assurances.** The Contractor covenants and agrees to do such acts and enter into such agreements and other documents as OPG may reasonably require to preserve, protect and perfect OPG's interest in the TBM, the TBM Accessories, and the TBM Agreement.

2.11 Commissioning and Completion

(a) **Commissioning Phase.** During the commissioning phase of the Work as set out in the detailed contract schedule, the Contractor will:

(1) be responsible for the testing, verification, calibrating, refining, adjusting and watering-up of all mechanical or electrical elements, equipment or systems in the presence of OPG's personnel, to ensure that installation and performance are as specified in this Agreement and suitable for use by OPG;

(2) demonstrate operation of equipment and systems for the Tunnel Facility Project and train OPG's staff to operate and maintain the Tunnel Facility Project;

(3) develop systems and procedures for use by OPG in the control of the operation and maintenance of, and record keeping for, the Tunnel Facility Project; and

(4) provide manufacturers' authorized representatives, specialists and/or representatives of Subcontractors as may be required by OPG for the Work.

(b) **Demonstrations.** The Contractor will, before any demonstrations, inspect and put into operation all equipment and systems in accordance with the Final Submittals and this Agreement; perform testing, adjusting and balancing; ensure equipment and systems are fully operational; and provide to OPG copies of completed operation and maintenance manuals for use in demonstrations. The Contractor will submit a schedule, for OPG's approval, with the time and date for the demonstration of each item of equipment and each system, with a list of all personnel to be present, not more than one month and not less than two weeks before designated dates.

(c) **Post Substantial Completion Date.** Commencing on Substantial Completion, the Contractor will provide to OPG at the Site a representative, qualified to operate the Tunnel Facility Project, at all reasonable times, as an Allowed Cost. The Contractor will cause this representative to advise OPG in respect of the operation of the Tunnel Facility Project. The Contractor will provide this representative for a reasonable period satisfactory to OPG's Representative, such

period not to be less than one week. During such period, the Contractor's representative will not make, or direct the making of, any change or adjustment to any part of the Goods or Tunnel Facility Project without the prior written approval of OPG's Representative.

2.12 Procurement

(a) **Goods.** Except to the extent otherwise expressly provided in this Agreement, the Contractor will be responsible, for manufacturing or supplying or procuring, factory testing, transporting, delivering, inspecting, receiving and installing all Goods, and providing all construction equipment, tools, transportation, fuel, construction and start-up power, air, light, heat, communications, water (including potable water), sewer connections and temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal, and all other goods and services reasonably required in respect of the Work. With respect to any Goods to be ordered on or after the Effective Date, the Contractor will provide OPG with the names of any proposed suppliers for requirements estimated to be greater than $100,000 and will not enter into any contract for the supply of Goods with any such supplier where OPG has provided a written notice of objection. OPG will have five (5) Business Days from the date of receipt of the names from the Contractor to provide its written notice of objection to any supplier. If OPG has not provided the Contractor with the written notice of objection within such five (5) day period, OPG will be deemed to have accepted the proposed list of suppliers. On receipt of quotations from the acceptable suppliers, the Contractor will submit to OPG the details of the quotations received along with a recommendation to place an order with one of the suppliers. The Contractor will list the reasons for such recommendation. OPG will have five (5) Business Days from receipt of Contractor's recommendation to accept such recommendation. If OPG has not provided the Contractor with the written notice of acceptance within such five (5) day period, OPG will be deemed to have accepted the proposed supplier. In the event that, as a result of OPG's objection, there is a material increase in the cost of the Work or a material impact on the Contract Schedule, then the Contractor shall be entitled to an equitable adjustment to the Target Cost and/or Contract Schedule. The Contractor will maintain all construction equipment, tools and such temporary structures and facilities in good working order. The Contractor will conduct all these activities in accordance with this Agreement. The Contractor will maintain absolute control over, and exclusive responsibility for, the Contractor's own, and each Subcontractor's own, operations and the Contractor's Personnel.

(b) **Warranty on Goods.** The Contractor will ensure that all Goods will be fit for the purposes intended by this Agreement, new, unused, not Defective and free from all Liens, of good quality and comply with all requirements under this Agreement. All warranties and guarantees set out in this Agreement are for the benefit of OPG. If required by OPG, the Contractor will provide satisfactory evidence (including reports of required inspections, tests and approvals) as to the kind and

quality of all Goods. The Contractor will ensure that all Goods will be constructed, applied, assembled, erected, installed, used, connected, adjusted, field tested, conditioned, cleaned, commissioned and cleaned up in accordance with instructions of the applicable Subcontractor, except to the extent as may otherwise be provided in this Agreement.

(c) **Quality Assurance.**

(1) **Quality Assurance Program.** The Contractor will submit a quality assurance program for review to OPG as a Submittal within 60 days after the Start Date which program will be based on the Outline Quality Assurance/Quality Control Program attached hereto as Appendix 2.12(c)(2). Once accepted as a Final Submittal pursuant to Section 2.8(g), such quality assurance program will be deemed to form part of this Agreement, and will be implemented by the Contractor. The quality assurance program of the Contractor will accord with the Contractor's own internal program and the other requirements, if any, set out in this Agreement. If there are any conflicts between the Contractor's internal program and this Agreement, this Agreement will prevail. Compliance with these quality assurance requirements will not relieve the Contractor of any of its obligations or liabilities under this Agreement. The Contractor will ensure that all of the Work is provided in accordance with the applicable quality assurance program. OPG may have any aspect of the quality assurance program of the Contractor reviewed by any auditors designated by OPG. The Contractor will provide such auditors prompt access to all premises and documents required for such review.

(2) **Quality Assurance Manager.** The Contractor will retain a full time third-party quality assurance manager who will oversee and monitor the implementation of the Outline Quality Assurance/Quality Control Program (as modified by a Final Submittal hereunder). The Quality Assurance Manager will be directly responsible to Contractor's project manager and will be on-Site on a full time basis. For greater certainty, all costs incurred in the hiring of the quality assurance manager and the payment of his/her salary by the Contractor will be Allowed Costs for the purposes of this Agreement.

(3) **Independent Inspection Agencies.** OPG may engage independent inspection or testing agencies for the purpose of inspecting and testing the quality of portions of the Work. The engagement of independent inspection or testing agencies by OPG will not relieve the Contractor of any of its obligations or liabilities under this Agreement. If the Work or the Tunnel Facility Project, in whole or in part, is found to be Defective during inspection or testing, the appointed agency will request additional inspection or testing to ascertain the full degree of the Defect. The Contractor will promptly correct Defective Work in accordance with Sections 9.7 and 9.8. The Contractor shall submit such samples and

materials required for testing as may be reasonably required by OPG. The Contractor will submit such samples and/or materials with reasonable promptness and in an orderly sequence so as not to cause delay in the Work. The Contractor will provide labour and facilities to obtain and handle samples and materials on Site and shall provide sufficient space to store and cure test samples.

(4) **Quality Documents.** The Contractor will provide OPG with signed and dated legible copies or originals of all inspection documents pertaining to the Work, including installation and testing.

(5) **Effects of Non-Conformance.** If the Contractor identifies anything which does not conform to the quality assurance program set out in Section 2.12(c)(1), the Contractor will promptly correct such non-conformance (unless the Contractor proposes to "use as is") and deliver a Notice in the form of Appendix 2.12(c)(4) to OPG's Representative reporting the corrective action taken by the Contractor or that the Contractor proposes to "use as is". OPG's Representative will return the Notice in the form of Appendix 2.12(c)(4) to the Contractor indicating OPG's agreement with the proposed disposition (with or without additional terms detailed in Appendix B to the Notice) or directing the Contractor to comply with the Contractor's Proposal Documents or the Final Submittals, as the case may be.

2.13 Construction

(a) **Direction and Competent Supervision.** The Contractor will perform (including all direction, supervision and inspection of) the Work competently and efficiently, devoting such attention and applying such skills and expertise as may be necessary to perform the Work in accordance with this Agreement. The Contractor will at all times maintain good discipline and order at the Site. The Contractor will be solely responsible for the means, methods, techniques, sequences and procedures used to perform the Work (except with respect to the INCW Part Project, in which case OPG will be the "constructor" and will have the control necessary to effectively carry out that role, as described more particularly in Section 2.20). The Contractor will keep OPG advised as to the quality and progress of the Work and the Tunnel Facility Project in such manner and at such times as OPG may request from time to time.

(b) **Temporary Structures and Facilities.** Except with respect to the INCW Part Project (as discussed on Section 2.20), the Contractor will have the sole responsibility for:

(1) the design, erection, operation, maintenance and removal of all temporary structures and facilities at the Site; and

(2) the design and execution of construction methods required in the use of such structures and facilities.

(c) **Time for Performance of the Work.** The Contractor may perform the Work at any time except to the extent that performing the Work is prohibited or restricted:

(1) by Applicable Laws;

(2) by the Approvals;

(3) in the Summary of Work; or

(4) elsewhere in this Agreement.

(d) **Control Monuments.** The Contractor will establish the lay out for the Tunnel Facility Project and will maintain and protect the control monuments established by OPG. The Contractor will ensure that such control monuments are not changed or relocated without the prior written consent of OPG's Representative. The Contractor will promptly report to OPG's Representative whenever any control monuments are lost or destroyed or require relocation because of necessary changes in grades or locations. If OPG's Representative provides consent to any change to, or relocation of, a control monument, the Contractor will cause such change or relocation to be carried out accurately by professionally qualified individuals.

(e) **Survey Verification.** OPG may periodically review the survey and setting out of the Tunnel Facility Project and calculations conducted by the Contractor, and will promptly provide the results of such reviews to the Contractor. In the event of discrepancy, the Contractor and OPG will collaborate to resolve the discrepancy. Unless otherwise directed by OPG in writing, successive setting out operations, that depend on previous work, shall not proceed until the discrepancy has been resolved.

(f) **Non-Compliance.** If the Contractor becomes aware of any Work which does not comply with any of the Owner's Mandatory Requirements, the Contractor's Proposal Documents, the Final Submittals or any provision of this Agreement, the Contractor will promptly correct such non-compliance (unless the Contractor proposes to "use as is") and deliver a Notice in the form of Appendix 2.13(f) to OPG's Representative reporting the corrective action taken by the Contractor or that the Contractor proposes to "use as is". OPG's Representative will return the Notice in the form of Appendix 2.13(f) to the Contractor indicating OPG's agreement with the proposed disposition (with or without additional terms detailed in Appendix B to the Notice) or directing the Contractor to comply with the Owner's Mandatory Requirements, the Contractor's Proposal Documents, the Final Submittals or any provision of this Agreement, as the case may be.

2.14 Labour and Subcontractors

(a) **Competent Workers.** The Contractor will ensure all of the Contractor's Personnel assigned to the Work or the Site, including any site manager and his or her delegates,

(1) are qualified because of knowledge, training and experience to organize the Work and perform the Work;

(2) are familiar with the *Occupational Health and Safety Act* (Ontario) provisions that apply to the Work;

(3) understand, and have the necessary skills to perform, their roles and obligations under this Agreement including those relating to safety, the environment, quality assurance, labour requirements, and Site rules and procedures; and

(4) have knowledge of any potential or actual danger to health or safety in the workplace and the plans and programs in place to address such danger.

(b) **Contractor Fully Responsible for Workers and Subcontractors.** The Contractor will be solely responsible for providing, scheduling and coordinating the Subcontractors and the Contractor's Personnel unless otherwise provided in this Agreement. The Contractor will cooperate with other Persons in all matters of common interest pertaining to services being provided under agreements between OPG and such other Persons, and ensure that the Work being performed on the Site does not obstruct the operations of OPG or other Persons providing services at or near the Site. Except where OPG's Representative requests in writing a specified form of communication, the Contractor will communicate with OPG and all such other Persons solely through OPG's Representative. Except where OPG's Representative requests in writing a specified form of communication, the Contractor will ensure that all Subcontractors communicate with OPG solely through the Contractor. The Contractor will be fully responsible for all acts and omissions of each member of the Contractor's Personnel and each of the Subcontractors and any such acts and omissions will be deemed to be those of the Contractor. Accordingly, respecting each obligation of the Contractor under this Agreement, the Contractor will ensure that no worker of the Contractor, no Subcontractor and no worker of any Subcontractor will breach any such obligation. In addition, respecting each action which the Contractor is not permitted to take under this Agreement, the Contractor will ensure that no worker of the Contractor, no Subcontractor and no worker of any Subcontractor will take any such action that is not permitted. Where any Subcontractor performs any of the Work, the Contractor will ensure that the Subcontractor names OPG as a beneficiary/obligee under any performance, labour and material payment or lien bond posted in respect of that Work.

(c) **Major Subcontractors.** The Contractor will advise OPG in advance of any proposed changes or additions to Major Subcontractors. The Contractor will not:

(1) change any such Major Subcontractor;

(2) change in a material manner the Work performed by any Major Subcontractor;

(3) change the contractual or commercial arrangements with any Major Subcontractor including any changes that would result in an increase to the contract price of greater than $100,000;

(4) add any new Subcontractor who will be performing any Work where the value of all contracts with such new Subcontractor exceeds $100,000; or

(5) settle any claim with a Major Subcontractor or any claim or claims with a Subcontractor that, individually or in the aggregate, exceeds $100,000,

unless OPG's Representative consents, in advance, in writing to such change or addition. In the event that, as a result of OPG's objection to any proposed changes or additions to Major Subcontractors, there is a material increase in the cost of the Work or a material impact on the Contract Schedule, then the Contractor shall be entitled to an equitable adjustment to the Target Cost and/or Contract Schedule.

(d) **Subcontracts.** The Contractor will ensure that all Subcontractors and all Contractor's Personnel comply with the terms of this Agreement as are applicable to them, including the terms relating to safety, environment, quality assurance, labour requirements and Site rules and procedures. The Contractor will enter into a contract with each Subcontractor performing any of the Work that specifically binds the Subcontractor to the applicable terms of this Agreement, including the terms relating to safety, environment, quality assurance, labour requirements, and Site rules and procedures and this Section 2.14, for the benefit of OPG. The Contractor will ensure that each such contract contains a term stating: "Notwithstanding any term in this Agreement, the parties commit to each other and to Ontario Power Generation Inc. that each Party will comply in all respects with Section 2.14(d) of the Amended Design/Build Agreement dated as of December 1, 2008, between Ontario Power Generation Inc. and Strabag Inc." The Contractor will ensure that each contract with a Subcontractor respecting the Work or Tunnel Facility Project will give OPG the right to continue the contract with the Subcontractor in the place of the Contractor if OPG decides to entirely finish the Work in accordance with Section 9.8(c) or 10.3. In the case of assumption of a subcontract by OPG, all invoices submitted by the Subcontractor will be in the name of OPG. At the request of OPG, the Contractor will provide unpriced copies of any subcontract placed prior to the Effective Date (or evidence otherwise acceptable to OPG that such subcontract complies with this Section 2.14(d)) and priced copies of any subcontract placed on or after the

Effective Date. Notwithstanding the foregoing, the Contractor will provide unpriced copies to OPG of any subcontract with the manufacturer of the TBM.

(e) **Labour Obligations.** The Contractor will comply with all obligations set out in Appendix 2.14(e) including those set out in the "Labour Requirements Clause - Form 1" attached to Appendix 2.14(e). The Contractor will indemnify and save harmless all members of the OPG Group from and against any and all Losses suffered or incurred by any member of the OPG Group on account of claims made or grievances filed by any unions on account of any breach by the Contractor or any Subcontractor of the obligations set out in Appendix 2.14(e), as determined by the appropriate adjudicative body, in the course of performing the Work or on account of other non-unionized labourers performing portions of the Work.

(f) **WSIB.** The Contractor shall submit as a Submittal the Contractor's Workplace Safety and Insurance Board account number promptly after the account number has been obtained. The Contractor will be and remain at all times in good standing with the Workplace Safety and Insurance Board. Upon initial arrival on the Site, and from time to time at the request of OPG, the Contractor will submit a certificate of compliance from the Workplace Safety and Insurance Board as to the Contractor's status and that of all Subcontractors that will be performing Work at the Site. Together with the certificate, the Contractor will submit a list of the Workplace Safety and Insurance Board registration numbers of each of the Contractor's Personnel who will be employed at the Site, and will thereafter update the list as the Work progresses.

(g) **Foreign Nationals.** The Contractor will be solely responsible for taking all necessary steps and actions to obtain, (provided the Contractor has obtained prior approval of OPG for the necessary steps and actions), all Approvals from all applicable Governmental Authorities respecting all foreign nationals who may be engaged in performing the Work in Canada. OPG will have five (5) Business Days from the date of receipt of the plans respecting approval for foreign nationals to provide its written notice of objection of such plans. If OPG has not provided the Contractor with the written notice of objection within such five (5) day period, OPG will be deemed to have accepted the plans. In the event that, as a result of OPG's objection, subject to a suitably qualified candidate being proposed, there is a material increase in the cost of the Work or a material impact on the Contract Schedule, then the Contractor shall be entitled to an equitable adjustment to the Target Cost and/or Contract Schedule except where the foreign national objected to by OPG is intended to fill a position held by one of the key personnel in the Organizational Chart in Appendix 2.2(a).

(h) **Reasonable Objections by OPG.** The Contractor will not use, as part of the Contractor's Personnel, any individual against whom OPG has a reasonable objection. The Contractor will promptly remove from the Site any such Person whom OPG's Representative does not consider competent or otherwise considers unsuitable for performing the applicable Work, including for failure to comply

with any applicable health or safety obligations or any other obligations under this Agreement.

(i) **Payment of Subcontractors.** The Contractor will pay in a timely manner for all Work performed or caused to be performed by a Subcontractor on the Site which could result in any Lien being filed under the *Construction Lien Act* (Ontario) or otherwise against any property owned, leased or licensed by OPG or any of its subsidiaries or in which OPG or any of its subsidiaries has an interest, in whole or in part, including the Site. If the Contractor fails to make, any such payment in a timely manner, OPG may make payment directly to the applicable Subcontractor, whereupon any invoiced amount of the Contractor in respect of such payment will be a Disallowed Cost and there will be a corresponding reduction in the Target Cost. At the request of OPG, the Contractor will cause the Subcontractor to issue any unpaid invoice directly to OPG and Section 7.5(e) will apply in respect of any such payment. Where OPG makes any such payment, OPG may set off the full amount of any such payment against any amount otherwise owing by OPG to the Contractor. However, no adjustment to the Target Cost will be made for any payment made by OPG to a Subcontractor where the Contractor is disputing in good faith the right of the Subcontractor to receive such payment.

(j) **Liens.** The Contractor will keep title to the Site and every part of the Site free and clear of all Liens respecting the performance of the Work. The Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person in respect of any Liens registered by a Subcontractor against any property owned, leased or licensed by OPG or any of its subsidiaries or in which OPG or any of its subsidiaries has an interest, in whole or in part, including the Site where the costs of vacating such Lien would be a Disallowed Cost. The Contractor will immediately notify OPG of any Lien, claim of Lien or other action of which it has knowledge and which affects the title to any property owned, leased or licensed by OPG or any of its subsidiaries or in which OPG or any of its subsidiaries has an interest, in whole or in part, including the Site. If any Lien is registered against any such property, in whole or in part, including the Site, by a Subcontractor, the Contractor will cause the Lien to be vacated or discharged from title within 10 Business Days of registration. If the Contractor fails to vacate or discharge any such Lien in a timely manner, OPG may vacate or discharge that Lien by paying into court any sum or providing such security as may be necessary to vacate or discharge the Lien. The costs of vacating or discharging any Lien shall be Allowed Costs, except to the extent the costs are Disallowed Costs under Section 1.1(O)(4). The Contractor will immediately reimburse OPG on demand for all OPG's costs and expenses respecting the discharge, including the amount of the payment into court, the cost of any such security, OPG's legal fees and expenses and a reasonable charge for time spent by OPG personnel to the extent the costs of vacating or discharging such Lien are a Disallowed Cost under Section 1.1(O)(4). OPG may set off the full

amount of any such reimbursement obligation against any amount otherwise owing by OPG to the Contractor.

(k) **Local Community.** The Contractor will use its best efforts to provide opportunities to local residents to work on the Tunnel Facility Project and to acquire goods and services necessary in regard to the Tunnel Facility Project, including construction material and aggregate, from within the Regional Municipality of Niagara, all as more particularly described in the Community Impact Agreement. The Contractor will ensure that local contractors are provided with information about the Tunnel Facility Project and its labour requirements, and will be provided with timely bidding opportunities, all as more particularly described in the Community Impact Agreement.

(l) **General.** With the exception of Sections 2.14(i) and 2.14(j), references to Subcontractors in this Section 2.14 apply only to Subcontractors providing services at the Site.

2.15 Use of Site and Other Areas

(a) **Documents to be Maintained on Site.** The Contractor will maintain in a safe place on the Site one record copy of this Agreement (including all Amendments), the Owner's Mandatory Requirements, Submittals, Final Submittals, Project Change Directives, Project Change Notices, the Contractor's Proposal Documents, the Concept Drawings, the daily records described in Section 2.7(d) and quality assurance documentation, in good order and annotated to show all changes made during the performance of the Work. The Contractor will make all these documents available to OPG at any time for reference at the Site. On Substantial Completion, the Contractor will deliver those documents requested by OPG to OPG at the time and place designated by OPG.

(b) **Access to Areas.** If the Contractor requires access to any area outside of the Site, the Contractor will obtain, as an Allowed Cost (provided the Contractor has obtained prior approval of OPG for the necessary steps and actions), such access for such purposes as the Contractor requires; provided that no approval of OPG shall be required for the rental of houses for employees where such rentals are permitted by the Contractor's 2009 policy as provided to OPG. OPG consents to the leasing by the Contractor of a warehouse at 3481 Stanley Avenue, Niagara Falls, Ontario. OPG will have five (5) Business Days from the date of receipt of the plan to access outside areas from the Contractor to provide its written notice of objection to such plans. If OPG has not provided the Contractor with the written notice of objection within such five (5) day period, OPG will be deemed to have accepted the plans. In the event that, as a result of OPG's objection, there is an increase in the cost of the Work or a material impact on the Contract Schedule, then the Contractor shall be entitled to an equitable adjustment to the Target Cost and/or Contract Schedule.

(c) **Designated Areas.** The Contractor will ensure that:

(1) all Goods, construction equipment, tools, fuel and temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal, whether in use or in storage; and

(2) the operations of the Contractor and all Subcontractors,

will be restricted only to those areas designated "as available" on the Concept Drawings in Appendix 1.1(h) and any other areas outside of the Site permitted by Applicable Laws and will comply with the requirements set out in the Summary of Work and the Owner's Mandatory Requirements. The Contractor will ensure that all such temporary structures and facilities will be of metal construction and will be removed from OPG's property when any such structure or facility is no longer needed, and in any event, within 60 days after the Final Completion Date as an Allowed Cost. If the Contractor does not so remove any such structure or facility, OPG may remove such structure or facility at its own cost and the Target Cost will be correspondingly reduced. The Contractor will conduct all activities in the areas designated in accordance with this Agreement.

(d) **Surrounding Community and Environment.** The Contractor recognizes that the Site is located in an urban/tourist area and recognizes the potential intrusiveness of construction on the activities of the local residents and that the Tunnel Facility Project is subject to the constraints set out in the Summary of Work.The Contractor will ensure that the Contractor's Personnel performing Work at the Site and each of the Subcontractors are aware of these conditions and the corresponding restrictions placed on them (e.g. noise limitations, transportation routes, respect for the local population and tourists, dust concerns) and that cooperation with local authorities and the public is essential. The Contractor will perform the Work in accordance with the Community Impact Agreement and conduct or attend meetings, participate in local committees, respond to information requests and do such other things as may be beneficial in maintaining a co-operative relationship with the local community. The Contractor will promptly notify OPG's Representative of any complaints it receives from the public. The Contractor will co-operate fully with OPG's Representative in responding to all complaints.

(e) **Site Conditions.** The Contractor will keep all of the Contractor's Personnel fully informed in a timely manner of all Site rules and conditions and any changes to such rules and conditions.

(f) **Contractor Responsibility for Damages.** The Contractor will have exclusive responsibility for any damage, injury or loss to any area on the Site or to OPG or any other occupant of the Site or to any adjacent area, respecting the performance of the Work. The Contractor will make good and pay all costs incurred by others in making good any such damage, injury or loss. If any claim, demand, action,

suit or proceeding is made against OPG by any Person for any Losses arising in respect of the Work, the Contractor will promptly resolve the claim. The Contractor will indemnify and hold harmless each member of the OPG Group, from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person in connection with any damage, injury or loss to any area on the Site or to OPG or any other occupant of the Site or to any adjacent area, to the extent that the circumstances giving rise to the claim, demand, action, suit or proceeding were caused or attributable to any breach of any Applicable Laws or the wilful misconduct of the Contractor, a Subcontractor or any member of the Contractor's Personnel or the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii).

(g) **Clean Site.** During the performance of the Work on the Site, the Contractor will keep the Site, and any roads, Site accesses, sidewalks and walkways used in the course of performing the Work, free from accumulations of snow, ice, water, rubbish, debris and other waste materials. The Contractor will implement a housekeeping program to ensure that all rubbish and debris is kept to a minimum and cleared away daily and that all materials are stored in a safe manner. Promptly following Substantial Completion, as an Allowed Cost, the Contractor will remove all rubbish, debris and other waste or surplus Goods from and about the Site as well as all applicable construction equipment, tools, fuel, temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal, and all other Goods not otherwise necessary to complete punch list items. Except as set out in Section 2.15(c), any materials remaining to complete punch list items will be removed by no later than the Final Completion Date, if not otherwise agreed by OPG. The Contractor will leave the Site clean and ready for occupancy by OPG once the Tunnel Facility Project is entirely finished. The Contractor will restore to original condition, as at the date of this Agreement, all property not designated for alteration by this Agreement. In addition, the Contractor will provide any other cleaning activities required by this Agreement.

(h) **Signage on Site.** The Contractor will not erect signage on the Site directed to the public without OPG's prior written approval.

(i) **Load Limits.** The Contractor will not load the Project, the Site or any roads used in the course of providing the Work and will ensure that no part of the Project, Site or such roads will be loaded in any manner that will endanger the Project, Site or such roads. The Contractor will not subject any part of the Project or any property on, under, over or near the Site to unsafe stresses or pressures.

(j) **Natural and Historical Objects.** All fossils, coins, articles of value or antiquity and structures and other remains or things of geological or heritage interest discovered on the Site shall be the absolute property of OPG. The Contractor will take all reasonable precautions and any precautions required by OPG to prevent

the Contractor's Personnel or other Persons from removing or damaging any such article or thing and immediately on discovery and before removal acquaint OPG of such discovery and carry out at the expense of OPG, OPG orders as to the preservation and disposal of the same. OPG will provide direction to the Contractor in connection with the precautions required by OPG to prevent the Contractor's Personnel or any other Person from removing or damaging any such article or thing and in connection with the preservation and disposal of such article or thing and to the extent such direction has the effect of materially increasing the cost or time of performing the Work, then such direction will be treated as a Project Change Directive issued by OPG under Section 5.1(a).

(k) **Lands.** In addition to the Contractor's obligations in Section 2.15(b), if, in the performance of the Work, the Contractor notifies OPG that it requires any interest, right of way, easement, license or other use right for access (an "**Interest**") in land which is not required to be provided by OPG pursuant to Section 3.1(i) where the Interest in such land has acquisition cost or rental or other payments of greater than $100,000, then upon OPG's prior written approval, the Contractor may acquire the necessary Interest in such land as an Allowable Cost. If the Contractor has not received a written notice of objection from OPG within five (5) Business Days of OPG receiving notification, the Contractor will have deemed acceptance to acquire an Interest. For greater certainty, this Section 2.15(k) will apply if the as-built tunnel alignment deviates from the Interest required to be provided by OPG pursuant to Section 3.1(i).

2.16 Intellectual Property

(a) **Grant of Intellectual Property Rights.** Subject to Section 2.16(c), the Contractor grants to OPG all rights (including ownership of the physical property) in the Work, Tunnel Facility Project, Submittals, results of the Work, and all other documents of any kind, designs, drawings (including as built drawings), inventions, ideas, processes, discoveries, techniques, diagrams, illustrations, schedules, performance charts, brochures, specifications, plans, photographs and other recordings, reports, manuals (including operating and maintenance manuals), software (hard copies and machine readable formats), information, data, models, samples and other deliverables whether complete or incomplete, provided or required to be provided by the Contractor to OPG under this Agreement (collectively the "**Property**"). Without limiting the foregoing, but subject again to Section 2.16(c), this grant includes all intellectual property rights (including all trade secrets, confidential information, patents, patent applications, rights to file patents, trade-marks, trade-mark applications, rights to file trade-marks, copyrights, industrial and similar designs, rights to file for industrial and similar designs, and know-how) contained, embedded or disclosed in or otherwise existing in respect of, used in the production of, or required or desirable for the provision, use, reproduction, modification, maintenance, servicing, improvement or continued operation of the Property (collectively, the "**Intellectual Property**"). Effective on the date of each such grant, each such item will be deemed to be Confidential Information owned by OPG, despite Section 2.17(a)(2).

(b) **No Diminishing of Intellectual Property Rights.** The Contractor will not take any action that may compromise or diminish the grant to OPG of rights in the Property. The Contractor will perform any acts required to confirm or document OPG's rights in the Property. These acts include obtaining, at the request of OPG and as an Allowed Cost, assignments of rights from the Contractor's Personnel, as applicable, any applicable Subcontractor's employees and any applicable Subcontractor. These acts also include providing, at OPG's expense, access to the Contractor's Personnel, as applicable, and any applicable Subcontractor to assist OPG to protect fully its rights in the Intellectual Property.

(c) **Exception and Licence.** Notwithstanding any term in Section 2.16(a), the Contractor and each Subcontractor retains its rights in its part of the Intellectual Property and provides no grant thereof except in accordance with the provisions of this Section 2.16(c), so long as the Contractor or the applicable Subcontractor can establish through written records that such Intellectual Property existed before the earlier of, the date of the Original Agreement or the date that the Contractor commenced the Work (the "**Retained Intellectual Property**"). In respect of all such Retained Intellectual Property that the Contractor or a Subcontractor owns or claims to own, the Contractor grants to OPG, or, in the case of a Subcontractor, the Contractor will provide to OPG a perpetual, irrevocable, royalty-free, non-exclusive, fully paid up, freely assignable licence to:

(1) use all such Retained Intellectual Property in respect of the design, operation and maintenance, construction, commissioning, refurbishment, replacement, alteration, relocation, decommissioning, dismantling or demolition of the Sir Adam Beck Generating Complex and related facilities (including the Tunnel Facility Project), in whole or in part, to which the Retained Intellectual Property applies;

(2) use all such Retained Intellectual Property for any of the actions referred to in Section 2.16(c)(1) in respect of any transaction relating to the financing, sale, lease or other transfer of rights to a successor in interest involving the Sir Adam Beck Generating Complex and related facilities (including the Tunnel Facility Project), in whole or in part, to which the Retained Intellectual Property applies;

(3) disclose any Retained Intellectual Property to any Person who requires such Retained Intellectual Property in respect of any of the actions referred to in Section 2.16(c)(1) or 2.16(c)(2);

(4) use, reproduce, copy, transmit, modify and create derivative works from any Retained Intellectual Property for any of the actions referred to in Section 2.16(c)(1); and

(5) sublicence any or all rights granted to OPG under this Section 2.16(c) to an affiliate of OPG or to any Person who provides goods or services to OPG for any of the actions referred to in Section 2.16(c)(1).

(d) **Representation and Warranty.** The Contractor represents and warrants to OPG as follows.

(1) **No Suits.** There is no claim, demand or suit respecting any part of the Property or the Retained Intellectual Property.

(2) **No Potential Claims.** There is no potential claim, demand or suit respecting the Property or the Retained Intellectual Property, in whole or in part, that could affect the performance, function or use of the Property or Retained Intellectual Property, in whole or in part, as intended by this Agreement.

(3) **Ownership.** Before transferring ownership in the Property to OPG, the Contractor is the exclusive owner of, and has good and marketable title to, all the Property. Except in regard to the Retained Intellectual Property, there is no ownership interest, agreement option or other right, title, benefit, interest or privilege outstanding in favour of any Person for the purchase or licence from the Contractor of, or any Lien in favour of any other Person in, any of the Property.

(4) **Right to Grant Licence.** The Contractor has the right to grant the licence rights in the Retained Intellectual Property and will obtain such rights from Subcontractors as contemplated by this Agreement.

(e) **OPG's Remedy for Breach.** The Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person arising in respect of any breach or infringement or alleged breach or infringement by any member of the OPG Group of any right of any Third Party in any of the Property or the Retained Intellectual Property. If any such claim, demand, action, suit or proceeding arises, the Contractor will, as a Disallowed Cost:

(1) obtain the right for OPG to continue using the Property and the Retained Intellectual Property in the manner intended by this Agreement;

(2) make such modifications to the Property and the Retained Intellectual Property so that it becomes non-infringing, without incurring any diminution in the performance, function or use of the Property or the Retained Intellectual Property, as intended by this Agreement; or

(3) replace the Property and the Retained Intellectual Property to the extent necessary with non-infringing substitutes, so long as such substitutes do not result in a diminution in the performance, function or use of the Property, the Intellectual Property or the Retained Intellectual Property as intended by this Agreement.

2.17 Confidential Information

(a) **Definition of Confidential Information.** In preparation for, and in the course of, performing the Work, OPG and OPG's Representative will disclose to the Contractor certain OPG information which is confidential, a trade secret or otherwise proprietary to OPG, including this Agreement and the fact that the Contractor is performing the Work (collectively, the "**Confidential Information**"). Confidential Information does not include, however, information that the Contractor is able to demonstrate to OPG's satisfaction, acting reasonably:

(1) was or becomes generally known to the public through no fault of the Contractor, a Subcontractor or their respective shareholders, directors, officers, partners, members, representatives, agents, advisors or any of the Contractor's Personnel or any other Person for whom the Contractor or any Subcontractor is responsible at law; or

(2) was specifically known by the Contractor before disclosure by OPG and was not subject to any confidentiality obligation.

(b) **Ownership and Treatment of Confidential Information.** All Confidential Information remains, at all times, the exclusive property of OPG. Except as expressly set out in this Section 2.17(b), the Contractor has no licence or other right to use or disclose any Confidential Information for any purpose whatsoever. The Contractor may use Confidential Information only in respect of the preparation for, and the performance of, the Work, including in negotiations with proposed Subcontractors. The Contractor will ensure that none of its or any Subcontractor's current or former shareholders, directors, officers, partners, members, representatives, agents and advisors or any of the Contractor's Personnel or any other Person for whom the Contractor or any Subcontractor is responsible at law will use any of the Confidential Information for any purposes other than those expressly set out in this Section 2.17(b).

(c) **Return of Confidential Information.** At any time, at OPG's request, the Contractor will deliver promptly to OPG all, or an OPG-specified portion of, the Confidential Information, together with all copies, extracts or other reproductions in whole or in part of such Confidential Information. In addition, at any time, at OPG's request, the Contractor will destroy, demonstrably, promptly and irrevocably:

(1) all such copies, extracts or other reproductions of Confidential Information, or an OPG-specified portion of Confidential Information, which cannot, because of the device on which such Confidential Information is stored, be removed from the possession of the Contractor by delivery to OPG; and

(2) all documents, designs, drawings, specifications, plans, reports, information and other deliverables or data whatsoever (regardless of the form, medium or device on or in which such Confidential Information is written, recorded, stored or reproduced) prepared in respect of the Work and which is based on any of the Confidential Information.

Following such delivery and destruction, the Contractor will promptly provide OPG with written confirmation of completion. In any event, the Contractor will complete all such actions within 10 Business Days of receipt of OPG's initial request.

(d) **Remedies.** The Contractor acknowledges that OPG would not have an adequate remedy at law for money damages if the Contractor fails to fulfill any of its obligations under this Section 2.17. Accordingly, in addition to any other remedies under this Agreement, OPG will be entitled to any injunction, specific performance or other remedy in law or equity (without being required to post a bond or other security), in respect of any breach or threatened breach of this Section 2.17 and in which case, the Contractor consents to any such injunction, specific performance or other remedy in law or equity. The Contractor will indemnify and hold harmless each member of the OPG Group, from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person, to the extent arising in respect of a breach or threatened breach of this Section 2.17.

2.18 Conflicts of Interest

The Contractor has provided to OPG the declaration set out in Appendix 2.18, stating that, except as disclosed, the Contractor and all members of its consortium are free of actual or potential conflicts of interest. The Contractor will disclose any change in circumstance that may cause the declaration set out in Appendix 2.18 to be incorrect, inaccurate or incomplete. If the Contractor or consortium member discloses a change in circumstance during the course of the Tunnel Facility Project, OPG may request that the Contractor deliver further particulars regarding the conflict and may ask the Contractor to propose and institute measures which in OPG's opinion satisfactorily address the conflict.

2.19 Language and Units of Measure

(a) **Use of English Language.** The Contractor will ensure that all communication between OPG and the Contractor and between the Contractor and each of the local Subcontractors respecting the Work will be in English, including all drawings, notes on drawings and Submittals.

(b) **Units of Measurement.** The Contractor will ensure that the International System of Units (SI) will be used for all purposes with respect to the Work, including the calibration of any Goods.

(c) **Risk.** Any and all risk associated with language or units of measure shall be borne by and be for the account of the Contractor, but shall be an Allowed Cost.

2.20 Work Safety - INCW Part Project

The provisions in this Section 2.20 shall apply to the portion of the Work required for the INCW Part Project and carried out in the INCW Part Project Area. References to Subcontractors in this Section 2.20 apply only to Subcontractors providing services at the Site.

(a) **Primary Goal.** Safety of the Contractor's Personnel, individuals at or near the INCW Part Project Area and the public is of paramount concern to OPG. In the performance of the relevant Work, the Contractor will not in any manner endanger the safety of, or unlawfully interfere with, Persons on or off the INCW Part Project Area, including the public.

(b) **Constructor.** OPG will be the "constructor" (as that term is defined in the *Occupational Health and Safety Act* (Ontario)) in respect of the Work required for the INCW Part Project and carried out in the INCW Part Project Area. As such, OPG will submit the required notice of project and registration form to the applicable Governmental Authority. OPG will also have the authority necessary to carry out the role of "constructor" effectively.

(c) **Compliance.** The Contractor will perform all the Work required for the INCW Part Project in accordance with:

(1) all Applicable Laws and applicable collective agreements;

(2) and to the extent not inconsistent with Sections 2.20(c)(1), the INCW Part Project Specific Site Safety Plan, as described in Section 2.20(d);

(3) and to the extent not inconsistent with Sections 2.20(c)(1) and 2.20(c)(2), the Contractor's safety program (a copy of which is attached as Appendix 2.4(c), as amended from time to time); and

(4) and to the extent not inconsistent with Sections 2.20(c)(1), 2.20(c)(2) and 2.20(c)(3), the very best of practices respecting health and safety and in a manner that recognizes and minimizes the risks to workers, other individuals and property.

The Contractor will forward to OPG, for OPG's review and prior approval, without delay, any changes to the INCW Project Specific Site Safety Plan made during the course of performing the Work required for the INCW Part Project. OPG will monitor the compliance of the Contractor and Subcontractors with these requirements, including through field inspections during the course of the performance of the Work required for the INCW Part Project. The Contractor will rectify any deficiencies immediately upon written or verbal direction from OPG's Representative. OPG may also have any aspect of the INCW Project Specific Site Safety Plan reviewed by inspectors and other Persons designated by

OPG. The Contractor will provide these inspectors and other Persons with prompt access to the INCW Part Project Area and all premises and documents required for such review. The Contractor will forward to OPG, without delay, any change to the Council Amendment to Draft #7 (CAD-7) rating of the Contractor or to any Subcontractor performing Work in the INCW Part Project Area.

(d) **INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan.** The Contractor will have performed a safety hazard analysis to identify all significant safety hazards in respect of the Work required in the INCW Part Project Area. Based on this analysis and the Preliminary INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the Contractor will prepare a detailed safety plan for the INCW Part Project (as amended from time to time, the "**INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan**") which will document how the Contractor will address all significant safety hazards related to the INCW Part Project, including the methodology for safe work planning and will include provision for the regular and systematic review and audit of the plan elements by the Contractor to determine whether the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan requires modification to more appropriately and effectively address all safety hazards associated with the Work required in the INCW Part Project Area. The Contractor will provide for the communication of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to all workers performing Work on the INCW Part Project Area and all Subcontractors. The Contractor will submit the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to OPG as a Submittal within 30 days after the Start Date for review and comment and such plan will be deemed to form part of this Agreement. The INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan will be implemented by the Contractor. OPG retains the right to require modification of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, to its sole satisfaction, including in order to ensure that the plan meets OPG's safety requirements. To the extent OPG requires modification of the plan, the Contractor will modify the plan within 5 days after receiving Notice to do so from OPG. The Contractor will also submit to OPG the results of its own regular review and audit of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, including modifications thereto, within 10 days after each review and audit. OPG will monitor the compliance of the Contractor and Subcontractors with the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan through field inspections during the course of the performance of the Work required in the INCW Part Project Area.

(e) **Effect of Review.** If OPG reviews, comments on, accepts, rejects or fails to review, comment on, accept or reject any aspect of the Contractor's or a Subcontractor's safety program or the INCW Part Project Specific Site Safety Plan (including at a meeting or as part of OPG's inspections or reviews), or if the

Contractor or a Subcontractor satisfies or fails to satisfy any comments or concerns of OPG, such action or failure to act will not in any way relieve the Contractor from any of its safety obligations under this Agreement.

(f) **Safety Representative.** The Contractor will provide a qualified and experienced health and safety representative that will be responsible for the INCW Part Project Area. The Contractor will make this representative responsible for training the Contractor's Personnel in safety, prevention of accidents and the maintaining, reviewing and revising of safety precautions and programs.

(g) **Safety Precautions and Remedies.**

(1) **Protection.** Subject to a written or verbal direction from OPG's Representative to the Contractor, the Contractor will be responsible for initiating, maintaining, reviewing, revising and supervising all safety precautions and programs in respect of the Work required for the INCW Part Project. The Contractor will take all necessary precautions (including ensuring that all of the Contractor's Personnel are equipped with, and use, all safeguards and personal protective equipment necessary for the performance of the relevant Work) for the safety of, and will provide the necessary protection to prevent damage, injury or loss resulting from the performance of the Work required for the INCW Part Project to:

(A) each Person who is in the INCW Part Project Area or who may otherwise be affected by the performance of the Work required for the INCW Part Project, including the Contractor's Personnel and members of the public;

(B) any of the Goods, whether in storage on or off the INCW Part Project Area;

(C) the Tunnel Facility Project; and

(D) any other property on, under, over or near the INCW Part Project Area, whether belonging to OPG or to any other Person, including buildings and other structures, facilities, fences, gates, pavements, roadways, sidewalks, walks, vegetation, utilities and underground facilities that are not designated for removal and disposal in the course of performing the relevant Work.

(2) **Work Protection.** The Contractor will carry out the Work required in the INCW Part Project Area under work protection ensuring that equipment being worked on is safely isolated and de-energised. OPG will provide isolation and de-energisation, provided that the Contractor is responsible for co-ordinating all work protection with OPG's Representative. Where the Contractor is required to perform elements of the Work under OPG's Work Protection Code, the Contractor's personnel directly involved in execution of the Work must complete required mandatory training as

outlined in OPG, Electricity Production, Work Protection Code Training Requirements NPG-LP-HS-007 (current version dated April 15, 2003). All individuals who will be required to work as a work group member under a Work Protection must complete Level 2 - Worker Training (up to 1 hour). All individuals who will be required to hold Work Protection, and their supervisors, must successfully complete Level 5 - Instructor Led - Holder of Record Training (3 days plus field assignments). Requalification training is required every 2 years. The Contractor acknowledges that it has reviewed OPG's Work Protection Code.

(3) **Notification of Owners**. The Contractor will promptly deliver a Notice to OPG's Representative as the Contractor becomes aware of, and indicating the identity of, each utility, owner of underground facilities and owner of property (excluding OPG and its subsidiaries) on, under, over or near the INCW Part Project Area that may be affected by the relevant Work and how each such utility or owner may be affected. OPG will deliver a Notice to the Contractor confirming the identity of each such Person and the Contractor will, at OPG's direction, deal with or cooperate with OPG in dealing with settling any issue with such Person, including the protection, removal, relocation or replacement of the property of any such Person.

(4) **Repair of Damage**. To the extent that any Third Party, such as a utility, owner of underground facilities or owner of property (excluding OPG and its subsidiaries) on, under, over or near the INCW Part Project Area suffers or incurs any Losses to any property caused by the Contractor or a Subcontractor, the Contractor will remedy such Losses in a timely manner and as a Disallowed Cost. The Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by a Third Party in connection with Losses suffered or incurred to any property of such Third Party caused by the Contractor or a Subcontractor.

(h) **INCW Part Project Specific Site Security, Public Safety and Emergency Response.** The Contractor will have performed a security, public safety and emergency response analysis to identify all public safety hazards associated with the INCW Part Project Area and the relevant Work and to identify all potential means of unauthorized access to the INCW Part Project Area. Based on this analysis and the Preliminary INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, the Contractor will prepare a detailed project specific site security, public safety and emergency response plan for the INCW Part Project. Such plan as amended from time to time will be included in the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan and will document, among other things, how the Contractor will address all significant public safety hazards and prevent unauthorized access to the INCW Part Project Area, the matters described in

Appendix 2.4(g) (which shall apply to the INCW Part Project, *mutatis mutandis*) and will include provision for the regular and systematic review and field inspection of the plan elements to determine whether the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan requires modification. The Contractor will provide for the communication of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to all workers performing Work on the INCW Part Project Area and all Subcontractors. The Contractor will submit the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan to OPG as a Submittal within 30 days after the Start Date for review and comment and such plan will be deemed to form part of this Agreement. The INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan will be implemented by the Contractor. OPG retains the right to require modification of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, to its sole satisfaction. To the extent OPG requires modification of the plan, the Contractor will modify the plan within 5 days after receiving Notice to do so from OPG. The Contractor will also submit to OPG the results of its own regular review and audit of the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan, including modifications thereto, within 10 days after each review and audit. OPG will monitor the compliance of the Contractor and Subcontractors with the INCW Part Project Specific Site Safety, Security, Public Safety and Emergency Response Plan through field inspections during the course of the performance of the Work required in the INCW Part Project Area.

(i) **Safety Reports.** During the performance of the Work in the INCW Part Project Area, the Contractor will provide OPG's Representative with:

(1) a verbal report immediately of all accidents, near misses or "High Maximum Reasonable Potential for Harm" incidents (which are defined to be incidents that result in, or could reasonably be expected to result in, death from either immediate or delayed effects or permanent total disability, that is, where an individual is disabled to the point where maintaining gainful employment is unlikely) which the Contractor is required to provide to OPG in accordance with OPG's safety incident management standard, as amended from time to time (which the Contractor has reviewed), including any serious incident requiring off-site medical attention or near miss incidents which do or could have resulted in the death of, or serious injury to, a worker or other Person on or off the INCW Part Project Area or an incident which has resulted in the death of or serious injury to a worker or other Person on or off the INCW Part Project Area;

(2) an immediate verbal report of all High Maximum Reasonable Potential for Harm incidents (as that term is defined in Section 2.20(i)(1)) and evidence that a senior executive of the Contractor has also made this report immediately to OPG's Representative;

(3) within 24 hours of an accident, construction occurrence or incident report, a copy of all accident, construction occurrence and incident reports which the Contractor, any Subcontractor, or OPG is required to submit in respect of the relevant Work under the *Occupational Health and Safety Act* (Ontario) or the *Workplace Safety and Insurance Act*, 1997 (Ontario);

(4) within 24 hours, Notice of any visits by the Ministry of Labour and copies of any reports, orders to comply, charges, stop work orders, and notices of compliance under the *Occupational Health and Safety Act* (Ontario) or other Applicable Laws;

(5) if there is a joint health and safety committee, a copy of the minutes of each meeting of the joint health and safety committee; and

(6) a monthly report within 10 days of each month's end with safety statistics for the Contractor and all Subcontractors performing Work at the INCW Part Project Area. The Contractor will include in this report, with a brief description of each incident and injury:

(A) the number of injuries resulting in a worker requiring medical aid;

(B) the number of near miss incidents which could have resulted in the death of, or serious injury to, a worker;

(C) the number of injuries resulting in a worker's absence from one or more complete shifts;

(D) the time each worker takes off from work for each injury;

(E) the number of Ministry of Labour orders to comply; and

(F) the total number of person hours worked by the Contractor's Personnel broken down between the Contractor and each Subcontractor.

(j) **Stop Work Orders.** Where an order to comply, stop work order or any similar order or notice respecting the relevant Work is issued by the Construction Health and Safety Branch of the Ontario Ministry of Labour or any other Governmental Authority or OPG, where in OPG's opinion, the stoppage is necessary to protect the safety of Persons or property, such order or notice will not be grounds for any change to the Contract Schedule or Target Cost to the extent that the underlying circumstances were caused by or were attributable to the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii). To the extent OPG or another member of the OPG Group was immediately and directly responsible for causing the underlying circumstances giving rise to such order or notice, this situation will be deemed to constitute an OPG Caused Event for the purposes of Section 5.4(a). The Contractor will promptly deliver to OPG's Representative a copy of any such

order or notice. The Contractor will not recommence any Work that has been stopped or suspended without the prior written approval of OPG's Representative.

(k) **Investigations.** The Contractor will, as an Allowed Cost, participate in, co-operate with OPG in, at OPG's request, co-operate with any Governmental Authority in, and, at OPG's request, carry out, reporting and investigating safety violations caused by any act or failure to act of the Contractor or any Subcontractor.

(l) **Emergencies.** In emergencies affecting the safety or protection of individuals, the relevant Work or the INCW Part Project or property on, under, over or near the INCW Part Project Area, the Contractor, without the express consent of OPG, will take reasonable actions to prevent or minimize all threatened or actual damage, injury and loss.

(m) **Requirement to Leave.** In the case of an emergency requiring the Contractor to leave the INCW Part Project Area at the direction of OPG, the Contractor will put all equipment in a safe state in accordance with the Occupational Health and *Safety Act* (Ontario) and leave the INCW Part Project Area in an orderly fashion pending further instructions from OPG's Representative.

(n) **Hazard Communication Programs.** The Contractor will co-ordinate all exchanges of material safety data sheets and other hazard communication information related to the Work required in the INCW Part Project Area to be made available to, or exchanged between or among, Persons in the INCW Part Project Area.

(o) **Designated Substances and Other Hazardous Materials.**

(1) The Contractor is solely responsible for any "designated substances" (as defined under the *Occupational Health and Safety Act* (Ontario)) brought onto the INCW Part Project Area by it, and shall fully remove any remaining amounts prior to or upon completion of the Work required in the INCW Part Project Area. The Contractor shall also ensure that in no event will designated substances be incorporated into the permanent facilities.

(2) Any other potentially hazardous materials or substances to which OPG personnel may be exposed during operation and maintenance of the facility must be in conformance with OPG's HAZMAT approved material list.

(3) The Contractor acknowledges that prior to execution of this Agreement, OPG provided the Contractor with a list of designated substances present at the INCW Part Project Area (a copy of which is attached as Appendix 2.20(o)), as required pursuant to the *Occupational Health and Safety Act* (Ontario). OPG is not aware of any other designated substances at the INCW Part Project Area.

(p) **Direction from OPG.** Notwithstanding anything contained in this Section 2.20, as "constructor" (as defined under the *Occupational Health and Safety Act* (Ontario)) in respect of the Work required for the INCW Part Project, OPG retains the right to direct the Work performed on the INCW Part Project Area, in its sole discretion.

(q) **Indemnity Relating to Safety.** To the extent that the Contractor is responsible for, caused or contributed to, in whole or in part, the circumstances giving rise to a charge or fine pursuant to legislation applicable to worker health and safety, including the *Occupational Health and Safety Act* (Ontario) or its Regulations, the Contractor will indemnify and hold harmless each member of the OPG Group from and against all Losses suffered or incurred by a member of the OPG Group and from and against all claims, demands, actions, suits or any other proceedings for Losses made against any member of the OPG Group in connection with such charge or fine.

SECTION 3. OPG'S OBLIGATIONS

3.1 Take Actions Promptly

OPG will take each of the following actions in a responsible manner so as not to materially delay the Contractor:

(a) designate in writing from time to time an individual to act as OPG's project representative to monitor performance of the Work and administer this Agreement;

(b) provide access to Site, subject to any restrictions respecting certain parts of the Site set out in the Summary of Work or otherwise set out in this Agreement;

(c) provide information known to OPG relating to the presence on the Site of Hazardous Material in addition to those described in this Agreement, in such quantities or circumstances that there is a material danger to any Person performing the Work;

(d) discharge its obligations under Section 2.8 with respect to Submittals;

(e) obtain those Approvals listed in the Summary of Work as being the responsibility of OPG, provided that the Contractor fulfills its responsibilities with respect to such Approval;

(f) obtain such other Approvals as Contractor may identify as being required to be obtained by OPG, provided that the Contractor prepares the required documentation, submits it to OPG and supports the obtaining of such Approvals;

(g) provide the Contractor with all reasonable information and the required documentation the Contractor, acting reasonably, identifies as being necessary to prepare applications for Approvals;

(h) support the Contractor as and when the Contractor requests to obtain Approvals;

(i) acquire sufficient interest in the lands upon which the Tunnel Facility Project is to be completed, the rights-of-way, easements, licenses and other use rights for access thereto indicated on the Concept Drawings as necessary for performance of Work; and

(j) furnish to the Contractor, as required for performance of the Work, the following, all of which the Contractor may use and rely upon in performing the Work under this Agreement:

(1) Environmental Assessment and Environmental Assessment Approval;

(2) property, boundary, easement, right-of-way surveys, 1:2000 topographic information from aerial photographs dated 1989 at 1-m intermediate intervals and indexed every 5 m; and

(3) the first order control monuments which in OPG's judgment are necessary to enable the Contractor to proceed with the Work.

3.2 Designation of OPG's Representative and Delegation to OPG's Designated Delegates

OPG will designate in writing an individual to act as OPG's Representative. OPG may, from time to time change this designation, or delegate duties, to OPG's Designated Delegates by delivering a Notice in the form of Appendix 1.1(qq) to this effect to the Contractor. OPG's Representative will specify the scope and the limits of authority of each of OPG's Designated Delegates. Any changes to or revocations of any delegations will also be specified by OPG's Representative in writing in a Notice delivered to the Contractor. All Notices delivered to OPG's Representative, or OPG's Designated Delegates (provided that the notice relates to a matter within OPG's Designated Delegate's scope of authority), by the Contractor will be as binding on OPG as if given to OPG under Section 14.4. If OPG has provided the Contractor with a Notice delegating duties to OPG's Designated Delegate as described in this Section 3.2, the Contractor shall communicate solely with OPG's Designated Delegate to the extent specified in the Notice. The Contractor may rely on any written instructions, directions or approvals (excluding safety related matters) provided by OPG's Representative or OPG's Designated Delegates (provided such instructions, directions or approvals are within OPG's Designated Delegate's scope of authority). OPG will take all reasonable steps to ensure that OPG's Representative and OPG's Designated Delegates are accessible to the Contractor during the performance of the Work (including outside of normal working hours in cases of emergencies) and are available to render any necessary decisions or instructions promptly to avoid delays to the Contract Schedule.

3.3 No OPG Control Over the Work

Except as may be necessary to fulfill its role as "Constructor" with respect to the INCW Part Project, OPG will not supervise, direct, have control or authority over, or otherwise be responsible for:

(a) the Contractor's means, methods, techniques, sequences or procedures respecting the Work; or

(b) the safety programs and precautions used in respect of the Work, subject to OPG's rights and obligations under the *Occupational Health and Safety Act* (Ontario).

OPG will not be responsible for any failure of the Contractor to comply with any Applicable Laws, Approvals or this Agreement in performing the Work. The Contractor acknowledges exclusive control over and commercial responsibility for any and all means, methods, techniques, sequences or procedures employed or necessary to complete the Work in accordance with the Contract Schedule.

3.4 Hazardous Conditions

(a) **Division of Responsibility.** OPG will be responsible for the costs of dealing with any Hazardous Materials to the extent such Hazardous Material presents a material danger to any Person performing the Work (a "**Hazardous Condition**") encountered at the Site that was not generally or specifically identified in this Agreement to be part of the Work. To the extent OPG is responsible for such costs and such Hazardous Condition has the effect of materially increasing the cost or time of performing the Work, then such change will be treated as a Project Change Directive issued by OPG under Section 5. Notwithstanding the previous sentence, the Contractor will be responsible for any Hazardous Condition caused by or resulting or arising from the performance of the Work or brought on the Site by or on behalf of the Contractor and no adjustment will be made to the Target Cost or Contract Schedule in respect of such Hazardous Condition where actions or omissions of the Contractor are negligent or involve wilful misconduct.

(b) **Actions on Discovery.** Immediately on the discovery of a Hazardous Condition on the Site, the Contractor will:

(1) in accordance with prudent practices, act to contain the Hazardous Condition in order to minimize the impact of the Hazardous Condition;

(2) stop all Work in the area that could reasonably be affected by the Hazardous Condition, subject to Section 2.4(j); and

(3) verbally notify OPG of the discovery and confirm by Notice within 24 hours of the discovery.

(c) **Corrective Action Plan.** The Contractor will implement a corrective action plan (and engage a specialized Subcontractor) and obtain any required Approvals. Such corrective action plan will be in accordance with prudent practices and will minimize impact on the Contract Price and Contract Schedule.

3.5 INTENTIONALLY DELETED.

3.6 INTENTIONALLY DELETED.

3.7 Team Building Program

(a) OPG seeks to encourage a voluntary team building program for the Project. This program will be a structured approach to improve communication between OPG and its representatives and the Contractor and its Subcontractors, and to facilitate problem solving, conflict avoidance, and issue resolution. The team building program objective is to maximize the effectiveness of each Project participant's resources to efficiently and safely achieve a quality end product, on time and within budget without unresolved disputes.

(b) Participation in the program is totally voluntary. Any cost associated with program implementation will be agreed to by both parties and will be an Allowed Cost. To implement this initiative, it is anticipated that within 60 days after the Start Date, the Contractor's site manager and OPG's on-Site representative will develop a plan to hold a team building workshop to be attended by key staff of both Parties. Follow-up workshops will be held periodically throughout the duration of the Agreement as agreed to by the Contractor and OPG.

3.8 INTENTIONALLY DELETED.

SECTION 4. SECURITY DOCUMENTS AND INSURANCE

4.1 Security Documents

(a) **INTENTIONALLY DELETED**.

(b) **INTENTIONALLY DELETED**.

(c) **Failure of Surety.** If the maintenance bond is cancelled for any reason or the surety issuing such bond is declared bankrupt, becomes insolvent, ceases to carry on any active business in Ontario or otherwise ceases to meet the requirements of this Agreement, the Contractor will notify OPG immediately and, within 60 days thereafter, deliver to OPG a substitute maintenance bond that complies with Section 4.1(f); provided that if the Contractor does not deliver the substitute bond to OPG prior to the 30th day after the maintenance bond is cancelled for any reason or the surety issuing such bond is declared bankrupt, becomes insolvent, ceases to carry on any active business in Ontario or otherwise ceases to meet the requirements of this Agreement, OPG will not be required to make payment to the

Contractor under this Agreement unless and until the substitute bond is so delivered to OPG.

(d) **Letter of Credit.** With effect from the Effective Date, the Contractor will provide one or more letter(s) of credit in a total amount that is not less than $70 million (the "**Performance LC(s)**"). The Performance LC(s) shall be available for OPG for drawing (i) in the event of default by the Contractor hereunder; (ii) to satisfy any obligations of the Contractor in respect of Sections 8.1, 8.3 and 8.4A; or (iii) to be applied in respect of any obligations of the Contractor for which OPG has a right to set off hereunder. The Performance LC(s) and any other letter of credit to be delivered to OPG under this Agreement shall be a letter of credit acceptable to OPG substantially similar to the form set out in Appendix 4.1(d). For clarity, the Contractor may satisfy such obligation by delivery to OPG of the amending letter also attached in Appendix 4.1(d), amending the letter of credit issued by Royal Bank of Canada and dated August 31, 2005 (Reference Number: P338960T09591) also included for reference in Appendix 4.1(d). The bank issuing the letter of credit must be acceptable to OPG and be set out in Schedule I of the *Bank Act* (Canada). Acceptance of any bank proposed by the Contractor shall not be unreasonably withheld, provided that acceptance may be withheld of a bank which does not have a credit rating of A- or higher by Standard & Poor's or A3 or higher by Moody's. Notwithstanding any term in this Agreement, OPG is not obliged to make any payment to the Contractor under this Agreement until the Contractor has delivered to OPG the Performance LC(s) and any other required letter of credit under this Agreement in accordance with this Section 4.1(d). The Contractor will maintain any letter of credit in force until the Contractor has met the requirements of Section 1.1(y)(2) and (3), and OPG, acting reasonably, determines that the Contractor has met the requirements of Section 1.1(y)(1), after which OPG will provide the Contractor with written confirmation addressed to the Contractor and the bank who issued the Performance LC, that the Performance LC is terminated.

(e) **Parental Indemnity.** On the date of this Agreement, the Contractor will provide to OPG a confirmation that the parental indemnity provided by Strabag SE under the Original Agreement continues in full force and effect in the form set out in Appendix 4.1(e).

(f) **Maintenance Bond.** Prior to delivery of the Notice described in the first sentence of Section 7.14(b), the Contractor will deliver to OPG an original, signed maintenance bond in connection with the Contractor's obligations under Sections 7.3(d)(6), 7.4(a), 9.7, 9.8, 9.9 and 9.10 of this Agreement, in the form set out in Appendix 4.1(f) (or in such other form acceptable to OPG) and in an amount that is up to 10% of the Target Cost. OPG will advise the Contractor at least 90 days prior to Substantial Completion of the amount of the maintenance bond to be obtained. For greater clarity, if the cost of the maintenance bond is greater or lesser than the amount carried in the Target Cost Baseline Items, the Target Cost will be adjusted accordingly. The surety must be acceptable to OPG

and licensed to issue such bonds in Ontario. Acceptance of any surety proposed by the Contractor shall not be unreasonably withheld, provided that acceptance may be withheld of a surety with A.M. Best ratings of below A- or a Standard & Poor's rating below BBB. The Contractor will maintain the maintenance bond described in this Section 4.1(f) in force until the expiry of the Warranty Period as per Section 9.8(a) (as such period may be extended in accordance with Section 9.8(d)).

4.2 Required Insurance

The Contractor will procure and maintain in full force and effect with financially responsible insurance carriers (with A.M. Best ratings of at least A- or a Standard & Poor's rating of at least BBB) of recognized standing acceptable to OPG, or with the appropriate Governmental Authorities, all coverages referred to in this Section 4.2. The Contractor will ensure that all such coverages cover all Subcontractors and that all insurance coverages applicable in Ontario will be obtained from insurance carriers that are duly licensed in Ontario to issue insurance policies for the limits and coverages required under Sections 4.2(a) to 4.2(f). If, at any time, the Contractor incurs costs for which there would have been insurance coverage but for the failure of the Contractor to obtain or maintain the insurance required to be procured by the Contractor pursuant to Sections 4.2(a) to 4.2(c), 4.2 (e) and 4.2 (f), such uninsured costs will be Disallowed Costs.

(a) **Workers' Compensation.** The Contractor will maintain or cause to be maintained workers' compensation coverage as required by the *Workplace Safety and Insurance Act, 1997* (Ontario) or any other Applicable Laws respecting all of the Contractor's Personnel to the extent they are performing Work at the Site.

(b) **Additional US Requirements (as required).** In respect of all of the Contractor's Personnel whose domicile of hire is the United States, the Contractor will maintain or cause to be maintained workers' compensation coverage in each applicable state while any such Person is engaged in performing the Work at the Site. The Contractor will also ensure that any such coverage includes employer's liability with a minimum limit of US$1,000,000 and, to the extent applicable, a foreign coverage endorsement, *Merchant Marine Act* (United States), *Longshore and Harbor Workers' Compensation Act* (United States) and *Federal Employers' Liability Act* (United States) coverage.

(c) **Motor Vehicle Liability Insurance.** The Contractor will maintain or cause to be maintained motor vehicle liability insurance on licensed motor vehicles owned, rented or leased by the Contractor and Subcontractors providing services at the Site and used in connection with the Work to be performed under this Agreement covering bodily injury and property damage liability to a combined inclusive limit of not less than $5,000,000 per occurrence and mandatory accident benefits, continuously from the date of this Agreement until the expiry of the Warranty Period.

(d) **Construction Equipment Insurance.** The Contractor will be permitted to self-insure for all construction equipment and tools owned, rented or leased by the

Contractor or a Subcontractor and used in respect of performing the Work. For greater clarity, the costs to repair, maintain or replace such construction equipment shall be an Allowed Cost.

(e) **Errors & Omissions Insurance.** Engineering consultants shall, at all times, maintain in full force and effect professional liability insurance in an amount not less than $10,000,000 per occurrence and in the aggregate, covering the period from start of conceptual design through to the Final Completion Date and for a further discovery period of five years from the Final Completion Date. Such insurance shall be obtained on or prior to November 1, 2005.

(f) **Marine Watercraft Hull and Liability Insurance (as required).** The Contractor will maintain hull and machinery insurance covering the full replacement cost of all barges, scows and other watercraft owned, rented or leased by the Contractor or any Subcontractor, and used in respect of performing the Work.

The Contractor will also maintain marine liability or protection indemnity insurance covering any barges, scows or other watercraft owned, rented or leased by the Contractor or any Subcontractor, and used in respect of performing the Work. The Contractor will ensure that this coverage covers special operations, pollution liability and voluntary removal of wreck for limits that are the greater of those afforded under a protection and indemnity club and not less than $25,000,000 per occurrence.

OPG will procure and maintain in full force and effect with financially responsible insurance carriers (with A.M. Best ratings of at least A- or a Standard & Poor's rating of at least BBB) of recognized standing, all coverages referred to in Sections 4.2(g) to 4.2(i). OPG will ensure that the coverage referred to in: (1) Section 4.2(h) will be maintained in force continuously from the Start Date until 60 days after the Final Completion Date or such other later date as OPG may designate; (2) Section 4.2(g) will be maintained in force continuously from and after the date the Contractor requires such coverage to be obtained, but in no event earlier than November 1, 2005 until 60 days after the Final Completion Date or such other later date as OPG may designate; and (3) Section 4.2(i) during the time period contemplated in Section 4.2(i). OPG will ensure that all such coverages cover all Work performed by the Contractor during the Warranty Period. OPG will ensure that all such coverages cover all Subcontractors and that all insurance coverages applicable in Ontario will be obtained from insurance carriers that are duly licensed in Ontario to issue insurance policies for the limits and coverages required under Sections 4.2(g) to 4.2(i).

(g) **Builders' All Risks Insurance.** OPG will maintain builders' all risks insurance on a repair or replacement cost basis, including OPG, any applicable subsidiary of OPG, OPG's Designated Delegate, the Contractor and the Subcontractors as named insureds, to an aggregate limit of the Target Cost, plus the Interim Completion Fee, plus the Substantial Completion Fee, plus the Overhead Recovery Fee, with a sub-limit on the Underground Work (as defined in the builders' all risk policy) of $80,000,000 and such other sub-limits as are customary, covering physical loss or damage to the Work, the materials, operating

equipment, and supplies for incorporation therein, expendable construction tools, the TBM (however, excluding coverage for the perils of mechanical and electrical breakdown) and all temporary structures used in the performance of the Work or for which OPG is responsible, including property while in transit or elsewhere (except property insured under Section 4.2(i)) before and during erection and until completed and while awaiting tests and during tests and until the Final Completion Date. This insurance shall be subject to the LEG 2/96 (The London Engineering Group Model "Consequences" Defect Wording) defects exclusion or equivalent and will include a 24 month maintenance period unless similar coverage for the maintenance period is included under the wrap-up liability insurance described in Section 4.2(h) below in which case OPG may elect to maintain coverage during the maintenance period under either the Builder's All Risks Insurance policy or the Wrap-Up Liability Insurance policy.

(h) **Wrap-Up Liability Insurance.** OPG will maintain wrap-up liability insurance in the joint names of OPG, any applicable subsidiary of OPG, OPG's Designated Delegate, the Contractor and the Subcontractors. This coverage will include limits of no less than $50,000,000 inclusive per occurrence for bodily injury, death and damage to property. OPG will also ensure that this coverage specifically includes:

(1) blanket contractual liability;

(2) pollution liability coverage on at least a sudden and accidental basis;

(3) blasting, pile driving, caisson services, underground services;

(4) products and completed operations, including a term that such coverage will be maintained throughout the Warranty Period ;

(5) cross liability;

(6) severability of interests;

(7) employer's liability;

(8) non-owned automobile liability;

(9) broad form property damage; and

(10) hook liability, if applicable.

If the Wrap-Up Liability Insurance provides coverage for a 24-month maintenance period and such coverage is similar to the coverage provided for such maintenance period under the Builder's All Risk Insurance described in Section 4.2(g) above, OPG may elect to maintain coverage during the maintenance period under either the Builder's All Risk Insurance policy or the Wrap-Up Liability policy.

(i) **Marine Cargo Insurance (as required).** OPG will maintain marine cargo insurance for all Goods while in the course of marine transit. Marine Cargo insurance may also include, at OPG's option, inland transit. The Contractor will be an additional insured under the marine cargo insurance. OPG will ensure that this coverage will be in force from the time that such insured property leaves the last factory or warehouse of the Contractor or a Subcontractor, for shipment, and terminates after discharge at the Site. This insurance will include delay in start-up coverage.

4.3 General Insurance Terms

(a) **Certificates of Insurance.** Within 10 days after the date the Contractor is required to obtain insurance described in Sections 4.2(a) and 4.2(f), the Contractor will deliver to OPG certificates of insurance completed by a duly authorized representative of each of the Contractor's insurers certifying that at least the minimum coverages required under Sections 4.2(a) to 4.2(f) are in effect. OPG will review the certificates of insurance within 10 Business Days. The Contractor agrees that it will not, and will not allow any of its agents, representatives or any of the Subcontractors, to access or enter the Site (the foregoing shall not restrict the Contractor from conducting on-Site visits under the supervision of OPG) until such insurance certificates in respect of the coverage described in Sections 4.2(a) and 4.2(c) have been delivered to OPG, in a form acceptable to OPG, in accordance with this Section 4.3(a) and until OPG has obtained the insurance coverage described in Section 4.3(h). The Contractor will ensure that each certificate will state that the coverages will not be cancelled, will not fail to be renewed and will not be materially changed by endorsement or through issuance of any other policy of insurance which restricts or reduces coverage, without 60 days advance written notice by courier given to OPG's Representative, with a copy delivered by fax as follows:

Ontario Power Generation Inc.
Risk Management & Insurance - Treasury
700 University Avenue H18-H17
Toronto, Ontario, Canada M5G 1X6

Attention: Director, Risk Management & Insurance
Fax: 416-592-4775

To the extent that the Contractor is required to maintain any coverages under Sections 4.2(a) to 4.2(f) in force after final payment in accordance with Section 7.14, the Contractor will deliver to OPG, at the time that the Contractor submits its Final Application for Payment in accordance with Section 7.14, a certificate of insurance completed by a duly authorized representative of such Person's insurer certifying that such insurance will remain in force for the period of time required under Section 4.2. Within 10 days after the Start Date, OPG will deliver to the Contractor a certificate of insurance completed by a duly authorized

representative of OPG's insurers certifying that at least the minimum coverages required under Section 4.2(h) are in effect.

(b) **Copies of Policies and Deductibles.** Within 30 days after the date the Contractor is required to obtain the insurance described in each of Section 4.2(a) to 4.2(f), the Contractor will provide OPG with a certified copy of any insurance policy referred to in each of Sections 4.2(a) to 4.2(f). Within 90 days after a request by Contractor, OPG will provide Contractor with a certified copy of any insurance policy referred to in Section 4.2(h) and, if then in effect, Sections 4.2(g) and 4.2(i). At the time of the execution of this Agreement, the Contractor will provide OPG with documentation related to the applicable deductibles for each insurance policy to be obtained by the Contractor hereunder.

(c) **No Waiver by OPG.** If OPG fails to demand any certificate referred to in Section 4.3(a) or otherwise fails to demand other evidence of full compliance with Sections 4.2 or 4.3 or fails to identify a defect from evidence provided, OPG has not waived, and OPG will not be deemed to have waived, any of the Contractor's obligations. The Contractor's obligation to purchase and maintain insurance under this Agreement will in no way limit or otherwise qualify the liabilities or obligations of the Contractor under this Agreement.

(d) **No Approval by OPG.** If OPG receives, reviews and accepts any certificate or other evidence under this Section 4.3, OPG has not approved or agreed, and OPG will not be deemed to have approved or agreed, that the Contractor has satisfied any of its obligations under Sections 4.2 or 4.3.

(e) **OPG May Purchase Insurance.** If the Contractor fails to maintain any insurance required under Sections 4.2(a) to 4.2(f) or any such insurance is inadequate in its scope, OPG may purchase any such insurance and the Target Cost will be correspondingly reduced, or OPG may terminate this Agreement immediately due to default by the Contractor in accordance with Section 10.1(l). In the event that OPG must purchase insurance under this subclause, OPG may set off the costs thereof against any monies then or thereafter due, owing or payable to the Contractor and may set off and retain, in addition, and in consideration for its services in procuring such insurance, an amount equal to the cost thereof, in addition to the cost of such insurance.

(f) **Deductibles.** The Contractor will incur the cost of deductibles under Section 4.2(a) through 4.2(h), except Section 4.2(g), and such deductibles shall be Disallowed Costs. In the event that a deductible is payable in respect of a claim as defined in the builder's all risk insurance policy in Section 4.2(g) as "All Other" (meaning claims not covering the TBM or Underground Construction, as defined in the builder's all risk insurance policy) the Actual Cost and Target Cost will be adjusted by 50% of the $250,000 deductible and the remaining 50% will be a Disallowed Cost. In the event that a deductible is payable in respect of a marine cargo insurance claim in Section 4.2(i) the Actual Cost and Target Cost will be

adjusted by 50% of the deductible up to $100,000 and the remaining 50% or any deductible above $100,000 will be a Disallowed Cost.

(g) **Insurance Not Contributory.** With the exception of the insurance referred to in Section 4.2(c), the Contractor will ensure that all other insurance referred to in Sections 4.2(a) to 4.2(f) will specify that such insurance is primary coverage and not contributory with, or in excess of, any insurance that may be maintained by OPG.

(h) **Subrogation.** The Contractor will ensure that each insurer which provides insurance under Sections 4.2(b), 4.2(c) and 4.2(f) will provide a waiver of subrogation to OPG, any applicable subsidiary of OPG, OPG's Designated Delegates, the Contractor and all the Subcontractors.

(i) **OPG as Additional Insured.** The Contractor will ensure that each insurer that provides insurance under Sections 4.2(c), 4.2(e) and 4.2(f) will include OPG, any applicable subsidiary of OPG, OPG's Representative and OPG's Designated Delegates as an additional insured.

(j) **No Invalidation by OPG.** The Contractor will ensure that no insurance referred to in Sections 4.2(a) to 4.2(f) will be invalidated or vitiated by any action or failure to act by OPG, any applicable subsidiary of OPG, OPG's Representative or OPG's Designated Delegates, or by any breach by the Contractor or any other Person of any declarations, warranties or other terms in such policies.

(k) **Notice and Processing of Claims.** The Contractor will process all proper claims under policies of insurance hereunder in accordance with this Section 4.3(k) and both Parties will use best efforts to recover under such policies. Insurance claims will be asserted and processed on the following basis:

(1) In connection with the insurance described in Sections 4.2(a) to 4.2(f), the Contractor will be solely responsible to process and settle all such claims directly with the insurer. In the case of a claim under the insurance described in Sections 4.2(a) to 4.2(f), the Contractor will deliver a Notice to OPG's Representative detailing the claim at least three Business Days prior to asserting such a claim. The Contractor will include in any Notice provided under this Section 4.3(k) the date of the events giving rise to the claim, a summary of the circumstances respecting the claim and the amount of the claim. The Contractor will provide OPG any additional information respecting the claim that OPG's Representative may request.

(2) In connection with the insurance described in Sections 4.2(g) and 4.2(i), OPG will be solely responsible to process and settle all such claims directly with the insurer.

(3) In connection with the insurance described in Section 4.2(h), the Contractor will assert all of its claims through OPG who will notify the insurer which provides such insurance within three Business Days after

the Contractor has delivered Notice to OPG's Representative detailing the claim. The Contractor will not be permitted to assert any claim under any insurance referred to in Section 4.2(h) until OPG has completed its review and verification of such claim, which shall be completed within the time period required under the applicable policy to assert the claim, after which the Contractor will be responsible to further process and settle all claims directly with the insurer.

(l) **Cooperation on Insurance Claims.** The Parties will fully cooperate with each other to investigate, pursue, and settle all claims against insurers. For greater clarity, the Party processing the claim against the insurer shall have sole and absolute discretion in the settlement of the claim.

4.4 Construction Equipment

In respect of each member of the OPG Group, the Contractor waives all Losses whatsoever arising in respect of loss of, loss of use of, or damage to any construction equipment, tools, fuel and temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal.

SECTION 5. CHANGES IN TARGET COST AND CONTRACT SCHEDULE

5.1A Changes to Target Cost/Contract Schedule

The Target Cost and/or Contract Schedule may only be adjusted in accordance with this Section 5 if one or more of the following occur:

(a) OPG directs the Contractor to make a change to the Work under Section 5.1;

(b) OPG approves a request of the Contractor to make a change in the Work under Section 5.2;

(c) a Change in Law;

(d) an event which is covered by the builders' all risks insurance coverage carried pursuant to Section 4.2(g) or marine cargo insurance coverage carried pursuant to Section 4.2(i) where the insurer has acknowledged that its coverage applies (an "**Insurable Event**");

(e) a tidal wave, lightning, earthquake, cyclone, legal strike or lockout on the Site, war, riot or act of public enemies, including terrorists (a "**Force Majeure Event**");

(f) a Major Risk Event;

(g) an OPG Caused Event;

(h) there is a change to a Target Cost Baseline Item;

(i) deductibles are incurred under Section 4.3(f); or

(j) where as a result of OPG providing a notice of objection to the intentions of the Contractor in Sections 2.12(a), 2.14(c), 2.14(g) and 2.15(b) there is a material increase in the cost of the Work or a material impact on the Contract Schedule.

If any of the events in Sections 5.1A(a) through 5.1A(j) occurs, the Target Cost and/or Contract Schedule shall be adjusted as more specifically set out below in Sections 5.1 through 5.8, as applicable. For greater clarity, there shall be no change to the Target Cost unless expressly provided for hereunder.

5.1 Changes Requested by OPG

(a) **Issue Project Change Directive.** OPG may, without invalidating this Agreement, direct the Contractor to make changes in the Work by issuing a Project Change Directive. Subject to the provisions of Section 5.1(d), if OPG issues a Project Change Directive, the Parties will execute an Amendment made in accordance with this Section 5 covering the applicable changes to the Work and the changes, if any, to the Target Cost or Contract Schedule. OPG may include in any Project Change Directive, OPG's expectations as to the changes, if any, that the changes in the Work will cause to the Target Cost and/or Contract Schedule. OPG may amend the Owner's Mandatory Requirements by issuing a Project Change Directive.

(b) **Review of Project Change Directive.** At OPG's request, the Contractor will review the Project Change Directive before making the changes and advise OPG as to the Contractor's views as to:

(1) any impact of the change on the Tunnel Facility Project that the Contractor is aware of;

(2) any proposed change to the Target Cost, calculated in accordance with Section 5.6; and

(3) any proposed changes to the Contract Schedule that the Contractor estimates will occur as a result of such changes.

The Contractor acknowledges that a change in the Contract Schedule will not necessarily result in a change in the Target Cost and a change in the Target Cost will not necessarily result in a change in the Contract Schedule. The Contractor will co-operate with OPG and will use all reasonable efforts to carry out each Project Change Directive in such a manner so as to reduce, avoid or minimize any additions to the Target Cost and extensions to the Contract Schedule.

(c) **Obligation to Implement Project Change Directive.** OPG may require, in any Project Change Directive, that the Contractor proceed with the Project Change Directive before the Parties have agreed on the terms of an Amendment. Upon receipt of any such Project Change Directive, the Contractor will comply with the

applicable Project Change Directive and any Dispute will be resolved in accordance with Section 5.9. Section 2.7(e) expressly applies to any changes set out in a Project Change Directive.

(d) **Project Change Directives as Amendments.** Any Project Change Directive that does not direct, or provide OPG's consent to, a material change to the Work, the Target Cost or the Contract Schedule, will be deemed to be an Amendment for purposes of Sections 5.1 and 5.8, and no further or additional written agreement must be executed, provided that the terms of the Project Change Directive expressly state that the Parties have adopted the Project Change Directive as an Amendment to this Agreement and both Parties sign the Project Change Directive in accordance with Section 14.2.

For certainty, but without limitation, each of the following is considered a material change:

(1) any change in the Work, Target Cost or Contract Schedule as a result of a change in Applicable Laws pursuant to Section 5.3;

(2) any change in the Contract Schedule; and

(3) any change in the Target Cost greater than $100,000.00.

(e) **Dispute Resolution.** If the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost in a Project Change Directive issued under this Section 5.1, the resulting Dispute will be resolved in accordance with Section 5.9.

5.2 Changes Requested by the Contractor

The Contractor will not make any change in the Work except in accordance with this Section 5. The Contractor will ensure that no changes are made in the Work without the prior written consent of OPG's Representative in a Project Change Directive. If the Contractor desires to make any changes in the Work, in whole or in part, the Contractor must first advise OPG in a Project Change Notice as to the matters referred to in Section 5.1(b) and obtain the prior written consent of OPG's Representative in a Project Change Directive. Nothing in this Agreement obliges OPG to agree to any change proposed by the Contractor. OPG may in its sole and absolute discretion refuse to agree to any change proposed by the Contractor affecting quality of the Work (as determined by OPG), the Contract Schedule, Actual Cost or the Target Cost. OPG will, however, act reasonably in approving any other change requested by the Contractor. Any written consent of OPG's Representative in a Project Change Directive to any such proposed change requested by the Contractor will constitute a Project Change Directive issued by OPG in accordance with Section 5.1.

5.3 Changes in Applicable Laws

If, after the Effective Date of this Agreement, there is any:

(a) change in Applicable Laws (except those that relate to Taxes) or any applicable standards, specifications, manuals or codes of any technical organization or Governmental Authority; or

(b) new Canadian federal or provincial sales, use or excise taxes or any changes in the rates of such taxes,

(an event in (a) or (b), being a "**Change in Law**") which directly and materially impacts the Work or Contract Schedule that is neither known nor foreseeable on the date of this Agreement and that has the effect of materially increasing or decreasing the cost or time of performing the Work, then such change will be treated as a Project Change Directive issued by OPG under Section 5.1. The Contractor will promptly provide OPG's Representative with a Notice in the form of Appendix 5.3 detailing the impact the change described in Section 5.3(a) or 5.3(b) has on the Work, Target Cost and Contract Schedule. OPG's Representative will discuss the impact and provide a prompt direction to the Contractor resolving the issue by way of a Project Change Directive. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.3A Insurable Events

If, after the Effective Date of this Agreement, an Insurable Event occurs, which has a material impact on the Target Cost and/or Contract Schedule, then OPG will issue a Project Change Directive indicating the extent of a change in the Target Cost and/or the Contract Schedule (including the impact on Substantial Completion and Final Completion Dates) that OPG attributes to such event. For greater clarity, OPG will issue a Project Change Directive immediately if the event is covered in Appendix 5.3C for which the cost and schedule impacts are pre-determined. Where the event is not covered by Appendix 5.3C, OPG will issue a Project Change Directive at the earlier of a) when the cost and schedule impacts can be accurately determined; or b) within six months of the return to normal operations. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

For any insurance proceeds received by the Contractor in respect of the Insurable Event there shall be a corresponding reduction in Target Cost to the extent these costs were previously increased in a Project Change Directive before insurance proceeds were recovered. Any insurance proceeds received by OPG in respect of an Insurable Event will not reduce Actual Cost.

5.3B Force Majeure Events

(a) **Force Majeure Event.** If, after the Effective Date of this Agreement, a Force Majeure Event occurs, the Contractor will not be responsible for any delay in

fulfilling any obligation under this Agreement to the extent the delay has a material impact on the Contract Schedule.

(b) **Exception.** Section 5.3B(a) does not apply to the extent a delay is caused by the fault or negligence of the Contractor. Furthermore, Section 5.3B(a) does not apply if the Contractor fails, within three Business Days after the commencement of any such delay, to give a Notice in the form attached as Appendix 5.3B to OPG describing the event under Section 5.3B(a) giving rise to the delay and the anticipated period of the delay. Failure by the Contractor to give such Notice within such three Business Day period is sufficient reason for denial by OPG of any extension of time.

(c) **Actions During Delay.** During any period of delay resulting from events referred to in Section 5.3B(a), the Contractor will:

i) act prudently in all respects to mitigate the impact of the delay on the Contract Schedule; and

ii) keep OPG informed in a timely manner of the status of the event under Section 5.3B(a) giving rise to the delay and of the actions being taken to mitigate the impact of such delay.

(d) **Steps After Delay Ends.** Within three (3) Business Days after cessation of the period of delay resulting from events referred to in Section 5.3B(a), the Contractor will deliver an updated Notice in the form attached as Appendix 5.3B to OPG specifying the alleged duration of the excused delay and its impact, if any, on the Contract Schedule. OPG will review such Notice and issue a Project Change Directive. The dates in the Contract Schedule may not be extended by more than the delay reasonably attributable to the event causing the delay. The Target Cost may also be changed if the delay has or will have a material impact on the cost of completing the Work. The Target Cost may not be increased, however, by an amount that is more than is reasonably attributable to the event that caused the material delay. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.3C Major Risk Events

If, after the Effective Date of this Agreement, a Major Risk Event occurs, then OPG will issue a Project Change Directive indicating the extent of a change in the Target Cost and/or the Contract Schedule calculated in accordance with Appendix 5.3C. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.3D Changes to the Target Cost Baseline Items

If, after the Effective Date of this Agreement, a change to the Target Cost Baseline Items occurs, then OPG will issue a Project Change Directive indicating the extent of a change in the Target Cost calculated in accordance with Appendix 1.1 (UUU). If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.4 Changes Caused by OPG

(a) If, after the Effective Date of this Agreement:

(1) OPG or another member of the OPG Group is responsible for causing the underlying circumstances giving rise to a stop work order or similar notice under Sections 2.4 and 2.20;

(2) OPG fails to obtain the Approvals required pursuant to Sections 3.1(e) and 3.1(f);

(3) OPG fails to acquire sufficient interest in the lands required pursuant to Section 3.1(i);

(4) OPG fails to furnish to the Contractor the items and information required pursuant to Sections 3.1(c), 3.1(g), and 3.1(j);

(5) OPG fails to discharge its obligations pursuant to Section 3.1(d);

(6) OPG requests the Contractor to uncover a part of the Project where no Defective part of the Work was found as described in Section 9.4;

(7) OPG has not paid the amounts required under Section 7.3(b) within 30 days of the date OPG is required to make payment under Section 7.3(b) and the Contractor has suspended the performance of the Work in accordance with Section 2.7(e);

(8) OPG disputes a Submittal that is determined to be in conformity with the Agreement as described in Section 2.8(e); or

(9) OPG fails to provide access to the Site in accordance with Section 3.1(b);

(the events in Sections 5.4(a)(1) through 5.4(a)(9) being, "**OPG Caused Events**") and the delay resulting from events referred to in this Section 5.4(a) has resulted or will result in a material impact on the Contract Schedule, OPG will issue a Project Change Directive covering the applicable changes to the Contract Schedule and Target Cost where the delay has the effect of materially increasing the cost of performing that Work. The Contractor will act prudently in all respects to mitigate the impact of the delay on the Contract Schedule. The Target Cost may not be increased by an amount that is more than is reasonably

attributable to the event that caused the material delay. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.4A Changes Due to Incurred Deductibles

In the event that a deductible is payable by the Contractor as per Section 4.3(f) in respect of a claim as defined in the builder's all risks insurance policy in Section 4.2(g) as "All Other," the Contractor will inform OPG and OPG shall issue a Project Change Directive increasing the Target Cost as set out in Section 4.3(f). If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.4B Changes Due to Notice of Objection Provided by OPG

Where the Contractor is of the reasonable opinion that as a result of OPG providing a notice objection to the intentions of the Contractor in Sections 2.12(a), 2.14(c), 2.14(g) and 2.15(b) there is a material increase in the cost of the Work or a material impact on the Contract Schedule, the Contractor will inform OPG and OPG shall issue a Project Change Directive showing the impact on Target Cost and Contract Schedule. If OPG declines to issue a Project Change Directive, or the Contractor disagrees with the proposed changes to the Contract Schedule or Target Cost, the resulting Dispute will be resolved in accordance with Section 5.9.

5.5 Delays Caused by Subcontractors and Suppliers

Delays attributable to or as a result of delays caused by or within the control of Subcontractors or suppliers shall be deemed to be delays within the control of the Contractor and the Contractor shall not be granted any extension of time.

5.6 Changes to Target Cost and Contract Schedule

If a Project Change Directive will have the effect of changing the Target Cost or Contract Schedule, the Parties will change the Target Cost or Contract Schedule by an Amendment made in accordance with Section 5 by application of a mutually agreed amount based on Section 5.7, except where such changes are predefined in Appendices 5.3C or 1.1(UUU).

5.7 Calculation of Change in the Target Cost Related to Changes in the Work

(a) **Allowed Costs of Calculating Value in Change in the Work**. Where the Parties calculate the amount of the costs applicable to any change in the Work under this Section 5.7, the Parties will calculate and include all the applicable amounts under Sections 5.7(a) and 5.7(c) without duplication, but will not include any amounts for items under Section 5.7(b). Notwithstanding any term in this Section 5.7, no amount calculated under Sections 5.7(a) and 5.7(c) will exceed the applicable amounts then prevailing in the locality of the performance of the applicable Work. The terms of this Section 5.7 apply equally whether the amount of the Work is being increased or decreased due to the change in the Work. The amount of credit

to be allowed by the Contractor to OPG for any change which results in a net decrease in cost as calculated under Section 5.7(a) will be the amount of the actual net decrease in Target Cost.

(1) **Payroll Costs of Labour.** In calculating the amount of the costs applicable to any change in the Work, the Parties will calculate the payroll costs, including shift and overtime premiums, for hourly paid labour in the direct employ of the Contractor that would be involved in providing the increase and/or decrease in Work. Such payroll amounts will be determined under the applicable terms of the applicable collective agreements. Such payroll costs include all contributions, premiums, allowances and remittances due to any Governmental Authority, travel and subsistence costs, pension fund, benefit plan, or union fund in accordance with a collective agreement and all Canada Pension Plan contributions, employment insurance premiums and Workplace Safety and Insurance Board premiums. Notwithstanding any term in this Section 5.7, under no circumstance will any tax equalization payment respecting any Person performing any of the Work be an Allowed Cost.

(2) **Work of Subcontractors.** In calculating the amount of the costs applicable to any change in the Work, the Parties will calculate the actual purchase cost to the Contractor, net of discounts, rebates and other refunds, of the increase or decrease in the applicable Work performed by a Subcontractor.

(3) **Professional Services.** To the extent that the changes in the Work require specific Professional Services from Major Subcontractors, the rates payable therefore shall be subject to review and approval of OPG prior to undertaking any change in the Work.

(4) **Purchased Goods.** In calculating the amount of the costs applicable to any change in the Work, the Parties will calculate the actual purchase cost to the Contractor, net of discounts, rebates and other refunds and returns from the sale of surplus Goods, of the increase or decrease in the applicable Goods, delivered to the Site.

(5) **Rented Construction Equipment.** In calculating the amount of the costs applicable to any change in the Work, the Parties will calculate the actual rental cost to the Contractor, net of discounts, rebates and other refunds, of the increases or decreases in the applicable rented construction equipment, delivered to the Site. The rental costs may not exceed the lesser of the Contractor's rental rates or the rates set out in the latest edition of the Ontario Provincial Standards, OPSS 127 Schedule of Rental Rates for Construction Equipment without the prior consent of OPG, which shall not be unreasonably withheld. All rental rates will be subject to approval by OPG and will exclude the cost of the operator. For utilization in excess of 8 hr/day or 176 hr/mo, or for standby charges, or for transportation to

and from the Site, reduced rates shall apply and shall be as agreed by OPG.

(6) **Owned Construction Equipment.** In calculating the amount of the costs applicable to any change in the Work, only the operating costs of owned construction equipment shall be included. The equipment is already an asset of the Project.

(7) **Taxes.** In calculating the amount of the costs applicable to any change in the Work, the Parties will calculate the actual cost of additional or reduced Taxes, excluding income taxes and goods and services tax levied under the *Excise Tax Act* (Canada).

(b) **Disallowed Costs in Calculating Value of Change in the Target Cost.** Notwithstanding any term in Section 5.7(a), where the Parties calculate the amount of the costs applicable to any change in the Work, the Parties will exclude the costs of each of the amounts set out in this Section 5.7(b).

(1) **Payroll Costs of Management above the Level of Project Manager.** In calculating the amount of the costs applicable to any change in the Work, the Parties will exclude all payroll costs, additives and other costs respecting individuals above the level of project manager, whether on or off the Site.

(2) **Specialized Tunneling Equipment.** In calculating the amount of the costs applicable to any change in the Work, ownership or rental costs, including but not limited to excess utilization or standby costs for specialized tunneling equipment, including but not limited to the TBM, trailing gear, tunnel mucking equipment, and grouting equipment. Such cost will be deemed to have been adequately provided for and included elsewhere in the Target Cost.

(3) **Office Costs.** In calculating the amount of the costs applicable to any change in the Work, the Parties will exclude all costs respecting the Contractor's offices, whether on or off the Site, except where there is an extension to Contract Schedule.

(4) **Capital Costs.** In calculating the amount of the costs applicable to any change in the Work, the Parties will exclude:

(A) any debt carrying charges, including principal payments, interest or other carrying charges; and

(B) all capital costs, including interest, on the Contractor's capital employed for the Work and charges against the Contractor for late payments, if any.

(5) **Breaches of the Standard of Care.** In calculating the amount of the costs applicable to any change in the Work, the Parties will exclude Disallowed Costs as per Section 1.1(O)(1).

(c) **Subcontractor Overhead and Profit Fee.** Where the Parties calculate the amount of the costs applicable to any change in the Work, the Parties will include an additional fee, calculated as follows: where one or more tiers of Subcontractors in place on the Effective Date are reimbursed for additional costs on the basis of cost of the Work plus a fee, the intent is that the Subcontractor who performs the Work, at whatever tier, will be paid a fee of 10% of the costs incurred by such Subcontractor under Section 5.7(a)(2). Any higher tier Subcontractor will each be paid a fee of 5% of the cost amount only paid to the next lower tier Subcontractor in accordance with the provisions of Section 5.7(b).

5.8 Execution of Amendments

Except in the case of Project Change Directives that are deemed to be Amendments in accordance with Section 5.1(d), OPG will not be deemed to have agreed to, or be required to pay for, any changes to the Work, Target Cost, or the Contract Schedule, until the Parties have executed an Amendment evidencing the Project Change Directive.

5.9 Resolution of Claims

(a) **Filing Notice of Claim.** If the Parties are unable to agree as to the extent, if any, of a change in the Target Cost or the Contract Schedule that should be made as a result of changes under Section 5.1A or where OPG has declined to issue a Project Change Directive, either Party may deliver a Notice in the form attached as Appendix 5.9(a) of its intent to the other Party to resolve the Dispute under this Section. The Contractor will issue such Notice with respect to a Project Change Directive no later than 30 Business Days of receipt of the Project Change Directive that OPG has advised the Contractor in writing is final or the date where OPG's Representative advises the Contractor in writing of OPG's Representative's refusal to issue a Project Change Directive, as the case may be.

(b) **Claim Documentation.** The Party that delivers a Notice under Section 5.9(a) will submit to the other Party all reasonable documentary evidence and a concise statement of the rationale of the Party's position within 20 Business Days after delivery of such Notice.

(c) **Decision.** The Party receiving a Notice under Section 5.9(a) will review the documents and rationale received under Section 5.9(b) and will render a decision, including a concise statement setting out the reasons for its decision, no more than 20 Business Days after the receipt of the documents and rationale received under Section 5.9(b). This decision will be final and binding on the Parties unless the Party giving Notice under Section 5.9(a) gives to the other Party, within five Business Days of receiving the decision, a Notice of Informal Resolution. If a

Notice of Informal Resolution is provided, the resolution of the issue will be determined pursuant to Section 11.

SECTION 6. INTENTIONALLY DELETED

SECTION 7. PAYMENT OF CONTRACT PRICE

7.1 Payment

OPG shall make payments to the Contractor for:

(a) Actual Costs;

(b) the Overhead Recovery Fee;

(c) the administration fee in accordance with Section 9.1(a)(2);

(d) the Interim Completion Fee in accordance with Section 8.7;

(e) the Substantial Completion Fee in accordance with Section 8.8; and

(f) the Cost Performance Incentive and/or the Schedule Performance Incentive and/or the Guaranteed Flow Amount Incentive, if and to the extent payable under Section 8.

7.2 Application for Payment

OPG shall make monthly payments to the Contractor in accordance with this Section 7. The Contractor will submit a draft Application for Payment to OPG's Designated Delegate three (3) Business Days before the 25th of each month for acceptance in respect of an estimate of the Work to be performed in the month following the month in which the Application for Payment is submitted by the Contractor. After receiving OPG's Designated Delegates' acceptance, the Contractor will deliver to OPG a complete Application for Payment. The Contractor will so deliver each Application for Payment in .pdf or .tif format. As part of each Application for Payment, the Contractor will submit to OPG an invoice containing:

(a) the Contractor's best estimate for Allowed Costs to be incurred in the calendar month following the month in which the Application for Payment is submitted by the Contractor;

(b) a reconciliation of the best estimate of Allowed Costs for the month prior to the month in which the Application for Payment is submitted by the Contractor to the Actual Costs incurred for such month;

(c) the amount of Overhead Recovery Fee in respect of the estimate of Allowed Costs submitted under Section 7.2(a) as adjusted for any reconciliation under Section 7.2(b);

(d) as a credit to OPG, the amount of proceeds on sales of material and equipment received in the month prior to the month in which the Application for Payment is submitted by the Contractor;

(e) as a credit to OPG, the amount of proceeds of insurance received by the Contractor in respect of Allowed Costs in the month prior to the month in which the Application for Payment is submitted by the Contractor; for greater clarity, any proceeds of insurance paid to OPG in respect of a Disallowed Cost shall be paid to the Contractor;

(f) as a credit to OPG, the amount of any deductible (in accordance with Section 4.2) applied by the insurance company on any payment of insurance proceeds referred to in Section 7.2(e);

(g) as a credit or debit to OPG, as the case may be, the exchange rate gains or losses incurred on payment of Actual Cost;

(h) the Interim Completion Fee, after it has become earned in accordance with Section 8.7, and the Substantial Completion Fee, after it has become earned in accordance with Section 8.8, and the administrative fee when due in accordance with Section 9.1(a)(2);

(i) the Schedule Performance Incentive or the Schedule Performance Disincentive (the latter as a credit to OPG); the Guaranteed Flow Amount Incentive or Guaranteed Flow Amount Disincentive (the latter as a credit to OPG); and the Cost Performance Incentive or Cost Performance Disincentive (the latter as a credit to OPG) when the Contractor is entitled to invoice OPG in accordance with Section 8.4C(c);

(j) any adjustments permitted under this Agreement including with respect to advanced payment or subsequent adjustment to the final payment made by OPG under Section 7.3A; and

(k) the following additional information:

(1) the total amount owing by OPG in Canadian dollars (showing separately all amounts of Ontario Retail Sales Tax, and all amounts due as goods and services tax levied under the *Excise Tax Act* (Canada);

(2) the OPG purchase order number;

(3) the Contractor's full name and address;

(4) the name of a contact individual at the Contractor, with a telephone number;

(5) electronic transfer instructions;

(6) the Contractor's invoice number (which must be unique for each invoice);

(7) the invoice date (which must be the date the invoice is delivered); and

(8) the Contractor's registration number for the purposes of Part IX of the *Excise Tax Act* (Canada).

In addition to the invoice, the Application for Payment will also include:

(l) a statutory declaration in the form set out in Appendix 1.1(d) signed by a director or officer of the Contractor declaring that:

(1) all payments due to Subcontractors, all wages and benefit payments due to any of the Contractor's Personnel, and all contributions, premiums, allowances and remittances due to any Governmental Authority, pension fund, benefit plan, or union fund in accordance with a collective agreement or Applicable Laws, have been paid on or before the date of the Application for Payment in a timely manner, subject to any withholdings or holdbacks required by Applicable Laws;

(2) title to the applicable part of the Tunnel Facility Project will pass to OPG in accordance with Section 7.4 no later than the date of OPG's payment; and

(3) there are no known unnotified claims for extra time or extra compensation of any nature or kind whatsoever as of the date of the statutory declaration;

(m) a certificate in the form set out in Appendix 1.1(d) signed by an officer of the Contractor certifying:

(1) that the coverages that the Contractor is obliged to maintain under Section 4.2 remain in full force;

(2) that the Contractor has paid in a timely manner all amounts payable under the *Workplace Safety and Insurance Act, 1997* (Ontario);

(3) that the Contractor remains in compliance with all its other obligations under the *Workplace Safety and Insurance Act, 1997* (Ontario); and

(4) that the Contractor has provided OPG with the Workplace Safety and Insurance Board registration number for each member of the Contractor's Personnel performing Work at the Site for the period covered by the certificate;

(n) a certificate in the form set out in Appendix 1.1(d) signed by an officer of the Contractor respecting outstanding claims; and

(o) a certificate of compliance from the Workplace Safety and Insurance Board as to the Contractor's status and that of all Subcontractors that will be performing Work at the Site.

7.3 Progress Payments

(a) **OPG Reviews Each Application for Payment.** If OPG's Designated Delegate does not accept an Application for Payment in full, it will, within two (2) Business Days after receipt of the draft Application for Payment return the Application for Payment to the Contractor, indicating in writing its reasons for rejection. If OPG's Designated Delegate has rejected the Application for Payment because it disputes the amount payable in the Application for Payment, the Contractor shall have the right to adjust its Application for Payment and to resubmit it until the 25th day of each month. No such adjustment will constitute acceptance of OPG's position on the amount payable or in any other way preclude the Contractor's right to dispute OPG's rejection.

(b) **Payment Terms.** Subject to Sections 7.3B and 7.5(e) and OPG's right to set off under this Agreement (as limited by Section 8.4C(c)) and pursuant to Applicable Laws, OPG will pay the Contractor the amount of any Application for Payment, except for those items in dispute between the Parties, on the 30th day of the month following the month in which the Application for Payment was submitted. Amounts due but unpaid shall bear interest at the rate equivalent to the prevailing Bank of Canada Prime Lending Rate plus 2%.

Amounts held back by the Contractor from amounts otherwise payable to Subcontractors to comply with the *Construction Lien Act* (Ontario) shall be excluded from the monthly amounts invoiced by and payable to the Contractor.

OPG shall pay the Contractor the purchase price and any other deposit, advance or other payment in respect of capital assets for the Tunnel Facility Project when the Contractor is invoiced by the supplier of the assets for such price or payment. OPG shall pay the Contractor the increases or decreases in the value of inventory for the Tunnel Facility Project on a monthly basis.

(c) **No Deemed Acceptance.** No payment made by OPG under this Agreement and no use or occupancy of the Project, in whole or in part, by OPG will constitute acceptance of any part of the Work that is not in accordance with this Agreement.

(d) **Refusal of Payment.** Notwithstanding any term in this Agreement, but except on account of any costs being claimed to be Disallowed Cost under Section 1.1(O)(1) (any reduction, nullification of previous payment or other setoff must be made within the time period set forth in Section 1.1(O)(1)), OPG may (i) reduce any payment, or set off from any payment, otherwise payable to the Contractor under this Agreement, other than the incentive payments in accordance with Section 8.4C(c), an amount to be determined by OPG or (ii) nullify any previous payment,

because of subsequently discovered evidence or the results of subsequent inspections or tests on account of:

(1) the current or any previous Application for Payment including Disallowed Costs (in which event such reduction shall be limited to the extent of such Disallowed Costs);

(2) OPG having corrected or replaced a Defective part of the Work or Tunnel Facility Project in accordance with this Agreement;

(3) Losses suffered or incurred by any member of the OPG Group or claims, demands, actions, suits or proceedings for Losses having been made against a member of the OPG Group by any Person in respect of which the Contractor is required to indemnify under this Agreement;

(4) a Lien having been filed in respect of an undisputed amount payable for the Work or Goods (except to the extent that the Contractor has delivered to OPG a specific security instrument, satisfactory to OPG, to secure the discharge of such Lien) and any Losses incurred by OPG in respect of such Lien;

(5) any other terms of this Agreement or rights under Applicable Law entitling OPG to a set off against the amount for which Application for Payment was made; or

(6) Contractor's failure to deliver the substitute bond to OPG prior to the 30th day after the maintenance bond is cancelled for any reason or the surety issuing such bond is declared bankrupt, becomes insolvent, ceases to carry on any active business in Ontario or otherwise ceases to meet the requirements of this Agreement, as more particularly described in Section 4.1(c).

7.3A Advance Payment

On June 30th, 2009, OPG will make a one-time advance payment in an amount of $3,500.000.00 to provide the Contractor with an interest neutral position throughout the life of the Agreement. This amount shall be credited to OPG against the earlier of the final payment to the Contractor or the payment of the Substantial Completion Fee.

7.3B One-Time Adjustment

The Application for Payment payable on or about June 30th, 2009 will include:

(1) a one time debit or credit to OPG to adjust for the difference between the invoice dated November 25, 2008 and the amount finally determined for Work up to November 30, 2008;

(2) a one time debit or credit to OPG to adjust for the difference between the items set forth in Sections 7.2(a) to 7.2(g) and the amounts invoiced between the Effective Date and April 25, 2009;

(3) a one-time debit to OPG of $24,078,732.03 representing the outstanding balance of (i) the depreciated cost of assets, (ii) the inventory, (iii) prepaid amounts and (iv) amounts held back from amounts otherwise payable to Subcontractors to comply with the Construction Lien Act as of the Effective Date;

(4) a one time debit to OPG of $ 3,500,000 in accordance with Section 7.3A; and

(5) a calculated sum for interest due from OPG for sums included in Sections 7.3B(1) to Section 7.3B(4) from December 1, 2008 to June 30th, 2009. Such interest will be calculated at the rate defined in Section 7.3(b).

7.4 Title Warranty

(a) **Warranty.** The Contractor represents and warrants to OPG that, subject to the limitations set forth in Section 2.16, title to all Work (including documents, designs, drawings, specifications, plans, reports, information and other deliverables and data) and Goods (excluding the TBM and the TBM Accessories and vehicles) covered by any Application for Payment, whether used or incorporated in the Project or not and wherever situate, will pass to OPG no later than the time of payment, free and clear of all Liens. OPG's retention of any amount under Sections 7.3B or 7.5(e), will in no way affect the Contractor's representation and warranty in this Section 7.4, and for the purposes of this Section 7.4(a), OPG will be deemed to have paid each approved Application for Payment in full upon any payment required under Section 7.3(b) having been made.

(b) **Maintenance of Records.** The Contractor will compile and maintain at the Site, in accordance with the Final Submittals and Applicable Laws, detailed, itemized records of all items covered by each Application for Payment, including all Work (including documents, designs, drawings, specifications, plans, reports, information and other deliverables and data) and Goods. On request by OPG, the Contractor will promptly provide OPG access to such records for review and copying. The Contractor will maintain these records for the period expiring on the latest of:

(1) two years following expiration or termination of this Agreement;

(2) the period of time as may be specified in this Agreement, including the Contractor's Proposal Documents or the Final Submittals;

(3) the period of time as may be required by Applicable Laws; and

(4) such other period as OPG may set out in a Project Change Directive to the Contractor.

7.5 Taxes

(a) **Goods and Services Tax.** The Contractor represents and warrants to OPG that, for any goods and services tax invoiced to OPG, the Contractor will be duly registered for the purposes of Part IX of the *Excise Tax Act* (Canada) and that the Contractor will provide OPG with its registration number once available. The Contractor will deduct all Canadian goods and services tax levied under the *Excise Tax Act* (Canada) recovered or recoverable by the Contractor on the payment of expenses before submitting any Application for Payment to OPG covering any such expenses. The Target Cost does not include Canadian goods and services tax levied under the *Excise Tax Act* (Canada).

(b) **Provincial Sales Tax.**

(1) All amounts payable by OPG to the Contractor pursuant to this Agreement include any Ontario Retail Sales Tax payable pursuant to Applicable Law by the Contractor in respect of the Work but do not include any Ontario Retail Sales Tax payable pursuant to Applicable Law by OPG.

(2) OPG represents, warrants, and covenants to the Contractor that any electrical generating equipment that is acquired for incorporation into the Work is exempt from Ontario Retail Sales Tax pursuant to Section 7(1)(40) of the *Retail Sales Tax Act* (Ontario) and, accordingly, no Ontario Retail Sales Tax is payable pursuant to Applicable Law by the Contractor in respect of any such Goods or equipment that is acquired for incorporation into the Work. In addition, OPG has applied for and received retail sales tax ruling letters from the Ontario Ministry of Finance that set out certain Goods and equipment that when acquired by the Contractor for incorporation into the Work are exempt from Ontario Retail Sales Tax (all such ruling letters are attached hereto as Appendix 7.3(b)). The Contractor represents, warrants, and covenants to OPG that to the extent that these rulings indicate that the Contractor may acquire the particular Goods and equipment covered by the rulings exempt from the *Ontario Retail Sales Tax Act* by providing the supplier of the particular Goods or equipment with a properly completed Ontario Retail Sales Tax Purchase Exemption Certificate, the Contractor has calculated the Target Cost on the basis that the Contractor will acquire such Goods and equipment exempt from Ontario Retail Sales Tax and the Contractor will provide such supplier(s) with a properly completed Ontario Retail Sales Tax Purchase Exemption Certificate(s). The Contractor will not include any Retail Sales Tax in any Application for Payment in respect of Allowed Costs for the purchase of Goods and equipment where the Goods and equipment acquired by the Contractor were exempt from Ontario Retail Sales Tax. If the Ontario Ministry of Finance at any time revokes any of the rulings, determines that any Goods or equipment acquired by the Contractor exempt from Ontario Retail Sales Tax did not qualify as electrical generating equipment acquired for incorporation into the Work,

or determines that any of the rulings are not binding, any Ontario Retail Sales Tax, penalties, interest, and other costs assessed against the Contractor as a consequence will be an Allowed Cost and there will be a corresponding adjustment to the Target Cost.

(3) With respect to the TBM and the TBM Accessories, OPG represents, warrants and covenants to the Contractor that pursuant to the *Retail Sales Tax Act* (Ontario) and the regulations promulgated thereunder (collectively, the "**RSTA**"), regardless of the fact that legal title to the TBM and the TBM Accessories will be transferred by the Contractor to OPG pursuant to this Agreement, the Contractor will be considered to be the "purchaser" of the TBM and the TBM Accessories for RSTA purposes and, accordingly, (a) the Contractor is required to pay Ontario Retail Sales Tax on its costs of acquiring and commissioning the TBM and the TBM Accessories, (b) the Contractor is not required to charge and collect Ontario Retail Sales Tax from OPG in respect of that portion of the Actual Cost allocated to the TBM and the TBM Accessories, and (c) the Contractor is not required to pay Ontario Retail Sales Tax when legal title to the TBM and the TBM Accessories is transferred back to the Contractor from OPG as contemplated by this Agreement. Accordingly, the Contractor has determined the Target Cost and, more specifically, that portion of the Target Cost allocated to the TBM and the TBM Accessories, on the basis that the Contractor will be required to pay Ontario Retail Sales Tax on its costs of acquiring and commissioning the TBM and the TBM Accessories. If at any time it is determined that OPG is or was the "purchaser" of the TBM and the TBM Accessories for RSTA purposes and OPG is assessed for failure to pay Ontario Retail Sales Tax in respect of the TBM and the TBM Accessories, OPG shall pay the assessment, the Contractor shall apply for a refund of the Ontario Retail Sales Tax that it paid in respect of its acquisition and commissioning of the TBM and the TBM Accessories, and the Contractor shall pay any such refund (and interest thereon) received to OPG as a reduction to the Actual Cost and Target Cost. If at any time it is determined that OPG is or was the "purchaser" of the TBM and the TBM Accessories for Ontario Retail Sales Tax purposes and the Contractor is assessed for failure to charge and collect Ontario Retail Sales Tax from OPG, OPG shall indemnify and hold harmless the Contractor for any Ontario Retail Sales Tax, penalties, interest and other costs incurred or payable by the Contractor as a consequence of or in respect of any such assessment. OPG shall indemnify and hold harmless the Contractor for any Ontario Retail Sales Tax, penalties, interests and other costs incurred or payable by the Contractor as a consequence of any of these representations, warranties and covenants by OPG regarding the TBM and the TBM Accessories and Ontario Retail Sales Tax being inaccurate or in error.

(4) If the Contractor is a non-resident of Ontario, the Contractor will comply with Section 39 of the RSTA and provide OPG with a duplicate copy of an

applicable letter of compliance issued by the Ministry of Finance (Ontario) certifying that the Contractor has satisfied this requirement. In the event that OPG is not provided with a duplicate copy of an applicable letter of compliance, the Contractor acknowledges that OPG has an obligation to withhold and remit to the Minister of Finance (Ontario) 4% of all amounts payable to the Contractor.

(5) The indemnities contained in Section 7.5 of this Agreement shall not merge and shall survive termination or expiration of this Agreement indefinitely.

(6) Should the Ontario Retail Sales Tax cease to be applicable after the Effective Date, the Target Cost shall be adjusted to reflect the impact of such change in the Ontario Retail Sales Tax. For greater clarity, the Target Cost shall be reduced by the amount thereof that can reasonably be considered to be in respect of the Ontario Retail Sales Tax that is not payable.

(c) **The Contractor's Income Taxes and Withholdings.** OPG will have no liability for:

(1) any of the Contractor's income taxes imposed by any Governmental Authority respecting this Agreement; or

(2) any withholding (except for any amount withheld by OPG under Section 7.5(e)), collection, payment, remitting or reporting of any Taxes paid or payable by the Contractor in respect of this Agreement, including in respect of the Contractor's Personnel.

Nothing in this Section 7.5(c) is intended to expand the definition of Disallowed Costs under Section 1.1(O).

(d) **Refund of Taxes.** All remissions or refunds of any Taxes (other than income), paid or payable by any Governmental Authority in respect of the Work, in whole or in part, are the exclusive property of OPG. All amounts received by the Contractor or a Major Subcontractor, with whom the Contractor entered into individual contracts greater than $100,000, by way of a remission or refund of any Taxes will constitute trust monies to which OPG is exclusively entitled. The Contractor will promptly forward all such amounts to OPG. The Parties will co-operate with each other and take all actions required or desirable to apply for any applicable remission or refund of Taxes. Upon request by OPG, the Contractor will execute, or cause any Subcontractor to execute, all required or desirable documentation to allow OPG to act in the name of the Contractor or a Subcontractor, as the case may be, to apply for and receive any such remission or refund. OPG may be entitled to a rebate under the *Retail Sales Tax Act* (Ontario), for Retail Sales Tax paid in connection with this Agreement. The Contractor will show, in the manner directed by OPG, on each Application for

Payment, either the actual Ontario Retail Sales Tax paid by the Contractor by category or the portion of the Contract Price eligible under Applicable Law for the rebate.

(e) **Withholding for Non-residents.** Notwithstanding any term in this Agreement, OPG may withhold any amount that is required to be withheld by any Applicable Laws respecting Taxes. OPG will have no obligation to gross up or otherwise increase payments made to the Contractor or any Subcontractor because OPG withheld any amount in respect of Taxes. Where OPG so withholds any amount, OPG will remit such amount to the applicable Governmental Authority. If OPG is entitled to set off an amount owing by OPG under this Agreement against an amount owing to OPG under this Agreement and OPG is also required to withhold an amount under any Applicable Laws respecting Taxes, then OPG will set off an amount owing by OPG against an equal amount owing to OPG. For example, if OPG owes the Contractor $100 and of that amount OPG is required to withhold $15, and the Contractor owes OPG $95, then:

(1) OPG would withhold and remit to the Canada Revenue Agency $15; and

(2) the Contractor would pay OPG $10.

These payments would thus entirely extinguish both OPG's obligation to the Contractor and the Contractor's obligation to OPG.

(f) **Research Tax Credits**. The Parties agree that this Agreement may require the performance of Scientific Research and Experimental Development ("**SR&ED**") as defined in subsection 248(1) of the *Income Tax Act (Canada)* ("**ITA**"). The Parties further agree that where this is the case, the SR&ED is being performed by the Contractor on behalf of OPG and OPG will be entitled to include the amounts paid for SR&ED as permitted in subsection 37(1) of the *Income Tax Act (Canada)* in its tax returns. As such, it is agreed that OPG will be entitled to claim the Investment Tax Credits as defined in subsection 127 (9) of the *Income Tax Act (Canada)* that may arise from the activities of the Contractor for which OPG has made payments.

The Contractor will assist OPG or its agents to prepare a summary SR&ED project expenditure report which will include a summary and breakdown of cost data as required under the ITA, including details of current and capital expenditures, cost of materials consumed, salaries and wages of personnel directly engaged in the SR&ED, and overhead or other expenditures.

(g) **Importer of Record.** If any portion of the Goods is to be manufactured or fabricated outside Canada, the Contractor will ensure that either the Contractor or its agent will be the importer of record for customs purposes. OPG will reimburse the Contractor for Canadian goods and services tax paid to obtain customs clearance upon written request with sufficient supporting information provided

the Contractor is a non-resident and not registered for Part IX of the *Excise Tax Act* (Canada).

(h) **Capital Tax.** Capital tax imposed on the Contractor on or after the Effective Date shall be an Allowed Cost provided the Contractor provides the previous year's Notice of Assessment or such other supporting documentation to substantiate the cost.

7.6 INTENTIONALLY DELETED

7.7 INTENTIONALLY DELETED

7.8 INTENTIONALLY DELETED

7.9 Substantial Completion

(a) **Notice of Ready for Use.** The Contractor will deliver a Notice in the form attached as Appendix 7.9(a) to OPG (including a punch list of all items that remain unfinished and which will not impair the intended use of the Tunnel Facility Project and a schedule for entirely finishing each such item) when:

(1) "**substantial performance**" has occurred, as such term is defined in the *Construction Lien Act* (Ontario);

(2) the Work has progressed to the point where the Tunnel Facility Project is ready for use and is sufficiently complete, in accordance with this Agreement, so that the Tunnel Facility Project may be used as intended in accordance with this Agreement;

(3) the cost to entirely finish the Work that remains unfinished and to correct any known Defective parts of the Work does not exceed an estimated total of $4 million;

(4) the Contractor has obtained and delivered to OPG the Approvals which the Contractor is required to obtain under Section 2.6(b);

(5) the Tunnel Facility Project has been commissioned and meets all of the tests set out in the Final Submittals and this Agreement;

(6) water is flowing in the tunnel, with gates fully open, unrestricted between tunnel intake and outlet structure for a continuous period of 24 hours, provided that the Contractor will not water up the tunnel unless the tunnel is free of Defects, and provided that all other material obligations under this Agreement have also been satisfied;

(7) the Contractor has delivered to OPG copies of all certified reports of the performance tests described in this Section 7.9(a); and

(8) the Contractor has delivered to OPG an affidavit of each of the Contractor's design Professionals substantially in the form attached as Appendix 7.9(a)(8).

When OPG determines, acting reasonably, that all of the terms of Sections 7.9(a)(1) to 7.9(a)(8) inclusive have been complied with then "**Substantial Completion**" has occurred.

(b) **Joint Inspection.** Within a reasonable time after receipt of the Notice under Section 7.9(a), the Parties will make a joint inspection of the Tunnel Facility Project to determine the status of the Tunnel Facility Project and each outstanding item, including each item set out in the Notice delivered under Section 7.9(a). If OPG determines that Substantial Completion has not occurred in accordance with Section 7.9(a), OPG will deliver a Notice in the form of document attached as Appendix 7.9(b) to this effect to the Contractor, giving reasons. If OPG determines that Substantial Completion has occurred in accordance with Section 7.9(a), OPG will deliver a Notice in the form of document attached as Appendix 7.9(b) containing a certificate of Substantial Completion. This certificate will fix the date of Substantial Completion. The Parties will then sign a certificate of substantial completion as contemplated by Section 32(1)1 of the *Construction Lien Act* (Ontario). The Contractor will then promptly publish the notice in accordance with the *Construction Lien Act* (Ontario).

(c) **Punch List and Allocation of Responsibilities.** OPG will attach to the certificate of Substantial Completion a punch list of items that are to be entirely finished or are Defective and must be corrected or replaced by the Contractor before final payment will be made under Section 7.14. At the time of delivery of the certificate of Substantial Completion, OPG will also deliver to the Contractor a written allocation of responsibilities between OPG and the Contractor pending final payment made under Section 7.14 respecting safety, security, operation, maintenance, insurance and warranties and guarantees respecting the remaining Work. The Contractor will deliver a Notice to OPG each week setting out an update as to the status of completion of each punch list item. The costs of the Contractor to complete the items on the punch list are Allowed Costs, except for the costs to correct Defective work that were Disallowed Costs under Section 9.7.

(d) **Access to Perform Remaining Obligations.** OPG may exclude the Contractor from the Site, in whole or in part, after the date of Substantial Completion. OPG will, however, allow the Contractor reasonable access to such parts of the Site as are required to permit the Contractor to finish entirely or correct all items on the punch list.

7.10 Final Inspections

When the Contractor considers that it has entirely finished or corrected all items on the punch list, the Flow Verification Test has been conducted and the final Test report has been approved by the chief of test and delivered to OPG and the Contractor (as more particularly described in

Section 11 of Appendix 1.1(aa)), the Contractor may deliver a Notice to this effect to OPG. Promptly following receipt of this Notice, the Parties will make a joint inspection of the Tunnel Facility Project. OPG will then deliver a Notice in the form attached as Appendix 7.10 to the Contractor stating either that:

(a) OPG accepts the Work as being entirely finished, including because the Contractor has delivered to OPG all Approvals and other written or graphic documents, designs, drawings, specifications, plans, reports, information and other deliverables or data required to be provided by the Contractor to OPG under this Agreement and because the Contractor has satisfied all requirements of Applicable Laws; or

(b) there are items remaining to be entirely finished or that are Defective and must be corrected or replaced by the Contractor. The Contractor will promptly take such actions as are necessary to finish entirely, correct or replace all such items. Once the Contractor has finished all such actions, the Contractor will deliver another Notice to OPG in accordance with this Section 7.10.

7.11 INTENTIONALLY DELETED

7.12 INTENTIONALLY DELETED

7.13 Payment Procedure after Substantial Completion

After Substantial Completion, the Contractor shall no longer be allowed to invoice best estimates for Allowed Costs as per Section 7.2(a).

7.14 Final Payment and Acceptance

(a) **Final Application for Payment.** After OPG has accepted the Work as being entirely finished under Section 7.10(a) and three (3) Business Days before the 25th of the month of or following Final Completion Date, the Contractor will make a final Application for Payment in accordance with Section 7.2. The Contractor will submit with the final Application for Payment (except to the extent previously delivered by the Contractor and accepted by OPG as satisfactory), the following:

(1) as-built drawings, maintenance and operating instructions, security documents, certificates of insurance, certificates of inspection, all documents required to be maintained at the Site in accordance with Section 2.15(a) and all other documents required by this Agreement to be delivered to OPG on the Final Completion Date;

(2) the required consent of any surety, if any, to the final payment made under Section 7.14(c);

(3) a certificate of good standing from the Workplace Safety and Insurance Board or successor organization;

(4) releases in the form set out in Appendix 7.14(a), from the Contractor and each Subcontractor who performed Work in respect of the Tunnel Facility Project, respecting all Liens and other claims filed or otherwise arising in respect of the Work or Tunnel Facility Project;

(5) statutory declarations in the form set out in Appendix 7.14(a), signed by a director or officer of the Contractor, and each Subcontractor who has performed Work at the Site, declaring that all payments due to Subcontractors, all wages and benefit payments due to any of the Contractor's Personnel, and all contributions, premiums, allowances and remittances due to any Governmental Authority, pension fund, benefit plan, or union fund in accordance with a collective agreement, have been paid in a timely manner; and

(6) a statement setting out any reconciliation of incentives paid or disincentives paid under Section 8 following Substantial Completion and prior to the final Application for Payment.

If the Contractor is unable to deliver to OPG any release or statutory declaration referred to in Items (5) and (6) from a Subcontractor, the Contractor will deliver to OPG collateral or security satisfactory to OPG to indemnify OPG against any Lien or other claim until such time that any Lien or claim would expire by operation of Applicable Laws.

(b) **Final Payment and Acceptance.** On receipt of the Application for Payment under Section 7.14, OPG will review the Application for Payment within 10 Business Days after receipt and deliver a Notice in the form attached as Appendix 7.14(b) to the Contractor stating either that:

(1) OPG accepts the Application for Payment and OPG will make, subject to Sections 7.3A and 7.5(c), the final payment within 60 days after the delivery of such Application for Payment to OPG; or

(2) the Application for Payment does not yet satisfy all the obligations under this Agreement and setting out the reasons therefore. The Contractor will promptly take such actions as are necessary to satisfy its remaining obligations. Once the Contractor has satisfied all such obligations, the Contractor will deliver to OPG an amended final Application for Payment under Section 7.14(a).

Where OPG makes the final payment to the Contractor under this Section 7.14, such payment will not relieve the Contractor from any of its obligations or liabilities under this Agreement or otherwise. The Contractor will maintain the applicable records, including time sheets, accounts and invoices, for two (2) years following expiration or termination of this Agreement, or for such other period as OPG may set out in a Notice to the Contractor. OPG may in its sole discretion

require a final audit of the Project, and, on request by OPG, the Contractor will promptly provide OPG access to such records for review and copying.

(c) **Cost and Proceeds after Final Payment and Acceptance.**

(1) Actual Costs incurred after the final payment under Section 7.14 shall be invoiced to OPG within 30 days of its occurrence and shall be payable within 60 days thereafter.

(2) Any Cost Performance Incentive or Cost Performance Disincentive shall be adjusted to reflect Section 7.14(c)(1) above.

(3) The Overhead Recovery Fee shall be included in the invoice to OPG within 30 days of its occurrence and shall be payable within 60 days thereafter.

(4) A maximum of 50% of any insurance proceeds received by OPG for Allowed Costs after final Application for Payment shall (if such credit would affect the Cost Performance Incentive or Cost Performance Disincentive payments in Section 8) be credited to the Contractor in order to adjust the Cost Performance Incentive and Cost Performance Disincentive.

SECTION 8. PERFORMANCE INCENTIVES

8.1 Calculation of Schedule Performance Disincentive

Subject to the maximum disincentive set out in Section 8.5, the Contractor will pay OPG (by means of set off from the total amount due to the Contractor under this Agreement or, if insufficient amounts are due, by payment by the Contractor) $67,000 for each complete day that the day fixed for Substantial Completion as specifically defined in Section 8.4C(a) (and not as defined in Section 7.9 or elsewhere) falls after the date for Substantial Completion set out in the Contract Schedule (the "**Schedule Performance Disincentive**").

The Parties acknowledge that the precise amount of actual damages would be extremely difficult to calculate and that the amount of damages for failure to achieve Substantial Completion in accordance with the Contract Schedule as provided for in this Section represents a reasonable and genuine pre-estimate of actual damages and is not a penalty.

OPG acknowledges that the Schedule Performance Disincentive is OPG's sole remedy for the Contractor's delay in meeting the Substantial Completion Date in accordance with the Contract Schedule; provided that in no event shall the foregoing constitute a waiver by OPG of its right to claim damages for breach of this Agreement. The preceding sentence is not intended to and shall in no event limit the Contractor's obligations under Section 9.8 or in respect of claims of Third Parties.

8.2 Calculation of Schedule Performance Incentive

Subject to the maximum incentive set out in Section 8.6, OPG will pay the Contractor $200,000 for each complete day that the day fixed for Substantial Completion as specifically defined in Section 8.4C(a) (and not as defined in Section 7.9 or elsewhere) falls before the date for Substantial Completion set out in the Contract Schedule (the "**Schedule Performance Incentive**").

8.3 Calculation of Disincentive Related to Guaranteed Flow Amount

Within 2 weeks following Substantial Completion, the Contractor will arrange for the performance of the water flow performance test in accordance with the Flow Verification Test set out in Appendix 1.1(aa). OPG shall have the right to be represented at such test and shall have access to all data resulting from such test.

Subject to Section 8.4C(c), the Contractor will pay OPG (by means of set off from the total amount due to the Contractor under this Agreement or, if insufficient amounts are due, by payment by the Contractor) the following sum (the "**Guaranteed Flow Amount Disincentive**") for the difference in water flow calculated as follows:

PTWFA = Performance Test Water Flow Amount (performed and adjusted in accordance with Flow Verification Test, expressed in m^3/s)

GFA = Guaranteed Flow Amount (expressed in m^3/s)

GFA - PTWFA = A

0.02 = Assumed Flow Amount +/- 2% Test Uncertainty

(a) If "A" is positive and equal to or less than (PTWFA x 0.02), or if "A" is zero, no liquidated damages are due under this Section 8.3;

(b) If "A" is negative, the Contract may be entitled to a bonus as calculated in Section 8.4;

(c) For the portion of "A" greater than (PTWFA x 0.02), the amount of such portion shall be multiplied by the following sums within the specified ranges:

(1) $350,000 for each 1 m^3/s of incremental flow from 600 to 650 m^3/s, inclusive

(2) $390,000 for each 1 m^3/s of incremental flow from 550 to 600 m^3/s, inclusive

(3) $430,000 for each 1 m^3/s of incremental flow from 500 to 550 m^3/s, inclusive

(4) $600,000 for each 1 m^3/s of incremental flow from 400 to 500 m^3/s, inclusive

(5) $900,000 for each 1 m^3/s of incremental flow from 350 to 400 m^3/s, inclusive

(6) $1,800,000 for each 1 m^3/s of incremental flow less than 350 m^3/s.

The Parties acknowledge that the precise amount of actual damages would be extremely difficult to calculate and that the amount of damages for failure to achieve GFA as provided for in this Section represents a reasonable and genuine pre-estimate of actual damages and is not a penalty.

The amount of disincentives payable under this Section 8.3 shall be the sum of the amounts calculated under the applicable Sections 8.3(c)(1) to 8.3(c)(6), inclusively, above.

Example: If the Guaranteed Flow Amount is 560 m^3/s and the Performance Test Water Flow Amount is 500 m^3/s, then the disincentive payable would be based on 60 m^3/s - (500 m^3/s x 0.02) = 50 m^3/s. The calculation would be ((40 x $430,000) + (10 x $390,000)) = $21,100,000 (disincentive).

OPG acknowledges that the Guaranteed Flow Amount Disincentive is OPG's sole remedy for failure to achieve GFA; provided that in no event shall the foregoing constitute a waiver by OPG of its right to claim damages for breach of this Agreement. The preceding sentence is not intended to and shall in no event limit the Contractor's obligations under Section 9.8 or in respect of claims of Third Parties.

8.4 Calculation of Incentive Related to Guaranteed Flow Amount

Subject to Section 8.4C(c), OPG will pay the Contractor the following sum (the "**Guaranteed Flow Amount Incentive**") for the difference in water flow calculated as follows (using the value for "A" calculated in Section 8.3):

(a) If "A" is negative and the absolute value of "A" is equal to or less than (PTWFA x 0.02), no bonus is due under this Section 8.4.

(b) If "A" is negative and the absolute value of "A" is greater than (PTWFA x 0.02), for the portion of "A" that is greater than (PTWFA x 0.02), the amount of such portion shall be multiplied by the following sums below within the specified ranges:

(1) $175,000 for each 1 m^3/s of incremental flow from 600 to 650 m^3/s, inclusive

(2) $195,000 for each 1 m^3/s of incremental flow from 550 to 600 m^3/s, inclusive

(3) $215,000 for each 1 m^3/s of incremental flow from 500 to 550 m^3/s, inclusive

(4) $300,000 for each 1 m^3/s of incremental flow from 400 to 500 m^3/s, inclusive

(5) $450,000 for each 1 m^3/s of incremental flow from 350 to 400 m^3/s, inclusive

(6) $900,000 for each 1 m^3/s of incremental flow less than 350 m^3/s.

The total incentive payable under this Section 8.4 shall be the sum of the amounts calculated under the applicable Section 8.4(b)(1) to 8.4(b)(6), inclusively, above.

Example: If the Guaranteed Flow Amount is 520 m^3/s and the Performance Test Water Flow Amount is 570 m^3/s then the bonus payable would be based on 50 m^3/s - (570 m^3/s * 0.02) = 38.6 m^3/s. The calculation would ((30 m^3/s * $215,000) + (8.6 m^3/s * $195,000)) = $8,127,000 (Incentive).

8.4A Calculation of Cost Performance Disincentive for Exceeding Target Cost

Subject to the maximum disincentive set out in Section 8.5, if Actual Cost exceeds the Target Cost the Contractor will pay OPG (by means of set off from the total amount due to the Contractor under this Agreement or, if insufficient amounts are due, by payment by the Contractor) an amount equal to 50% of the difference between Actual Cost and the Target Cost (the "**Cost Performance Disincentive**").

OPG acknowledges that the Cost Performance Disincentive is OPG's sole remedy for the Actual Costs exceeding the Target Cost; provided that in no event shall the foregoing constitute a waiver by OPG of its right to claim damages for breach of this Agreement. The preceding sentence is not intended to and shall in no event limit the Contractor's obligations under Section 9.8 or in respect of claims of Third Parties.

8.4B Calculation of Cost Performance Incentive if Actual Cost is less than Target Cost

Subject to the maximum incentive set out in Section 8.6 if Actual Cost is less than the Target Cost, OPG will pay the Contractor an amount equal to 50% of the difference between the Target Cost and Actual Cost (the "**Cost Performance Incentive**").

8.4C Timing, Invoicing, and Payment of Incentives and Disincentives

(a) **Substantial Completion for Purposes of Calculation of Schedule Performance Incentive and Schedule Performance Disincentive**. Despite any definition of Substantial Completion to the contrary (including the definition in Section 7.9), for the sole purpose of calculating Substantial Completion for the Schedule Performance Incentive and Schedule Performance Disincentive under Sections 8.1 and 8.2, the following shall be the definition of Substantial Completion:

(1) the Work has progressed to the point where the Tunnel Facility Project is ready for use and is sufficiently complete, in accordance with this

Agreement, so that the Tunnel Facility Project may be used as intended in accordance with this Agreement;

(2) the Tunnel Facility Project has been commissioned and meets all of the tests required prior to OPG being able to use the Tunnel Facility Project for its intended use; and

(3) water is flowing in the tunnel, with gates fully open, unrestricted between tunnel intake and outlet structure for a continuous period of 24 hours, provided that the Contractor will not water up the tunnel unless the tunnel is free of Defects, and provided that all other material obligations under this Agreement have been satisfied, to the extent that such material obligations are required to be satisfied prior to OPG being able to use the Tunnel Facility Project for its intended use.

(b) **Calculation of the Cost Performance Incentive and Disincentive**. The Cost Performance Incentive and Cost Performance Disincentive will be calculated no later than three months following the date of Substantial Completion in Section 8.4C(a) and the Parties will use reasonable efforts to agree on a fixed cost amount for all remaining Work.

(c) **Payment of Incentives and Disincentives.** The Contractor shall be entitled to invoice OPG for all incentives and disincentives in Section 8 once Substantial Completion pursuant to Section 8.4C(a) has been achieved and the calculations in Section 8.4C(b) and the Flow Verification Test have been completed. Notwithstanding any other provision in this Agreement, OPG shall not be entitled to reduce or set-off against any payment for any incentives on account of any claim OPG may have under this Agreement. The foregoing shall in no way constitute a waiver by OPG of any claim it may have under this Agreement and OPG's remedies hereunder with respect to any such claim shall be unaffected by this Section 8.4C.

8.5 Maximum Disincentive

The aggregate of the Schedule Performance Disincentive and the Cost Performance Disincentive shall not exceed $20,000,000.00.

8.6 Maximum Incentive

The aggregate of the Schedule Performance Incentive and the Cost Performance Incentive shall not exceed $40,000,000.00.

8.7 Interim Completion Fee

Provided that progress on the tunnel lining is in accordance with the Contract Schedule, the Contractor will be entitled to and may submit an Application for Payment for $10,000,000 (the "**Interim Completion Fee**") on the TBM Completion Date. If progress on the tunnel lining is not in accordance with the Contract Schedule, then the Contractor will not be eligible for the

Interim Completion Fee at the TBM Completion Date but the Contractor will be entitled to payment of the Interim Completion Fee together with its payment of the Substantial Completion Fee.

8.8 Substantial Completion Fee

Upon achieving Substantial Completion, the Contractor will be entitled to and may submit an Application for Payment for $10,000,000 (the "**Substantial Completion Fee**").

SECTION 9. ACCEPTANCE OF TUNNEL FACILITY PROJECT AND CORRECTION OF DEFECTS

9.1 Warranty

(a) **Basic Warranty.** The Contractor warrants and guarantees to OPG that:

(1) notwithstanding anything else in this Agreement, the Work will in all respects be fit for the purposes intended by this Agreement, including the Owner's Mandatory Requirements, Contractor's Proposal Documents and the Final Submittals;

(2) costs for warranty work under Section 9.8 ("**Warranty Work**") will be borne by the Contractor and will be Disallowed Costs, except for an administration fee for Warranty Work to be paid by OPG at Substantial Completion. The administration fee will be $100,000 per year of Warranty existing on the date of Substantial Completion (pro-rated for partial years). Where the Warranty Period is extended under Section 9.8(d), OPG will pay the Contractor a one-time $50,000 administrative fee to cover such extensions; and

(3) all Work will be performed in accordance with this Agreement.

(b) **Exclusions.** The Contractor's warranties and guarantees in Section 9.1(a) do not apply to the extent that any breach of the warranty or guarantee is due to:

(1) maintenance or operation by OPG contrary to any maintenance or operating instructions delivered by the Contractor to OPG; or

(2) the negligence of OPG or any Person providing services to OPG, other than the Contractor or a Subcontractor.

(c) **No Deemed Acceptance.** The Contractor's obligations under Section 9.1(a) are absolute. These warranties and guarantees will not be affected in any way by any certificate, acceptance, approval, payment or any other act, matter or thing done or omitted under this Agreement. For greater certainty, none of the following actions will constitute any acceptance of the Work or Tunnel Facility Project by OPG in whole or in part or will constitute a waiver or release of any of the Contractor's obligations under this Agreement:

(1) any review, comment, acceptance, rejections or failure to review, comment, accept or reject by OPG of a Submittal or other document under this Agreement;

(2) any inspection, test or approval by OPG or any third party;

(3) any payment under this Agreement;

(4) any certificate of Substantial Completion issued under Section 7.9(b);

(5) any use or occupancy of the Tunnel Facility Project in whole or in part by OPG; or

(6) any correction or replacement of a Defective part of the Work or Tunnel Facility Project by, or at the request of, the Contractor, OPG or OPG's Representative.

(d) INTENTIONALLY DELETED

(e) **Indemnity.** The Contractor will indemnify and hold harmless each member of the OPG Group, from and against all claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Third Party but only to the extent such Losses are caused by:

(i) a breach of this Agreement (including in respect of any breach of Applicable Laws) by the Contractor; or

(ii) any act or omission of a Person performing any of the Work.

The obligations of the Contractor under this Section 9.1(e) will not be affected in any way by any certificate, acceptance, approval, payment or any other act, matter or thing done or omitted under this Agreement, including any act by OPG or OPG's Representative referred to in Sections 9.1(c)(1) to 9.1(c)(6) inclusive.

The Contractor's indemnification and hold harmless responsibility set forth in this Section 9.1(e) shall not apply to the extent that the Losses at issue were caused by or attributable to the wilful misconduct or negligence of OPG, a subsidiary of OPG, OPG's Representative, or one of OPG's Designated Delegates and shall exclude liability for loss of use of the Tunnel Facility Project, loss of power from the Tunnel Facility Project, and the loss of the ability to sell, purchase or use power from the Tunnel Facility Project to the extent set out in Section 10.9.

9.2 Access to Tunnel Facility Project

The Contractor will provide access to the Tunnel Facility Project, the Site and the premises of the Contractor and, to the extent requested by OPG acting reasonably, Subcontractors, at all reasonable times and from time to time, to OPG's Representative, and at the request of OPG's Representative, to OPG's Designated Delegates and any other Person, for the purposes of

Site visits, compliance with access rights, emergency maintenance and repairs, viewing, performing surveillance on, inspecting, testing and/or accepting the Work and/or Tunnel Facility Project, in whole or in part, including to monitor compliance with the Owner's Mandatory Requirements, the Contractor's Proposal Documents, the Final Submittals and any applicable quality assurance program. In particular, the Contractor will deliver a Notice to OPG's Representative providing OPG with Notice of at least two Business Days before OPG is required to inspect any Goods at any hold point in any inspection plan. At the request of OPG's Representative, the Contractor will promptly provide to OPG's Representative a copy of all the documents (unpriced, if the Contractor desires) respecting any subcontract subject to viewing, performing surveillance, inspecting, testing and/or accepting. No such viewing, performing surveillance, inspecting, testing and/or accepting by OPG will relieve the Contractor of any of its obligations or liabilities under this Agreement. The Contractor will advise each applicable representative of OPG of the Contractor's or Subcontractor's applicable site safety procedures and policies. The Contractor will provide each such representative with proper and safe transportation and conditions for such access.

9.3 Inspections, Tests and Approvals

The Contractor will with promptness and in an orderly sequence so as not to cause any delay to the Work, arrange for and obtain all inspections, tests and approvals required for the acceptance of Goods that are to be incorporated or used in the Tunnel Facility Project. The Contractor will ensure that each inspection, test or approval that is required to be carried out, in whole or in part, by a Professional, is so carried out by a Professional. The Contractor will pay all costs respecting such inspections, tests and approvals and such costs will be Allowable Costs. If this Agreement, the applicable quality assurance program or any Applicable Laws or Approvals require any part of the Work or the Tunnel Facility Project to be inspected, tested or approved, in whole or in part, the Contractor will arrange for and obtain all such inspections, tests and approvals as an Allowable Cost. The Contractor will pay all costs in connection with such inspections, tests and approvals. The Contractor will deliver to OPG all certificates, reports and other documents respecting any inspections, tests and approvals made in accordance with this Section 9.3, the Contractor's Proposal Documents or the Final Submittals. The Contractor will give OPG reasonable Notice of the date, time and location for all inspections, tests or approvals carried out under this Section 9.3 so that OPG can attend. If Notice is not given, OPG may require the inspection, test or approval to be redone as a Disallowed Cost. If any such approval is to be issued in the name of OPG or that will affect the operation of the Project following the Final Completion Date, the Contractor will submit the draft approval to OPG's Representative for acceptance, before the Contractor obtains this approval. The Contractor will only obtain any such approval following receipt of the written acceptance of OPG's Representative of the draft approval. In addition to any other inspection, test or approval set out in this Agreement, OPG may require, as an Allowed Cost, any other inspection, test or approval of any part of the Work or the Tunnel Facility Project, in whole or in part, either on or off the Site, upon Notice to the Contractor.

9.4 Uncovering Project

(a) **Covered Without OPG's Consent.** If, without the prior written consent of OPG, the Contractor covers any part of the Project (or the construction work of any

Person) that is required under this Agreement or Applicable Laws or Approval to be inspected, tested or approved, but limited to the items listed in Appendix 9.4 (as may be amended from time to time), the Contractor will uncover and recover such part of the Project or construction work and such costs will be Disallowed Costs. If, however, the Contractor has given OPG timely Notice of the Contractor's intention to cover a part of the Project or the construction work that OPG has specified in a notice in the form of Appendix 9.4(a) as not to be covered, and OPG has not acted with reasonable promptness in response to such Notice, such costs will be treated as an Allowed Cost and there will be an adjustment to the Target Cost, calculated in accordance with Section 5.1A, of uncovering and recovering such part of the Project or the construction work.

(b) INTENTIONALLY DELETED.

(c) **OPG's Request to Uncover.** If, for any reason not set out in Section 9.4(a), OPG wishes to have part of the Project uncovered to be inspected, tested or approved by any Person designated by OPG, the Contractor will, at OPG's request, uncover the requested part of the Project for inspection, testing, approval and performing all necessary Work. If it is determined that any part of the Work uncovered under this Section 9.4(c) is Defective, the Contractor will:

(1) pay all costs for uncovering and recovering the part of the Work requested by OPG to be uncovered;

(2) INTENTIONALLY DELETED; and

(3) correct or replace the Defective part of the Work in accordance with this Section 9.

If, however, it is determined that none of the Work uncovered under this Section 9.4(c) is Defective, the Contractor's reasonable costs for uncovering and recovering the part of the Project requested by OPG to be uncovered will be treated as an Allowed Cost with an adjustment to the Target Cost, which costs will be calculated in accordance with Section 5.1A.

The Contractor's costs incurred in respect of Sections 9.4(c)(1) and 9.4(c)(3) are Disallowed Costs.

9.5 Notice of Defective Tunnel Facility Project

OPG will, within a reasonable period of time after having actual knowledge of a Defective part of the Work, deliver Notice to the Contractor of the Defective part, but OPG's failure to do so will not impose any liability on OPG and the Contractor will be estopped from making any claim against OPG for failure to do so. In addition, OPG's failure to do so will not:

(a) have the effect of transferring any obligation under this Agreement from the Contractor to OPG or otherwise have the effect of amending this Agreement; or

(b) will not affect or change in any way the Contractor's:

(1) obligation to entirely finish the Work in accordance with this Agreement, or

(2) responsibility for repairing, replacing or re-providing any Defective part of the Work or Tunnel Facility Project.

Notwithstanding anything to the contrary in this Section 9.5, OPG's failure to properly deliver to the contract a Disallowed Cost Notice in accordance with Section 1.1(O)(1) will prohibit OPG from disallowing any costs arising from a Defective part of the Work, to the extent that the Defective part of the Work is due to a breach of the standard of care of the Contractor in Section 1.1(O)(1).

9.6 OPG May Stop Construction

OPG may at any time and from time to time, by delivering a Notice to the Contractor, direct the Contractor to stop the performance of the Work, in whole or in part, including, if

(a) the Work or the Tunnel Facility Project is Defective, in whole or in part;

(b) the Contractor fails to supply suitable Goods, in whole or in part; or

(c) the Contractor fails to perform the Work, in whole or in part, in a manner that ensures that the entirely finished Tunnel Facility Project will conform to this Agreement.

The Contractor may resume the stopped Work to which OPG's direction applies only once the Contractor has remedied the issue that was the cause for OPG to deliver such Notice. OPG is not obliged to deliver a Notice to the Contractor under this Section 9.6 for any reason whatsoever.

9.7 Correction or Removal of Defective Part of Tunnel Facility Project - Before Substantial Completion

(a) **Work Required.** Before Substantial Completion, OPG may accept or reject any Defective parts of the Work or the Tunnel Facility Project, whether or not such part has been incorporated into the Project, on delivery of Notice to this effect to the Contractor. The Contractor will promptly correct all Defective parts of the Work and the Tunnel Facility Project either upon discovery or upon rejection by OPG under this Section 9.7. If reasonably requested by OPG, the Contractor will remove any and all Defective parts of the Tunnel Facility Project from the Site, whether or not such parts have been incorporated into the Project, and replace such parts with parts that are not Defective and that comply with this Agreement.

(b) **Cost to Correct or Remove.** All costs respecting the correction of a Defective part of the Work or the Tunnel Facility Project ("**Correction Costs**"), including:

(1) all incidental costs of the corrective services, including, as may be required for disassembly, removal, re-installation, re-erection, re-assembly, transportation, insurance and any applicable Taxes;

(2) all of OPG's fees and charges of engineers, architects, accountants, lawyers (on a solicitor and client basis and subject to Section 14.11A), and other professionals, all court, arbitration and other dispute mediation or resolution costs and charges, whether incurred through settlement or otherwise, together with interest calculated in accordance with Section 1.1(mm); and

(3) all costs and charges respecting correction or replacement of any Defective part of the Work or the Tunnel Facility Project, including any part of the Work or Tunnel Facility Project that was rendered Defective because of the Defective part of the Work or Tunnel Facility Project, including in respect of any damage or loss arising in respect of such correction or replacement or in respect of any inspections conducted to determine whether any such correction or replacement was required, including for loss of use,

will, in the event the Defective part of the Work is discovered by OPG, be Disallowed Costs and will, in the event the Defective part of the Work is discovered by the Contractor and brought to the attention of OPG, be Allowed Costs. For greater clarity, any Correction Costs attributable to the wilful misconduct of the Contractor, a Subcontractor or any member of the Contractor's Personnel or the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii) (so long as OPG complies with the notice requirements set forth in Section 1.1.(O)(1)) are Disallowed Costs.

9.8 Correction or Removal of Defective Part of Tunnel Facility Project - After Substantial Completion

(a) **Warranty Period.** "**Warranty Period**" means, in respect of each part of the Work and Tunnel Facility Project, beginning at Substantial Completion and continuing until the greatest of:

(1) one year from the date of Substantial Completion;

(2) the warranty period specified in any warranty from a Subcontractor for any specific part of the Work and Tunnel Facility Project;

(3) the warranty period specified in this Agreement, including the Contractor's Proposal Documents or the Final Submittals, for any specific part of the Work and Tunnel Facility Project; and

(4) the warranty period for any specific part of the Work and Tunnel Facility Project provided under any Applicable Laws,

subject to any extension made under Section 9.8(d).

(b) **Warranty Work.** If at any time after commencement of the Warranty Period and from time to time before the expiration of the relevant Warranty Period, the Work or the Tunnel Facility Project, in whole or in part, including any part of the Work or Tunnel Facility Project that was rendered Defective because of the Defective part of the Work or Tunnel Facility Project, becomes or is determined to be Defective or fails because of any defect, the Contractor will promptly, without cost to OPG (except for the administrative fee provided for in Section 9.1(a)(2)) and in accordance with OPG's instructions and at times and within the period of time reasonably specified by OPG:

(1) satisfactorily correct such Defective part of the Work and Tunnel Facility Project, or, to the extent reasonably requested by OPG, remove such Defective part of the Work or Tunnel Facility Project from the Site and replace such Defective part with parts which are not Defective and which comply with this Agreement; and

(2) satisfactorily correct or replace any other damage arising in respect of the actions taken in respect of Section 9.8(b)(1) or in respect of any inspections conducted to determine whether any actions were required in respect of Section 9.8(b)(1).

The Contractor will pay all Correction Costs under this Section 9.8(b) and such costs will be Disallowed Costs. In providing any corrective services under this Section 9.8(b), the Contractor will comply with all applicable terms of this Agreement and will endeavour to minimize interference with, and impact on, OPG's operations.

(c) **Failure to Comply.** If the Contractor fails to comply with its obligations under Section 9.8(b) or any other term in this Agreement as expeditiously as is commercially reasonable and within the time period reasonably specified by OPG, or if there is an emergency that poses a significant risk of loss or damage to the Project or any Person, OPG may take, directly or indirectly, any of the actions contemplated under Section 9.8(b) or such other actions as are reasonable in the circumstances, without affecting any other rights or remedies OPG may have against the Contractor under this Agreement. The Contractor will pay all Correction Costs as described in Section 9.7 respecting all such actions and deduct same from any monies otherwise due, owing or payable to the Contractor. In respect of any action taken by OPG, directly or indirectly, under this Section 9.8(c), OPG may without terminating this Agreement:

(1) eject and exclude from the Site the Contractor, any Subcontractor and any of the Contractor's Personnel and prohibit the Contractor from continuing the Work;

(2) suspend the Contractor's performance of the Work under this Agreement to the extent of such actions;

(3) take possession of the Site, work in progress, Goods, Contractor's construction equipment, tools, fuel and temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal, at the Site (and at no additional charge for the retention and use thereof);

(4) assume any and all subcontracts with Subcontractors;

(5) avail itself of any performance bond, guarantee, indemnity, letter of credit or other security provided by the Contractor or a Subcontractor with respect to the applicable Work;

(6) incorporate or use in the Project all Goods stored at the Site or for which OPG has paid the Contractor but which are stored elsewhere, including for greater certainty, the TBM; and/or

(7) withhold, without interest, payments to the Contractor under any agreement between OPG and the Contractor until the Contractor's liability to OPG is determined.

The Contractor will allow all members of the OPG Group and OPG's other contractors access to the Site to enable OPG to exercise its rights under this Section 9.8(c). The Contract Schedule will not be changed for any reason relating to any actions taken by OPG, directly or indirectly, under this Section 9.8(c).

(d) **Extension of Warranty Period.** Where any correction or replacement of any Defective part of the Work or Tunnel Facility Project, including any part of the Work or Tunnel Facility Project that ceases to be used in commercial operations because of the Defective part of the Work or Tunnel Facility Project, including in respect of any damage or loss arising in respect of such correction or replacement, is carried out under this Section 9.8, then the Warranty Period will:

(1) recommence at the beginning of the Warranty Period under Section 9.8(a) respecting the part of the Work or Tunnel Facility Project that was corrected or replaced, commencing on the date that such corrected or replaced part re-enters commercial operation; and

(2) respecting the part of the Work or Tunnel Facility Project that ceases to be used in commercial operations because of the Defective part of the Work or Tunnel Facility Project, be suspended as at the date that such Work or Tunnel Facility Project were taken out of commercial operation and will recommence on the date that such Work or Tunnel Facility Project re-enter commercial operation.

9.9 Acceptance of Defective Part of Tunnel Facility Project

If any part of the Work or the Tunnel Facility Project becomes or is determined to be Defective or fails because of any defect during the relevant Warranty Period (as that period may be extended under Section 9.8(d)), OPG may deliver a Notice to the Contractor directing the Contractor not to correct or replace the Defective part of the Work or the Tunnel Facility Project in whole or in part. The Contractor will pay all of OPG's costs respecting its evaluation of, and determination respecting, such Defective part of the Work and the Tunnel Facility Project (including all of OPG's fees and charges of engineers, architects, accountants, lawyers (to the extent required for evaluating if the Work is Defective but not legal fees for dispute resolution, except in accordance with Section 14.11A), and other professionals) and all court, arbitration, and other dispute mediation or resolution costs and charges). To the extent OPG accepts any such Defective part of the Work or the Tunnel Facility Project before OPG makes the final payment under Section 7.14, the Parties will offset the Actual Cost and Target Cost under an Amendment made in accordance with Section 5 to reflect an equitable reduction in the Contract Price for the Defective part of the Work or the Tunnel Facility Project. To the extent OPG accepts any such Defective part of the Work or Tunnel Facility Project after OPG makes the final payment under Section 7.14, the Contractor will pay OPG an agreed amount that reflects an equitable reduction in the Contract Price for the Defective part of the Work.

9.10 Warranty Work

The Contractor will perform in a timely manner all the warranty Work set out in this Agreement. In performing such Work at the Site, the Contractor will comply with all applicable terms of this Agreement respecting the performance of Work at the Site and will endeavour to minimize interference with, and impact on, OPG's operations.

SECTION 10. DEFAULT

10.1 Events of Default

Each of the following events and circumstances constitutes an event of default by the Contractor under this Agreement:

(a) the Contractor or any Person providing a parental indemnity to OPG in accordance with Section 4.1(e) has been dissolved or has had a resolution passed for its winding-up or liquidation, other than in respect of an amalgamation, merger or consolidation;

(b) the Contractor or any Person providing a parental indemnity to OPG in accordance with Section 4.1(e):

(1) makes a general assignment for the benefit of creditors;

(2) institutes proceedings seeking (i) to adjudicate it a bankrupt or insolvent, (ii) liquidation, winding-up, reorganization, arrangement, adjustment, protection, release or composition of it or its debt under any law relating to bankruptcy, insolvency, compromise or release of debtors including any

proceedings seeking to approve or impose a plan providing for the compromise of claims of creditors or imposing other limitations or restrictions on creditors' rights; or

(3) takes any corporate or other action to authorize any of the above actions;

(c) the Contractor or any Person providing a parental indemnity to OPG in accordance with Section 4.1(e) is adjudicated insolvent or ceases to be, or admits that it is no longer, able to satisfy its obligations as they become due;

(d) the Contractor or any Person providing a parental indemnity to OPG in accordance with Section 4.1(e) has instituted against it any proceedings seeking (i) to adjudicate it a bankrupt or insolvent, or (ii) liquidation, winding-up, reorganization, arrangement, adjustment, protection, release or composition of it or its debt under any law relating to bankruptcy, insolvency, compromise or release of debtors including any proceedings seeking to impose a stay of proceedings against creditors, seeking to approve or impose a plan of arrangement providing for the compromise of claims of creditors or imposing other limitations or restrictions on creditors' rights, and in any such case:

(1) such proceeding shall remain undismissed or unstayed for a period of 45 days;

(2) the Contractor or such Person providing a parental indemnity to OPG in accordance with Section 4.1(e) fails to diligently and actively oppose such proceeding; or

(3) any order or decree approving or ordering any of the foregoing shall be entered or granted;

(e) the Contractor or any Person providing a parental indemnity in accordance with Section 4.1(e) has consented or becomes subject to the appointment of a receiver, liquidator or trustee or assignee in bankruptcy in respect of all or a substantial part of its assets and in the case of any such process instituted against the Contractor or such Person providing a parental indemnity in accordance with Section 4.1(e), as the case may be, such process has not been stayed pending an appeal and dismissed, discharged, stayed or restrained within 30 days thereafter (or, where such appointment is being contested in good faith by appropriate proceedings diligently conducted, such longer period as is reasonably required for such appeal, stay, dismissal, discharge, or restraint to be effected under the law of the forum in which such action is brought);

(f) the Contractor or any Person providing a parental indemnity in accordance with Section 4.1(e) had an encumbrancer (including a receiver, liquidator, trustee, or assignee in bankruptcy) take possession of all or a substantial part of its assets;

(g) the Contractor or any Person providing a parental indemnity in accordance with Section 4.1(e) has a distress, execution, attachment, or sequestration enforced on or against all or a substantial part of its assets;

(h) the Contractor breaches in a material respect any of its obligations (including any representations, warranties, guaranties and indemnities) under this Agreement or under any document delivered under this Agreement and fails to remedy the breach within seven Business Days following receipt of Notice from OPG specifying the breach, or if the breach is capable of being cured but cannot reasonably be cured within such seven Business Day period, after such longer period of time as is reasonably required to cure the breach (but no longer than 60 days in any circumstances), so long as the Contractor diligently and constantly endeavours to cure the breach during such extended period provided, however, that absent any other event of default, no failure of the Contractor to progress the work in accordance with the Contract Schedule shall constitute an event of default in and of itself under this Subsection (h).

(i) the Contractor breaches or contravenes any Applicable Law in connection with this Agreement in any material respect, provided however, that no such event shall be an event of default under this Subsection (i) unless OPG first delivers Notice of the alleged default to the Contractor and, if such default is capable of being cured, the Contractor fails to cure (or begin to diligently pursue a cure) the event within seven Business Days of the Contractor's receipt of the Notice of the alleged default (or such longer period as is reasonably required to cure the alleged default but no longer than 60 days in any circumstances) provided that such breach or contravention does not otherwise restrict the Contractor (or such Person providing a parental indemnity in accordance with Section 4.1(e)) from performing a material obligation under this Agreement or expose OPG to material liability or legal sanction);

(j) the Contractor's conflict of interest declaration appended as Appendix 2.18 was incorrect when originally provided or becomes incorrect, inaccurate or incomplete due to a change in circumstances and either (i) measures cannot be instituted to address to OPG's satisfaction a conflict which resulted from the change in circumstances as described in Section 2.18 or (ii) the Contractor does not institute measures requested by OPG to address the conflict;

(k) the Contractor fails to obtain or maintain the maintenance bond, or the Performance LC(s) for this Agreement as required under Section 4.1;

(l) (x) the Contractor fails to obtain or maintain the insurance required to be procured by the Contractor pursuant to Section 4.2(e) or Section 4.2(f); or (y) the Contractor fails to obtain or maintain the insurance required to be procured by the Contractor pursuant to Sections 4.2(a) to 4.2(d) and OPG is prejudiced thereby;

(m) the Contractor, or any Subcontractor, or any Person providing a parental indemnity to OPG in accordance with Section 4.1(e), any of their shareholders,

directors, officers, partners, members, representatives, agents or any of the Contractor's Personnel gives or offers to give (directly or indirectly) to any Person, a bribe, gift, gratuity, commission or other thing of note, as an inducement or reward;

(1) for doing or forbearing to do any action in relation to this Agreement; or

(2) for showing favour or disfavour to any Person in relation to this Agreement;

provided that, to the extent the alleged violation was that of a Subcontractor or of a Person acting without authority (actual or tacit), no event of default shall be deemed to have occurred unless OPG first delivers Notice of the alleged default to the Contractor under this Subsection (m) and, if such default is capable of being cured, the Contractor fails to cure (or begin to diligently pursue a cure) the event within seven Business Days of the Contractor's receipt of Notice of the alleged default (or such longer period as is reasonably required to cure the default but no longer than 60 days in any circumstances); or

(n) the Contractor assigns or attempts to assign this Agreement, in whole or in part, except in a manner expressly permitted in Section 14.1.

10.2 Notice

OPG may terminate this Agreement immediately and without any cost to OPG by delivering a Notice to the Contractor on the occurrence of any event of default set out in Section 10.1.

10.3 OPG's Recourse

If OPG is entitled to terminate this Agreement under Section 10.2, OPG may, in addition to its rights under Section 10.2 and without terminating this Agreement:

(a) eject and exclude from the Site the Contractor, any Subcontractor and any of the Contractor's Personnel and prohibit the Contractor from continuing the Work;

(b) entirely finish the Work, in whole or in part, by whatever means OPG deems appropriate under the circumstances, acting reasonably (and the Contractor, at no additional charge to OPG, will promptly, and in any event within three Business Days, provide OPG with all such records and work in progress that are not located on the Site and that are requested by OPG in a Notice);

(c) take possession of all or part of the Site, any work in progress, drawings, designs, Goods, Contractor's construction equipment, tools, fuel and temporary structures and facilities, including for offices, lunchrooms, canteens, sanitation, showers, change rooms, accommodations, shops, warehouses and garbage disposal, at the Site (and at no additional charge for the retention and use thereof) (and the Contractor, at no additional charge to OPG, will cooperate to ensure the orderly transition of the foregoing);

(d) assume any and all subcontracts with Subcontractors;

(e) enforce any indemnity, performance bond, payment bond, maintenance bond, letter of credit, guarantee or other security provided by the Contractor, a Subcontractor or any other Person with respect to the applicable Work (although, if the terms of any such document permit earlier enforcement under any such document, OPG may enforce such rights in accordance with the terms of such other document);

(f) incorporate or use in the Tunnel Facility Project any or all Goods stored at the Site or for which OPG has paid the Contractor but which are stored elsewhere;

(g) withhold, without interest, all payments, in whole or in part, to the Contractor under any agreement between OPG and the Contractor until the Contractor's liability to OPG is determined; and

(h) terminate the license of the TBM and the TBM Accessories granted by OPG to the Contractor.

10.4 Deemed Termination

If at any time after OPG terminates this Agreement under Section 10.2 or exercises its rights under Section 10.3, or both, it is determined for any reason that an event of default had not occurred or the default was otherwise excusable, the rights and obligations of the Parties will be the same as if the termination of this Agreement by OPG had occurred under Section 13.2.

10.5 Contractor's Liability

If OPG terminates this Agreement under Section 10.2 or exercises its rights under Section 10.3, the Contractor will be liable to OPG for:

(a) all costs in excess of the Target Cost incurred by OPG to finish entirely the Work and the Tunnel Facility Project, including external and internal costs (including costs of additional engineering, management and administration);

(b) all costs of correcting Defective parts, if any, in the Work or Tunnel Facility Project, calculated in accordance with Section 9.8(c); and

(c) all other Losses suffered or incurred by OPG in respect of any event of default arising in respect of Section 10.1.

OPG may set off such amount, in whole or in part, as OPG determines is owing by the Contractor to OPG under this Section 10.5, against any amount otherwise owing by OPG to the Contractor.

10.6 Other Rights and Remedies

Any action by OPG under this Section 10 shall be without prejudice to OPG's other rights or remedies under any guarantee, indemnity, bond or security held by OPG for performance of the Work by the Contractor.

10.7 OPG's Liability

Notwithstanding any term in this Agreement, the Contractor may not make any claim against OPG for breach of this Agreement by OPG unless, the Contractor, within 30 Business Days after the Contractor discovered (as such term is defined in Section 5 of the *Limitations Act* (Ontario)) such breach by OPG of its obligations under this Agreement, gives Notice to OPG in the form attached as Appendix 10.7 describing the breach and the anticipated claim for the breach. The Contractor will be estopped from making any claim against OPG unless it provides this Notice in the time period required by this Section 10.7. Notwithstanding any term in this Agreement, other than a claim in respect of OPG's obligation to pay the Contractor, OPG's maximum liability for any claim for breach of this Agreement by OPG will not exceed the Target Cost.

10.8 Limitation of Liability

Notwithstanding any term in this Agreement (other than Section 10.9), the liability of Contractor respecting all claims arising in respect of this Agreement will not exceed the greater of:

(a) an amount equal to the Target Cost; and

(b) the amount of insurance recoverable under this Agreement.

10.9 Exceptions

The limitations of liability set out in Section 10.8 will not apply, however, to:

(a) the Contractor's obligations under Sections 2.4(f), 2.15(f), 2.16(e), 8.1, 8.3, 8.4A, 9.1(e) and 10.5; and

(b) Losses suffered or incurred by a member of the OPG Group or any claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person, to the extent arising in respect of:

(1) the deliberate or wilful breach of this Agreement by the Contractor; or

(2) any injury or damage to Third Parties for which the Contractor is obligated to indemnify OPG hereunder.

Except as set out in Sections 8.1, 8.3 and 8.4A (including, for greater certainty, in the event of default by the Contractor hereunder, the payments under Sections 8.1, 8.3 and 8.4A that would have been payable but for the exercise by OPG of its rights on default (using for this purpose the actual date of substantial completion of the work that was to be performed by the Contractor under this Agreement)), and except where recoverable under insurance or in respect of Losses

suffered or incurred by a member of the OPG Group or any claims, demands, actions, suits or proceedings for Losses made against any member of the OPG Group by any Person to the extent arising in respect of the deliberate or wilful breach of this Agreement by the Contractor, neither Party will be liable to the other Party for consequential liabilities, damages, losses, costs or expenses including any claim for the loss of use of the Tunnel Facility Project, loss of power from the Tunnel Facility Project, the loss of the ability to sell, purchase or use power related to the Tunnel Facility Project. For greater clarity, there is no limitation on Disallowed Costs hereunder and any provision hereunder which requires an action of the Contractor where the costs of such action are Disallowed Costs is not subject to any limitation, including Sections 9.4, 9.7 and 9.8.

SECTION 11. DISPUTE RESOLUTION

11.1 Dispute Resolution

(a) All disputes, disagreements, controversies, questions or claims (including claims for indemnification) arising out of or relating to this Agreement, including with respect to its formation, execution, validity, application, interpretation, performance, breach, termination or enforcement ("**Disputes**") shall first be submitted to a Steering Committee (the "**Steering Committee**") for informal resolution. Within five (5) days of the execution of this Agreement, each party shall appoint a representative individual to the Steering Committee. In the event that one of the nominees is unable to continue acting on the Steering Committee, or if the nominating party wishes to replace its nominee, such nominee shall be replaced by another representative individual from the respective nominating party.

(b) Either party may commence an informal resolution under this Section 11.1 by delivering a written notice of informal resolution to the other party (with a copy to the members of the Steering Committee) (the "**Notice of Informal Resolution**"). The Steering Committee will attempt to resolve the Dispute within thirty (30) days of the date of receipt of the Notice of Informal Resolution by the receiving party, provided that this time period may be extended by mutual agreement of the members of the Steering Committee.

(c) If the Steering Committee cannot resolve the Dispute, they will identify an expert or experts who will render a recommendation. Recommendations of expert(s) will not be binding on the Parties.

(d) Unless the Steering Committee otherwise agrees by mutual agreement of its members, all unresolved Disputes (except for a Dispute as to whether a default has occurred under Section 10.1 of the Agreement or a Dispute as to whether Substantial Completion has been achieved) will be held in abeyance until the earlier of (i) Substantial Completion; or (ii) termination of the Agreement, except to the extent that holding such Dispute in abeyance could prejudice, by operation of the provisions of the *Limitations Act, 2002* (Ontario), the right of the Dissatisfied Party to commence an arbitration regarding the unresolved Dispute. In such event, the Dissatisfied Party may commence an arbitration prior to the

expiry of the applicable limitation period. To the extent permitted by the *Limitations Act, 2002* (Ontario), as amended at any time or from time to time during the term of this Agreement, the Parties waive the application of such Act to any unresolved Disputes.

11.2 ICC Arbitration

Subject to the processes set out in Section 11.1, all unresolved Disputes arising out of or in connection with this Agreement shall be finally settled under the Rules of Arbitration of the International Chamber of Commerce by three arbitrators appointed in accordance with said Rules.

The arbitrators will apply the laws of the Province of Ontario and the federal laws of Canada to decide any Dispute. The place of arbitration will be Toronto, Ontario, Canada and arbitrations will be conducted in the English language.

All matters relating to an arbitration will be kept confidential to the fullest extent permitted by the Rules of Arbitration of the International Chamber of Commerce.

SECTION 12. INTENTIONALLY DELETED

SECTION 13. SUSPENSION OF WORK AND TERMINATION

13.1 Suspension of Work

OPG may at any time, and from time to time, for any reason without affecting the validity of this Agreement, suspend the performance of the Work in whole or in part for such period of time as OPG may notify the Contractor. Except to the extent that the underlying circumstances for which any suspension arises were caused by or attributable to the wilful misconduct of the Contractor, a Subcontractor or any member of the Contractor's Personnel or the failure of the Contractor, a Subcontractor or any member of the Contractor's Personnel to meet the standard of care in Section 1.1(O)(1)(ii), OPG will pay the Contractor the reasonable extra direct damages suffered by the Contractor arising from the suspension and the Target Cost and Contract Schedule will be equitably adjusted. Except for such extra direct damages, notwithstanding any term in this Agreement, in no circumstances whatsoever will OPG be liable to the Contractor for consequential liabilities, damages, losses, costs or expenses suffered or incurred by the Contractor in any such suspension. Severance costs respecting the termination of any of the Contractor's Personnel do not constitute direct damages. Before OPG pays the Contractor for such extra direct damages, the Contractor will provide to OPG such reasonable evidence of such damages as OPG may request. In addition, before making any payment, OPG may conduct an audit of such damages and the Contractor will provide OPG with all information reasonably requested by OPG in respect of such audit. Immediately following a Notice of resumption delivered by OPG to the Contractor, the Contractor will resume performing the Work in accordance with the schedule established by OPG.

13.2 Termination

OPG may from time to time, without cause and without affecting the validity of this Agreement, immediately terminate any unprovided Work, in whole or in part, by delivering a Notice to this effect to the Contractor. Upon receipt of such Notice, the Contractor will cease performing the designated portion of the Work which is the subject of termination, but will continue to perform all Work not subject to termination. Except to the extent any such termination arises in respect of any event of default by the Contractor, OPG will pay the Contractor:

(a) the amounts set out in this Agreement for all parts of the Work that have been entirely finished and delivered in accordance with the terms of this Agreement, and for which OPG has not made any payment;

(b) the amount of the Contractor's costs determined in accordance with Section 7.2 incurred in providing the work in progress, not including the Work referred to in Section 13.2(a);

(c) the reasonable extra direct damages suffered by the Contractor arising from the termination (such as the reasonable out-of-pocket costs of demobilization);

(d) the Interim Completion Fee;

(e) the Substantial Completion Fee, provided that as of the date of termination, the Contractor is less than 12 months behind the most current monthly progress schedule as submitted under Section 2.7(c); and

(f) the Cost Performance Incentive and the Schedule Performance Incentives on the following basis:

(1) if OPG terminates this Agreement under this Section 13.2 prior to January 1, 2012, the Contractor will not be entitled to either the Cost Performance Incentive or the Schedule Performance Incentive unless the Project is restarted with another contractor within 5 years from the date of termination, in which case the Contractor will be entitled to the incentives in (2) below;

(2) if OPG terminates this Agreement under this Section 13.2 after January 1, 2012, the Contractor will be entitled to a portion of the Cost Performance Incentive and/or the Schedule Performance Incentive based on how much the Contractor is ahead of the Contract Schedule or below the Target Cost at time of termination. (Example: if the Contractor is ahead of the Contract Schedule by 20 days at the date of termination, the Contractor would be entitled to a Schedule Performance Incentive valued at 20 days multiplied by $200,000 = $4,000,000);

(3) The Guaranteed Flow Amount Incentive shall not be paid to the Contractor if OPG terminates the Agreement.

Except for such amounts referred to in Sections 13.2(a), 13.2(b), 13.2(d), 13.2(e) and 13.2(f) and direct damages referred to in Section 13.2(c), notwithstanding any term in this Agreement, in no circumstances whatsoever will OPG be liable to the Contractor for consequential liabilities, damages, losses, costs or expenses, damages, loss of profit, economic loss, interest or any other damages or loss suffered or incurred by the Contractor in any such termination. Before OPG pays the Contractor for such amounts referred to in Sections 13.2(a), 13.2(b), 13.2(d), 13.2(e), and 13.2(f) and direct damages referred to in Section 13.2(c), the Contractor will provide to OPG such reasonable evidence of such amounts and damages as OPG may request. In addition, before making any payment, OPG may conduct an audit of such amounts and damages and the Contractor will provide OPG with all information reasonably requested by OPG in respect of such audit. On payment for such amounts and damages, title to all the remainder of the Work (including documents, designs, drawings, specifications, plans, reports, information and other deliverables and data) that had not to date vested in OPG, will vest automatically in OPG.

SECTION 14. GENERAL

14.1 Assignment and Benefit

The Contractor may not assign this Agreement, in whole or in part, without the prior written consent of OPG except to a wholly-owned subsidiary of the Contractor provided that the Contractor is not released from its obligations under this Agreement and provided further that the Contractor provides prior Notice to OPG. In the event of an assignment by the Contractor of this Agreement, any reference to the Contractor under this Agreement shall include the assignee. This Agreement enures to the benefit of and binds the Parties and their respective successors and permitted assigns. OPG may from time to time transfer, assign, sell, lease or otherwise dispose of certain assets relating to one or more electricity generating stations or other business units of OPG (each station or other unit being a "**Business Unit**"). Notwithstanding any term in this Agreement, OPG may, without the consent of the Contractor, assign this Agreement, in whole or in part, and sublicence, assign or transfer OPG's rights respecting the Retained Intellectual Property, as that term is defined in Section 2.16(c), in whole or in part, to any owner, operator, lessee or any other successor in interest of a Business Unit (an "**Assignee**"). OPG may disclose to an Assignee or a proposed Assignee any information and documentation respecting this Agreement. The Assignee may use the Retained Intellectual Property, in accordance with the rights sublicensed, assigned or transferred by OPG. In addition, OPG may divide OPG's rights under this Agreement with any Assignee in such a manner as to permit both OPG and the Assignee to realize the full rights that OPG is entitled to under this Agreement. Effective immediately upon any such assignment or transfer by OPG and assumption, in whole or in part, by an Assignee of any of OPG's obligations respecting such assignment or transfer, OPG will be automatically released and forever discharged from the obligations to the extent that they are assumed. The Contractor will from time to time and promptly upon request, sign and deliver all further documents and take all further action reasonably necessary or appropriate to give effect to the terms and intent of this Section 14.1.

14.2 Amendments

OPG's Representative, or an officer senior to OPG's Representative, are the only individuals authorized to execute any Amendment on behalf of OPG. Aside from those individuals, no other

Person has any authority to make any agreement, undertaking, representation, warranty, guarantee, release or waiver on behalf of OPG in respect of this Agreement. Except as expressly provided in this Agreement, no amendment (including an Amendment), restatement or termination of this Agreement in whole or in part is binding unless it is in writing and signed by each Party. Accordingly, this Agreement will not be amended by any Application for Payment, invoice or other document (even where such Application for Payment, invoice or other document purports, directly or indirectly, to be paramount to any term of this Agreement), unless such Application for Payment, invoice or other document is signed by both Parties.

14.3 Discretion Granted

Wherever OPG is granted sole and absolute discretion or the power to refuse a change requested by the Contractor in accordance with this Agreement, the exercise of such discretion or power will not be subject to the dispute resolution process under Section 11 or any other claim by the Contractor.

14.4 Notice

Except as otherwise provided in this Agreement, such as in Section 10.2, every Notice required or permitted under this Agreement must be in writing and may be delivered in person, by courier or by fax to the applicable Party, as follows:

If to OPG, Ontario Power Generation Inc.
700 University Avenue, H18-D15
Toronto, Ontario, M5G 1X6

Attention: Rick Everdell
Fax: 416-592-6552

with a copy to:

Hatch Mott MacDonald
2520 Stanley Avenue
Niagara Falls, Ontario, L2E 6S4

Attention: Harry Charalambu
Fax: 905-353-5518

if to the Contractor, Strabag Inc.
2520 Stanley Avenue
Niagara Falls, Ontario, L2E 6S4

Attention: Ernst Gschnitzer
Fax: 905-353-0636

with a copy to:

STRABAG AG
Donau-City-Strasse 9
A – 1220 Vienna

Attention: Gerald Zangl
Fax: +43 1 22 4 22 1227

or to any other address, fax number or individual that a Party designates by Notice. Any Notice under this Agreement, if delivered personally or by courier will be deemed to have been given when actually received, if delivered by fax before 3:00 p.m. on a Business Day will be deemed to have been delivered on that Business Day and if delivered by fax after 3:00 p.m. on a Business Day or on a day which is not a Business Day will be deemed to be delivered on the next Business Day.

14.5 Currency

Unless otherwise specified, all amounts to be paid or calculated under this Agreement are to be paid or calculated in Canadian dollars.

14.6 Set Off

With the exception of payment for incentives under Section 8.4C(c), OPG may set off any other amount owing to OPG from the Contractor from any amount otherwise due, owing, or payable by OPG to the Contractor.

14.7 Waivers

No waiver of any term of this Agreement is binding unless it is in writing and signed by all the Parties entitled to grant the waiver. No failure to exercise, and no delay in exercising, any right or remedy, under this Agreement will be deemed a waiver of that right or remedy. No waiver of any breach of any term of this Agreement will be deemed to be a waiver of any subsequent breach of that term.

14.8 Cumulative Remedies

OPG's rights and remedies under this Agreement and under any security held by OPG for the Contractor's performance under this Agreement are cumulative and are in addition to and not in substitution for any other rights and remedies available at law or in equity or otherwise. No single or partial exercise by a Party of any right or remedy precludes or otherwise affects the exercise of any other right or remedy to which that Party may be entitled.

14.9 Survival of Obligations

All representations, warranties, guarantees and indemnities made in, required by or given under this Agreement, as well as all continuing obligations under this Agreement, will survive final payment made under Section 7.14, Substantial Completion and acceptance of the Tunnel Facility Project and termination or expiry of this Agreement.

14.10 Relationship of Parties

Nothing in this Agreement will be construed as constituting either Party as the agent, partner, joint venturer or other representative of the other Party. The relationship between the Parties is that of a purchaser and an independent contractor. The Contractor's Personnel are solely the employees of the Contractor and Subcontractors (and not OPG's) for all purposes under this Agreement, including for all purposes under any Applicable Laws. Accordingly, none of the Contractor's Personnel or Subcontractors is entitled to any benefits respecting any pension or other benefit plan, program or policy of OPG. The Contractor will pay all Taxes respecting each of the Contractor's Personnel and each of the Subcontractors as an Allowed Cost and OPG will have no responsibility for any such Taxes.

14.11 No Third Party Beneficiary

This Agreement is solely for the benefit of the Parties and, to the extent expressly and specifically made beneficiaries of this Agreement. In particular, OPG holds the rights of all third party beneficiaries under Sections 2.4(f)(4), 2.4(j), 2.5(f), 2.14(e), 2.14(j), 2.15(f), 2.16(e), 2.17(d) and 9.1(e) in trust for the benefit of such third party beneficiaries. Otherwise, no term of this Agreement will be deemed to confer upon other third parties any claim, remedy, reimbursement or other right. The Contractor represents and warrants to OPG that the Contractor is entering into this Agreement solely on its own behalf and not as agent for any other Person.

14.11A Parties to Bear Expenses

Notwithstanding any other provisions hereof, each Party shall be responsible for its own legal costs in connection with the preparation and negotiation of this Agreement and any amendment of this Agreement. Subject to the ruling of the arbitrators in connection with a Dispute hereunder, each party shall bear all legal costs incurred in connection with any subsequent Dispute relating to this Agreement.

14.12 Acknowledgement as to Negotiation of this Agreement

Each Party acknowledges that all Parties have participated in the drafting of this Agreement. Accordingly, no term of this Agreement will be interpreted less favourably to any Party because that Party or its counsel was primarily responsible for the drafting of that term.

14.13 Choice of Language

The Parties confirm that it is their wish that this Agreement, as well as any other documents respecting this Agreement, including Notices, schedules and authorizations, have been and will be drawn up in the English language only. Les parties aux présentes confirment leur volonté que cette convention, de même que tous les documents, y compris tous avis, cédules et autorisations s'y rattachant, soient rédigés en langue anglaise seulement.

14.14 Counterparts

This Agreement and any Amendment, restatement or termination of this Agreement in whole or in part may be signed and delivered in any number of counterparts, each of which when signed and delivered is an original but all of which taken together constitute one and the same instrument. This Agreement and any Amendment, restatement or termination of this Agreement in whole or in part may be delivered by fax.

14.15 Freedom of Information

The Contractor expressly acknowledges that OPG is subject to the provisions of the *Freedom of Information and Protection of Privacy Act*, R.S.O. 1990, C.F.31, and any confidentiality covenants of OPG set out in this Agreement are granted expressly subject to any and all disclosure requirements that may exist or may in the future arise under the *Freedom of Information and Protection of Privacy Act*, as may be amended or replaced by time to time. Notwithstanding anything to the contrary in this Agreement, OPG may disclose any information

relating to the Tunnel Facility Project and the Work, including Actual Costs, Allowed Costs, Disallowed Costs and Target Cost, in connection with any regulatory proceeding involving OPG or request made of OPG.

14.16 Other Claims

The Parties acknowledge that this Agreement is part of the settlement of claims under the Original Agreement pursuant to the Principles Agreement, represents a good faith compromise between the Parties and does not represent an admission or acceptance of the other Party's position with respect to the claims referred to the Dispute Review Board under the Original Agreement or any other claims hereunder. Neither party will raise the fact that this Agreement was negotiated or entered into as an admission that either party was correct in its assertions to the Dispute Review Board under the Original Agreement.

14.17 Prior Agreements

This Agreement supersedes the Original Agreement and (i) Amendment 1, dated March 15, 2006; (ii) Amendment 2, dated July 5, 2006; (iii) Amendment 3, dated October 10, 2007; (iv) Amendment 4, dated November 7, 2007; and (v) Amendment 5, dated September 25, 2008.

The Parties have duly executed this Agreement.

ONTARIO POWER GENERATION INC.

By: _____
Name: JOHN D. MURPHY
Title: Executive Vice President, Hydro
H19

By: _____
Name: Jim Hankinson
Title: President & CEO

STRABAG INC.

By: _____
Name:
Title: Ernst Gschnitzer
Project Manager

Robert Radlinger
Finance & Admin. Manager

Strabag AG hereby agrees and acknowledges that it is bound by the terms of this Agreement and that it is obligated to perform the obligations under this Agreement as primary obligor and not as a guarantor.

STRABAG AG

By: _____
Name:
Title: Ernst Gschnitzer
Project Manager

Appendix 1.1(b)
Amendment Form

Appendix 1.1(b) - Amendment Form

AMENDMENT AGREEMENT NUMBER [1]

This Agreement is made as of **[•]**, 200• between

ONTARIO POWER GENERATION INC., a corporation existing under the laws of Ontario ("**OPG**"),

and

STRABAG INC., a corporation existing under the laws of Ontario (the "**Contractor**").

RECITALS

A. OPG and the Contractor entered into an amended design/build agreement dated as of December 1, 2008 (the "**Amended Agreement**").

B. OPG and the Contractor have agreed to amend the Amended Agreement to **[insert brief description of amendment, 1-2 lines]**.

C. For value received, the Parties agree as follows.

Interpretation

Any defined term used in this Agreement that is not defined in this Agreement has the meaning given to that term in the Amended Agreement. In this Agreement, the following terms have the respective meanings set out below.

- **[Insert any definitions required in this Agreement.]**

Change to Section [•] (Title of Section)

Section **[•]** of the Amended Agreement is deleted in its entirety and replaced with the following. OR Section **[•]** of the Amended Agreement is deleted in its entirety. OR The following Section is added as a new Section **[•]** to the Amended Agreement.

Change to Section [•] (Title of Section)

Section **[•]** of the Amended Agreement is deleted in its entirety and replaced with the following. OR Section **[•]** of the Amended Agreement is deleted in its entirety. OR The following Section is added as a new Section **[•]** to the Amended Agreement.

Amended Agreement Remains in Full Force

Except for changes to the Amended Agreement set out in this Agreement and any previous Amendment, the Amended Agreement remains in full force, unamended, including the

provisions relating to Target Cost and Contract Schedule. **[Note: Insert any changes to Target Cost or Contract Schedule if relevant.]**

The Parties have duly executed this Agreement.

ONTARIO POWER GENERATION INC.

By: _____

Name:

Title:

STRABAG INC.

By: _____

Name:

Title:

Appendix 1.1(d)
Payment Related Documents

Appendix 1.1(d) - Payment Related Documents

Certificate - Application for Payment

TO: Ontario Power Generation Inc. ("OPG")

RE: Amended Design/Build Agreement (the "Agreement") between OPG and Strabag Inc. (the "Contractor"), dated as of December 1, 2008 for the Niagara Tunnel Facility Project

I, **[name]**, am the **[title]** of the Contractor and am authorized to deliver this Certificate on behalf of the Contractor. I hereby certify, for and on behalf of the Contractor, that:

(c) the coverages that the Contractor is obliged to maintain under Section 4.2 of the Agreement remain in full force;

(d) the Contractor has paid in a timely manner all amounts payable under the *Workplace Safety and Insurance Act, 1997* (Ontario);

(e) the Contractor remains in compliance with all its other obligations under the *Workplace Safety and Insurance Act, 1997* (Ontario);

(f) the Contractor has provided OPG with the Workplace Safety and Insurance Board registration number for each member of the Contractor's Personnel performing Work at the Site for the period covered by the certificate; and

(g) [there are no known outstanding claims under the Agreement, except for those claims which have already been communicated to OPG in a timely manner in the form of Notice required by the Agreement and which are listed in the Appendix to this Certificate, including an estimate of the value of each such claim;] or

[there are outstanding claims which have not been communicated to OPG in the form of Notice required by this Agreement and each of these claims is described in the attached form of Notice required by this Agreement and is delivered to OPG in a timely manner, and there are no other known outstanding claims under the Agreement, except for those claims which have already been communicated to OPG in a timely manner in the form of Notice required by this Agreement and which are listed in the Appendix to this Certificate, including an estimate of the value of each such claim.]

Defined terms used in this Certificate that are not defined in this Certificate have the meanings given to those terms in the Agreement.

DATED: **[date]**, 200**[●].**

STRABAG INC

By: _____

Name:

Title:

Statutory Declaration - Application for Payment

C A N A D A	)	IN THE MATTER OF THE AMENDED DESIGN/BUILD AGREEMENT
	)	BETWEEN ONTARIO POWER GENERATION INC.
	)	AND
	)	STRABAG INC. (the "Contractor")
PROVINCE OF ONTARIO	)	DATED AS OF DECEMBER 1, 2008 FOR
	)	THE NIAGARA TUNNEL FACILITY
	)	PROJECT (the "Agreement")

I, **[•]**, of the **[City]** of **[•]**, Ontario, do solemnly declare that:

I am the **[title]** of Contractor and as such have personal knowledge of the facts set out in this solemn Declaration.

Defined terms used in this solemn Declaration but not defined in this solemn Declaration have the meanings given to those terms in the Agreement.

All payments due to Subcontractors; all wages and benefit payments due to any of the Contractor's Personnel; and all contributions, premiums, allowances and remittances due to any Governmental Authority, pension fund, benefit plan or union fund in accordance with a collective agreement or Applicable Laws, have been paid in a timely manner on or before the date of the Application for Payment to which this solemn Declaration relates, subject to any withholdings or holdbacks required by Applicable Laws.

Title to the applicable part of the Project will pass to OPG in accordance with Section 7.4 of the Agreement no later than the date of OPG's payment to which this solemn Declaration relates.

(h) [there are no known outstanding claims under the Agreement, except for those claims which have already been communicated to OPG in a timely manner in the form of Notice required by the Agreement and which are listed in the Appendix to this solemn Declaration, including an estimate of the value of each such claim;] or

(i) [there are outstanding claims which have not been communicated to OPG in the form of Notice required by this Agreement and each of these claims is described in the attached form of Notice required by this Agreement and is delivered to OPG in a timely manner, and there are no other known outstanding claims under the Agreement, except for those claims which have already been communicated to OPG in a timely manner in the form of Notice required by this Agreement and which are listed in the Appendix to this solemn Declaration, including an estimate of the value of each such claim.]

I make this solemn Declaration conscientiously believing it to be true and knowing it is of the same force as if made under oath.

DECLARED before me at the City of ■, in the County/Region of ■, this day of **[●]**, 200**[●]**.

A Commissioner, etc.

Name

Appendix 1.1(h)
Concept Drawings

Appendix 1.1(h) - Concept Drawings

1. CONCEPT DRAWINGS

Number	Title
NAW130-D0E-29230-0015, Rev 08	Diversion Tunnel General Arrangement
NAW130-D0E-29310-0007, Rev 10	Intake Works Intake Channel and Accelerating Wall Arrangement and Details
NAW130-D0E-29310-0008, Rev 05	Intake Works Modifications to INCW Control Structure
NAW130-D0E-29310-0009, Rev 04	Intake Works Intake Structure Arrangement and Details
NAW130-D0E-29710-0023, Rev 02	Outlet Works Outlet Structure and Canal Arrangement, Plan and Sections
NAW130-D0E-29710-0024, Rev 02	Outlet Works Closure Gate Hoist Structure Architectural Arrangement
NAW130-D0E-29270-0001, Rev 02	Diversion Tunnel Dewatering Station Arrangement, Plan, Sections and Details
NAW130-D0E-80000-0012, Rev 07	Construction Facilities Outlet Area West Plan
NAW130-D0E-80000-0013, Rev 07	Construction Facilities Outlet Area East Plan
NAW130-D0E-80000-0014, Rev 10	Construction Facilities Intake Area Plan and Section
NAW130-D0E-80000-0015, Rev 01	Construction Facilities Intake Area and INCW Part Project Area Site Plans
NAW130-D0E-84500-0001, Rev 02	Construction Facilities Designated Truck Routes

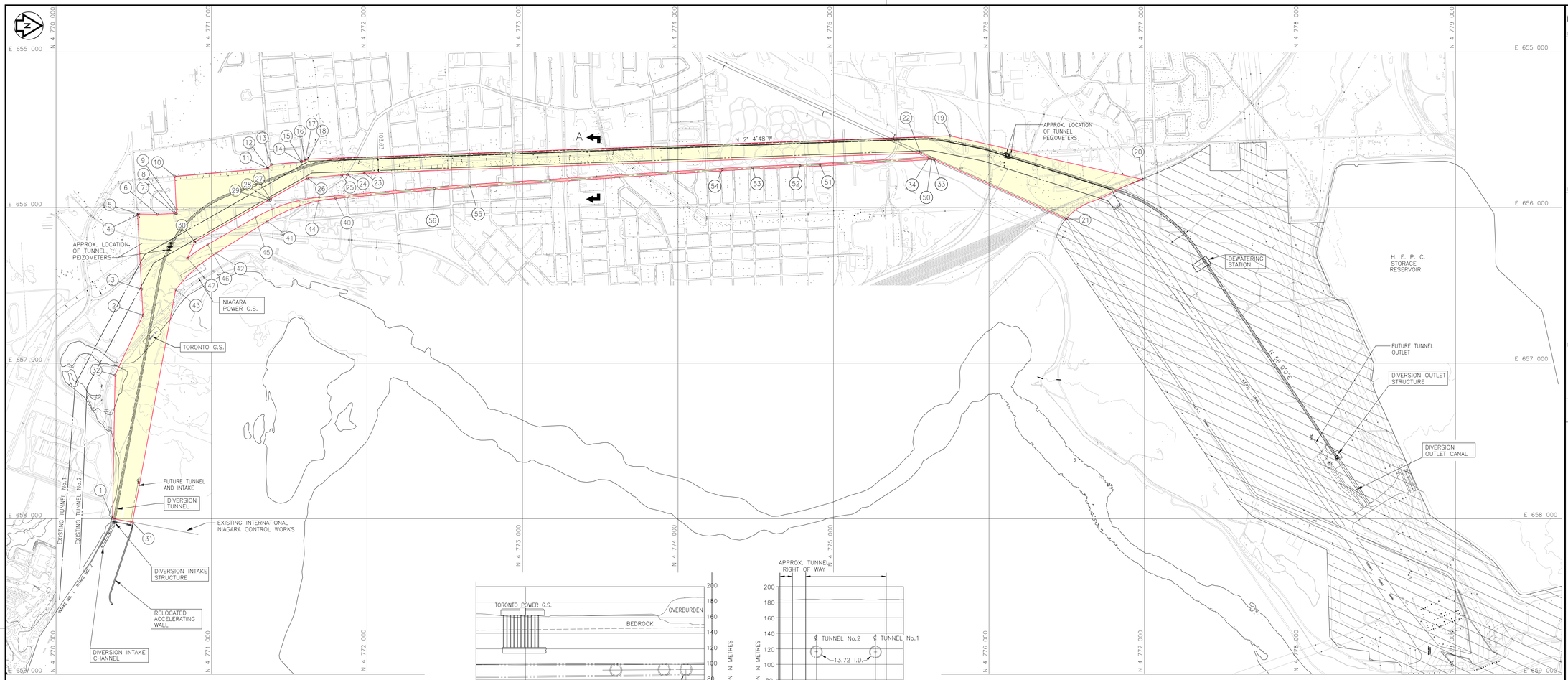
2. REFERENCE DRAWINGS

These reference drawings are in MIL format. They can be attached to an AutoCAD 2000 drawing as an image.

Number	Title
NF28-297-F Rev 08/15/89	Sir Adam Beck PGS and Surrounding Area Site Plan including Domestic Water System
NF28-d-2159	Chippawa-Grass Island Submersible Gates System and Cross Frame
NF28-e-2700	Intake Excavation Plan
NF28-d-2737	Intake Area Downstream Gravity Wall Concrete Details
NF28-e-2925 Rev 07/05/56	Chippawa-Grass Island Pool Control Structure General Arrangement of Typical Pier and Rollway
NF28-d-6000 Rev 02/02/55	Chippawa-Grass Island Pool Control Structure Dewatering Equipment Rollway General Arrangement
NF28-d-6001 Rev 12/07/54	Chippawa-Grass Island Pool Control Structure Dewatering Equipment Rollway Unit Assembly
NF28-d-6050 Rev 06/13/56	Chippawa-Grass Island Pool Control Structure Excavation Plan
NF28-d-6060	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 1 of 7
NF28-d-6061	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 2 of 7

Number	Title
NF28-d-6062	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 3 of 7
NF28-d-6063	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 4 of 7
NF28-d-6064	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 5 of 7
NF28-d-6065	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 6 of 7
NF28-d-6066	Chippawa-Grass Island Pool Control Structure Pier No. 1 Concrete Details Sheet 7 of 7
NF28-d-6070 Rev 12/07/77	Chippawa-Grass Island Pool Control Structure Piers 2 to 14 Concrete Details Sheet 1 of 7
NF28-d-6074 Rev 07/06/56	Chippawa-Grass Island Pool Control Structure Piers 2 to 14 Concrete Details Sheet 5 of 7
NF28-d-6076 Rev 07/06/56	Chippawa-Grass Island Pool Control Structure Piers 2 to 14 Concrete Details Sheet 7 of 7

Number	Title
NF28-d-6090 Rev 11/26/54	Chippawa-Grass Island Pool Control Structure Dewatering Equipment Rollway Generator Assembly - Emergency Gate
NF28-d-6100 Rev 02/09/55	Chippawa-Grass Island Pool Control Structure Piers 2 to 14 Construction Joints Sheet 1 of 4
NF28-e-6269 Rev 4	Upstream Accelerating and Downstream Training Walls and Weirs General Arrangement
NF28-f-6275 Rev D	Upstream Accelerating Wall Location &Typical Section Details
NF28-f-6276 Rev D	Upstream Accelerating Wall Typical Sections and Details
NF28-d-3397	Pumped Storage Canal Dewatering Structure Reinforcing Details
NF28-d-3399	Pumped Storage Canal Dewatering Structure Reinforcing Details
6-B-214	Niagara River Critical Navigation Depths In Grass Island Pool



PLAN
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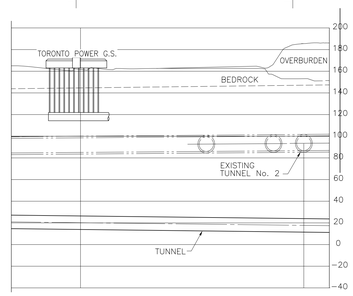
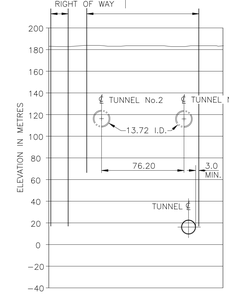


PART PROFILE OF TUNNEL
SCALE HORT. 1 : 5000
VERT. 1 : 2000



SECTION A–A
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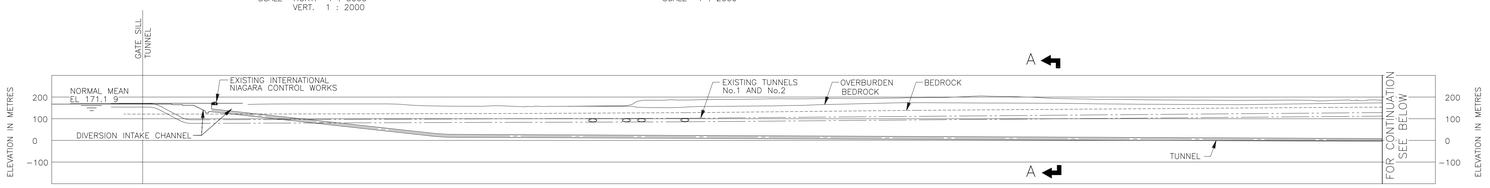
RIGHT OF WAY COORDINATES		
I.D.	NORTHING	EASTING
1	4 770 363.690	657 999.253
2	4770559.050	656690.594
3	4 770 550.220	656 524.318
4	4 770 524.949	656 048.417
5	4 770 531.580	656 041.525
6	4 770 651.610	656 043.288
7	4 770 767.697	656 038.345
8	4 770 773.964	656 037.715
9	4 770 772.599	656 007.251
10	4 770 763.830	655 799.809
11	4 771 362.802	655 747.552
12	4 771 362.616	655 745.608
13	4 771 384.944	655 722.652
14	4 771 578.573	655 705.850
15	4 771 578.177	655 701.505
16	4 771 600.752	655 699.446
17	4 771 602.306	655 698.564
18	4 771 620.013	655 688.510
19	4 775 749.616	655 538.521
20	4 776 988.567	655 819.333
21	4 776 496.540	656 073.982
22	4 775 559.060	655 649.129
23	4 771 982.267	655 779.039
24	4 771 874.377	655 788.473
25	4 771 838.638	655 790.317
26	4 771 617.107	655 809.320
27	4 771 378.366	655 944.881
28	4 771 378.999	655 951.583
29	4 771 364.346	655 952.842
30	4 770 892.356	656 221.003
31	4 770 491.122	658 022.827
32	4 770 379.732	657 077.152
33	4 775 648.845	655 689.818
34	4 775 617.491	655 675.609

RIGHT OF WAY COORDINATES AT TANGENTS			
I.D.	NORTHING	EASTING	RADIUS
40	4 771 796.850	655 941.748	
			992
41	4 771 359.304	656 087.836	
			NONE
42	4 771 028.209	656 293.986	
			992
43	4 770 769.473	656 527.153	
			–
44	4 771 692.827	655 934.821	
			1008
45	4 771 282.384	656 062.919	
			NONE
46	4 770 974.393	656 238.220	
			1008
47	4 770 845.254	656 325.599	

RIGHT OF WAY CENTRELINE COORDINATES		
I.D.	NORTHING	EASTING
50	4 775 633.168	655 682.713
51	4 774 912.982	655 724.463
52	4 774 784.272	655 731.093
53	4 774 480.243	655 744.789
54	4 774 285.370	655 755.474
55	4 772 663.264	655 860.303
56	4 772 433.402	655 877.820

NOTE:
RIGHT OF WAY IS 8 METRES TO EITHER SIDE OF CENTRELINE



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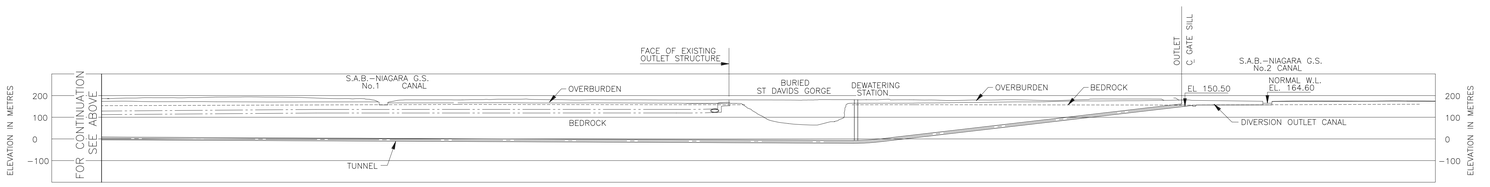

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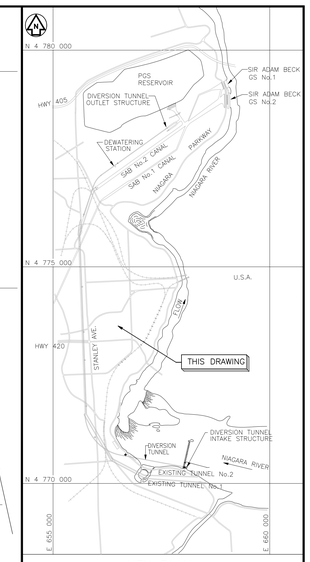

KEY PLAN
SCALE 1 : 50000

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS IN METRES UNLESS OTHERWISE NOTED. ELEVATIONS ARE BASED ON NAD83 SYSTEM.
3. THE GRID CO–ORDINATE SYSTEM IS BASED ON NAD83 SYSTEM. SURVEY BASED ON SECOND AND THIRD ORDER CONTROL.
4. ARRANGEMENT SHOWN AND ALL OTHER DIMENSIONS, ELEVATIONS AND SLOPES ARE FOR REFERENCE ONLY, OR TO CONVEY THE CONCEPT OF THE WORK.
5. CONCEPT ARRANGEMENT AND DIMENSIONS ARE SHOWN FOR A D=12650mm (NOMINAL) INSIDE DIAMETER TUNNEL.
6. ALL DIMENSIONS, ELEVATIONS AND SLOPES INDICATED WITH * SHALL BE MAINTAINED.
7. ALL DIMENSIONS AND ELEVATIONS INDICATED WITH ** SHALL BE ADJUSTED, BASED ON THE FINAL TUNNEL INSIDE DIAMETER (D).
8. SHOWING CONCEPT TUNNEL ALIGNMENT

LEGEND:

EXISTING STRUCTURES

APPROX. TUNNEL RIGHT OF WAY

APPROX. LIMITS OPG LAND AT OUTLET AREA

CONCEPT DRAWING

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	08	MAY 14 2009	REVISED RIGHT OF WAY – TO ACCOMMODATE HORIZONTAL REALIGNMENT OF TUNNEL			
	07	SEP 08 2008	REVISED RIGHT OF WAY – ISSUED FOR PCD 031			
	06	AUG 27 2007	ISSUED FOR AGREEMENT AMENDMENT 3			
	05	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT			
	04	APR 14 2005	ISSUED FOR AMENDMENT 4			
	03	MAR 18 2005	ISSUED FOR AMENDMENT 3			
	02	MAR 7 2005	ISSUED FOR AMENDMENT 2			
	01	DEC 17 2004	ISSUED FOR PROPOSAL			
	00	NOV 17 2004	ISSUED FOR REVIEW			

NIAGARA TUNNEL FACILITY PROJECT

DIVERSION TUNNEL
GENERAL ARRANGEMENT

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

dsn	designed by		cost use
chkd			
date yr/month/day 04/11/02	design approved		plot scale 1:1 M
			dist. code
scale 1:10000	authorized		CAD file type DWG

dwg no NAW130–D0E–29230–0015 | ver 08

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0 10 50 100 200 250 300 millimetres

A0 (841 x 1189)

standard drawing number
NAW130–D0E–29230–0015

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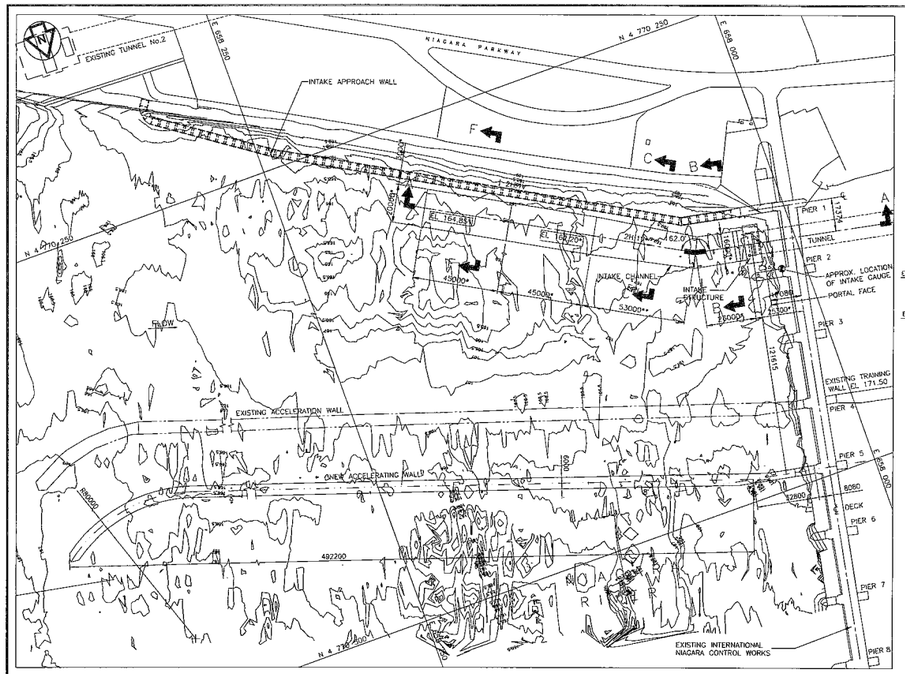

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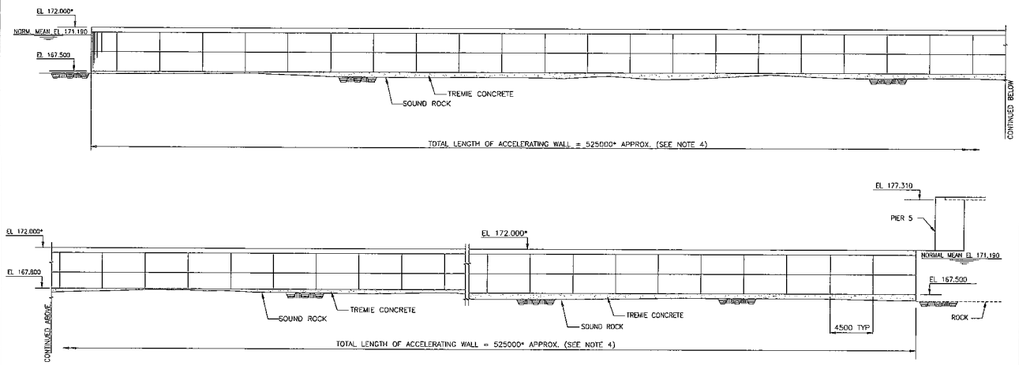
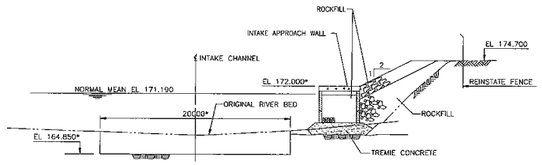


ELEVATION OF ACCELERATING WALL
SCALE 1:200



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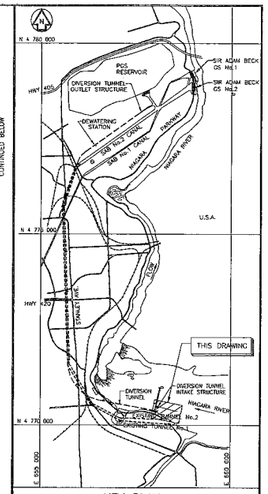
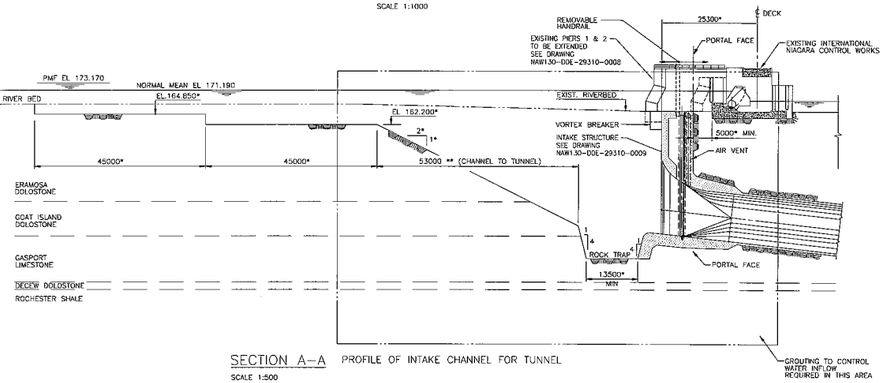


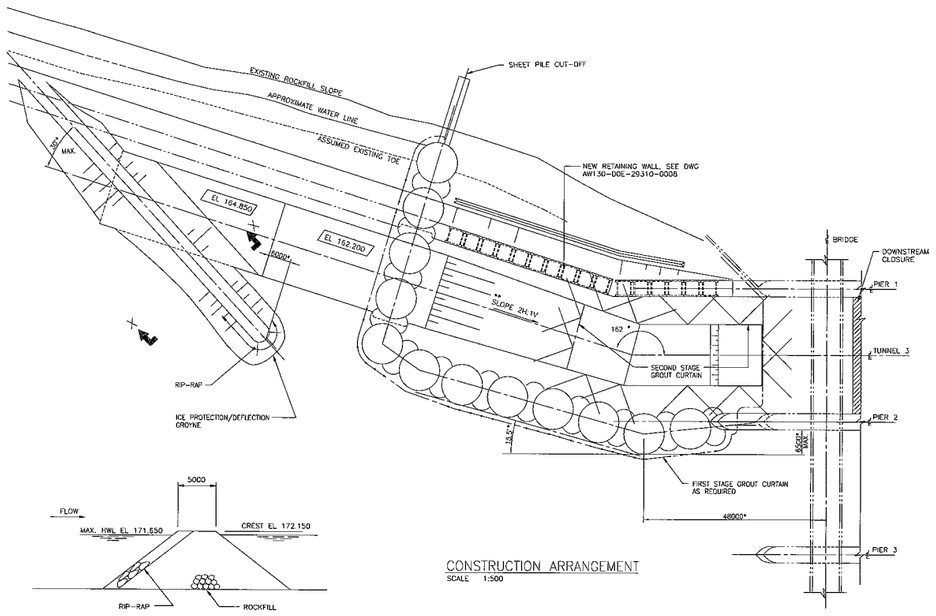
KEY PLAN
SCALE 1 : 50000

NOTES:

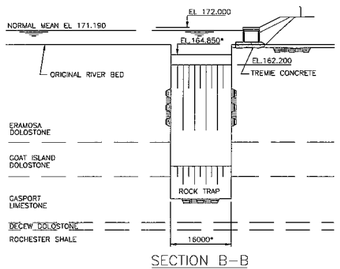
1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-D0E-29230-0015
3. EXISTING OVERBURDEN, BOULDERS, DEBRIS AND GLACIAL TILL TO BE REMOVED TO SOUND ROCK PRIOR TO PLACING TREMIE CONCRETE BASE BENEATH ACCERATING AND APPROACH WALLS.
4. TRAVEL RESTRAINT TO BE INSTALLED FULL LENGTH OF ACCELERATING WALL.



SECTION A–A PROFILE OF INTAKE CHANNEL FOR TUNNEL
SCALE 1:500



CONSTRUCTION ARRANGEMENT
SCALE 1:500



SECTION B–B
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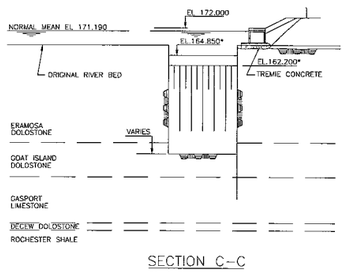

SECTION C–C
SCALE 1:500

SECTION X–X
SCALE 1:250

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CONCEPT DRAWING

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	09	AUG 21 2007	ISSUED FOR AGREEMENT AMENDMENT 3			
	08	JAN 24 2006	ISSUED FOR PCD NO. 005			
	07	DEC 14 2005	ISSUED FOR PCD NO. 003			
	06	NOV 25 2005	ISSUED FOR INFORMATION FOR LAYOUT OF ICE ACCELERATING WALL			
	05	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT			
	04	APR 14 2005	ISSUED FOR AMENDMENT 4			
	03	MAR 18 2005	ISSUED FOR AMENDMENT 3			
	02	MAR 7 2005	ISSUED FOR AMENDMENT 2			
	01	DEC 17 2004	ISSUED FOR PROPOSAL			
	00	NOV 17 2004	ISSUED FOR REVIEW			

NIAGARA TUNNEL FACILITY PROJECT
INTAKE WORKS
INTAKE CHANNEL AND ACCELERATING WALL ARRANGEMENT AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

dwn	designed by		
chkd			
date yr/month/day 04/11/02	design approved		plot scale 1:1 M
scale AS SHOWN	authorized		CAD file type DWG

dwg no NAW130-D0E-29310-0007 ver 10

AO (841 x 1189)

standard drawing number
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Aug 30, 2007 2:57pm
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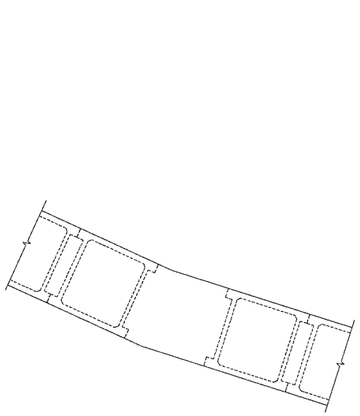

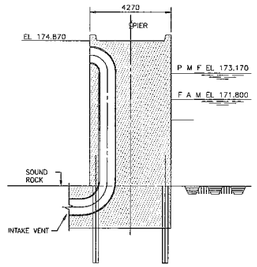

SECTION J–J
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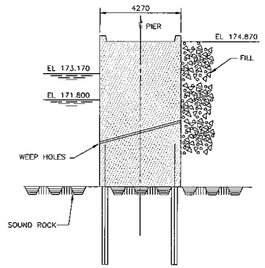

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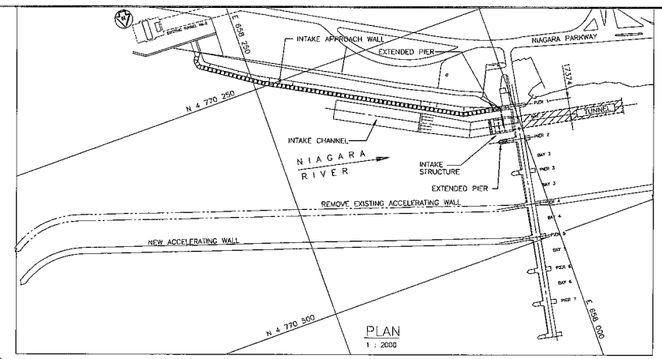

PLAN
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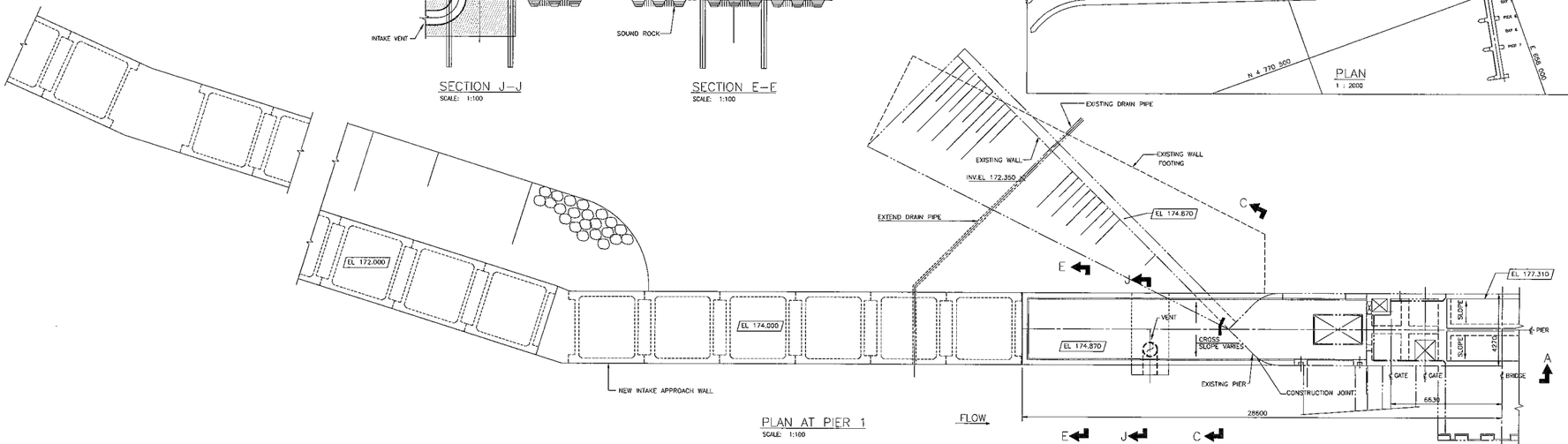

PLAN AT PIER 1
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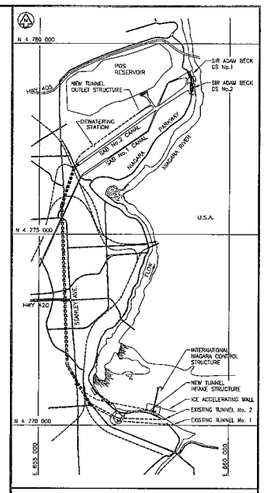
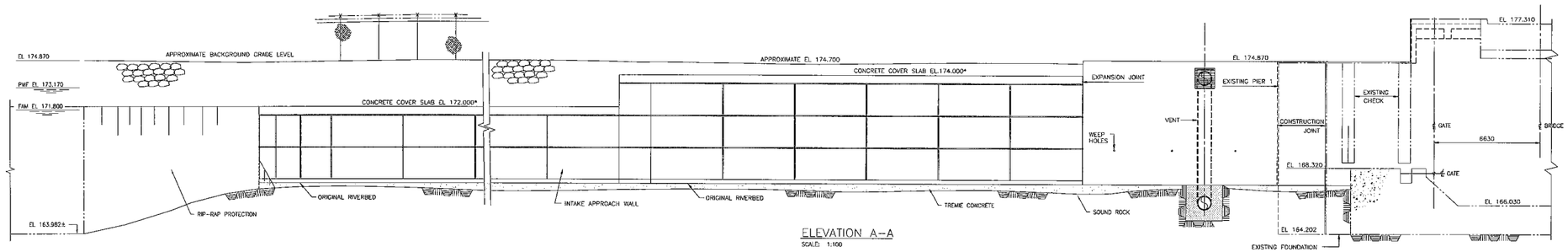


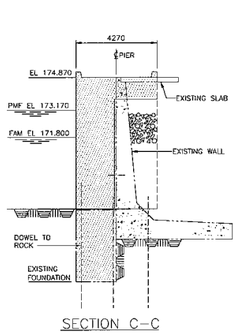
KEY PLAN
SCALE 1 : 50000

NOTES:

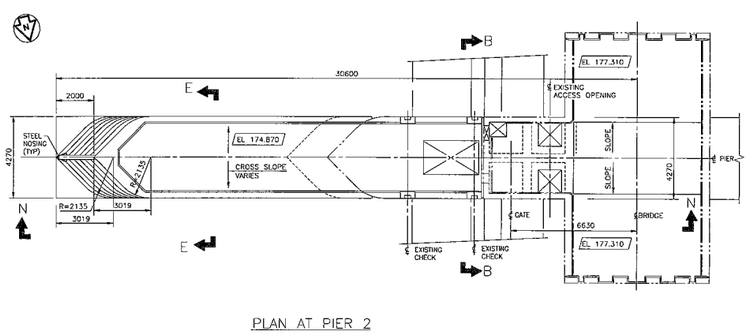
1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-DOE-29230-0015
3. EXISTING OVERBURDEN, BOULDERS, DEBRIS AND GLACIAL TILL TO BE REMOVED TO SOUND ROCK PRIOR TO PLACING TREMIE CONCRETE BASE BENEATH ACCELERATING AND APPROACH WALLS.



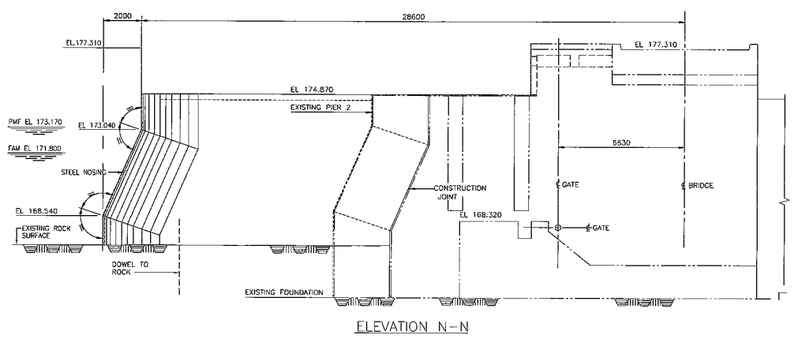
ELEVATION A–A
SCALE: 1:100



SECTION C–C
SCALE: 1:100



PLAN AT PIER 2
SCALE: 1:100



ELEVATION N–N
SCALE: 1:100

1:100 0 2 4 6 8 10 m
1:2000 0 40 80 120 160 200 m

CONCEPT DRAWING

mf roll number	ver no	date	particulars	can	dpd
	05	AUG 21 2007	ISSUED FOR AGREEMENT AMENDMENT 4		
	04	AUG 21 2007	ISSUED FOR AGREEMENT AMENDMENT 3		
	03	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	02	MAR 7 2005	ISSUED FOR AMENDMENT 2		
	01	DEC 17 2004	ISSUED FOR PROPOSAL		
	00	NOV 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
INTAKE WORKS
MODIFICATIONS TO INCW
CONTROL STRUCTURE

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

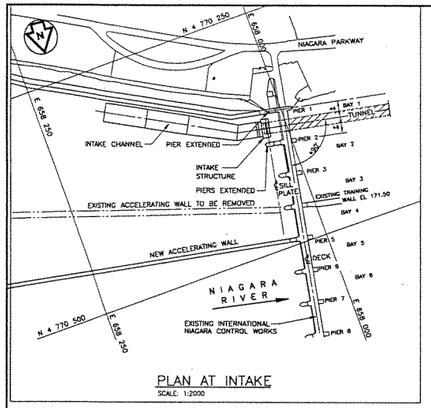
Hatch Mott MacDonald–Acres

drawn	designed by		
chkd			
date yr/month/day 04/11/02	design approved	plot scale 1:1M	
		dwg. code	
scale AS SHOWN	authorized	CAD file type DWG	
dwg no NAW130-D0E-29310-0008			ver 05

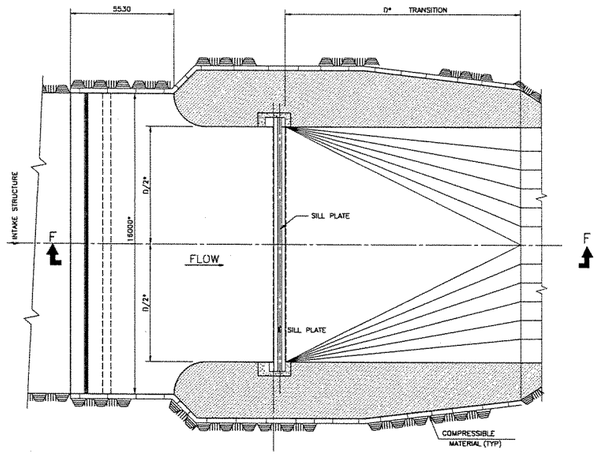
A0 (841 x 1189)
standard drawing number NAW130-D0E-29310-0008

0 10 50 100 200 250 300 millimetres

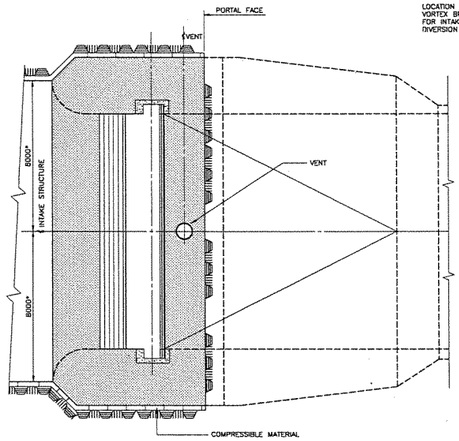
Aug 30, 2007 - 2:42pm
Drawing name: e:\Drawings\Final\NAW130-D0E-29310-0008.dgn
taylor wood: Plot0000



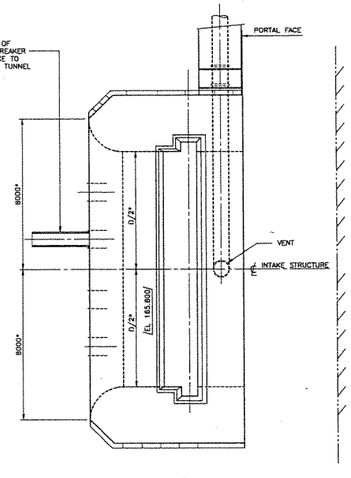
PLAN AT INTAKE
SCALE: 1:2000



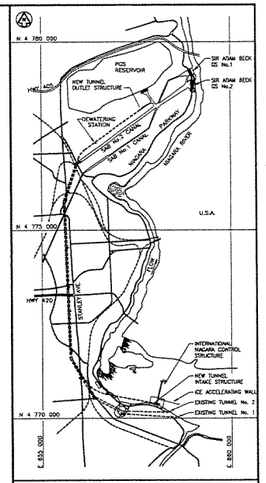
PLAN C–C
SCALE: 1:100



PLAN B–B
SCALE: 1:100



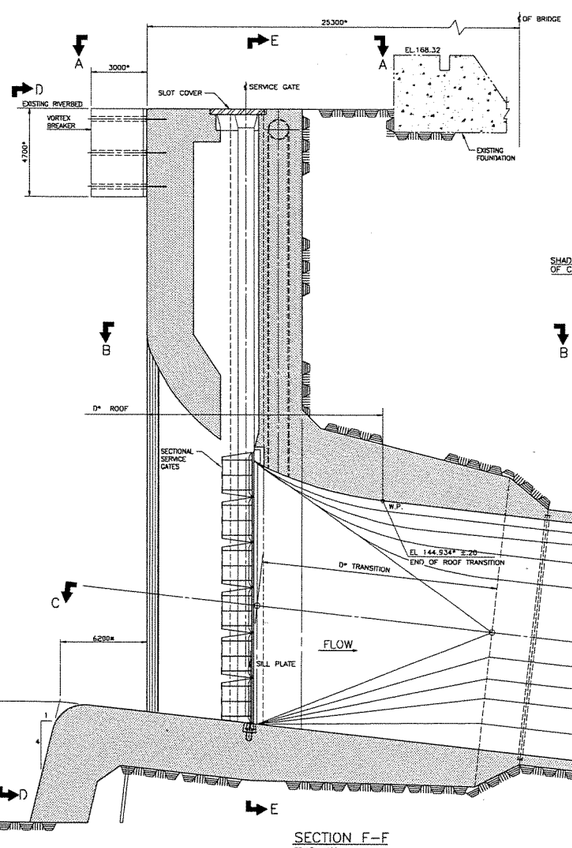
PLAN A–A
SCALE: 1:100



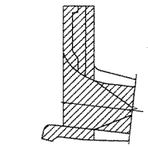
KEY PLAN
SCALE 1 : 50000

NOTES:

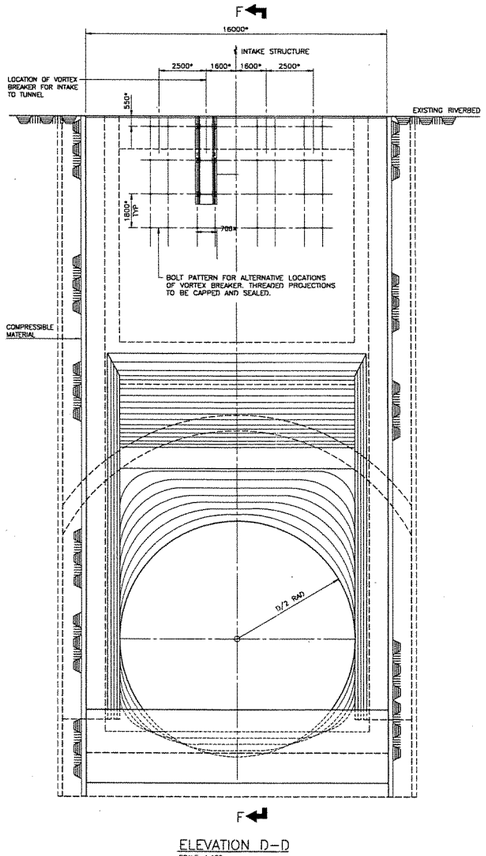
1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-D0E-29230-0015



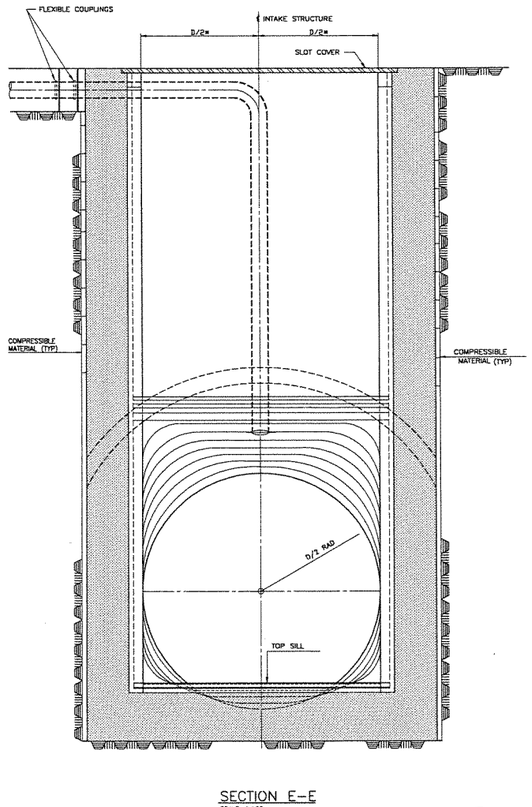
SECTION F–F
SCALE: 1:100



SHADED AREA INDICATES MINIMUM EXTENT OF COMPRESSIBLE MATERIAL



ELEVATION D–D
SCALE: 1:100



SECTION E–E
SCALE: 1:100

1:100 0 2 4 6 8 10 m
1:2000 0 40 80 120 160 200 m

CONCEPT DRAWING

mf roll number	ver no	date	particulars	drwn / chkd	appd
	04	AUG 04 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	03	APR 14 2005	ISSUED FOR AMENDMENT 4		
	02	MAR 2005	ISSUED FOR AMENDMENT 2		
	01	DEC 17 2004	ISSUED FOR PROPOSAL		
	00	NOV 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
INTAKE WORKS
INTAKE STRUCTURE
ARRANGEMENT AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

drwn	designed by	mf roll no	
chkd			
date yr/month/day 04/11/05	design approved	print scale 1:1M	
		electronic code	
scale AS SHOWN	authorized	CAD file type DWG	
dwg no NAW130-D0E-29310-0009			rev 04

AO (841 x 1189) standard drawing number NAW130-D0E-29310-0009

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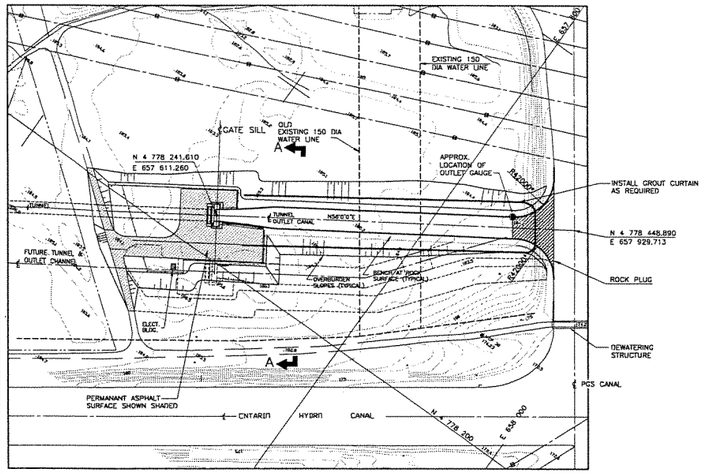
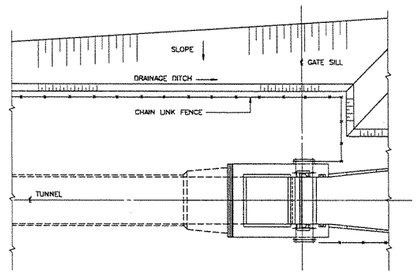
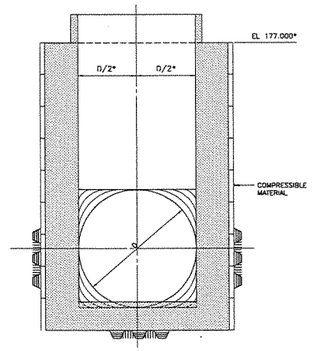


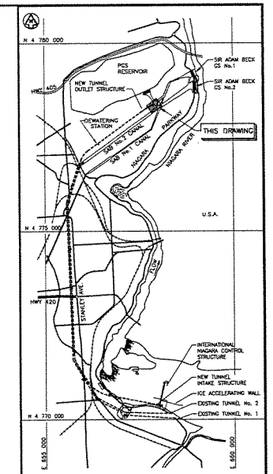
OUTLET PLAN
SCALE 1:2000



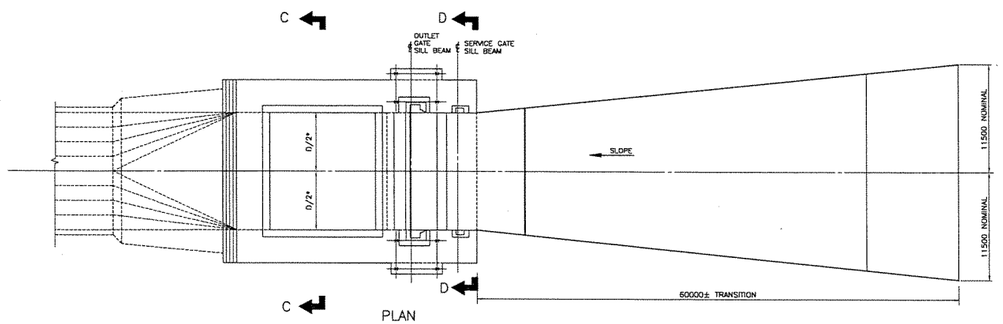
PLAN OF OUTLET STRUCTURE TO TUNNEL
SCALE 1:500



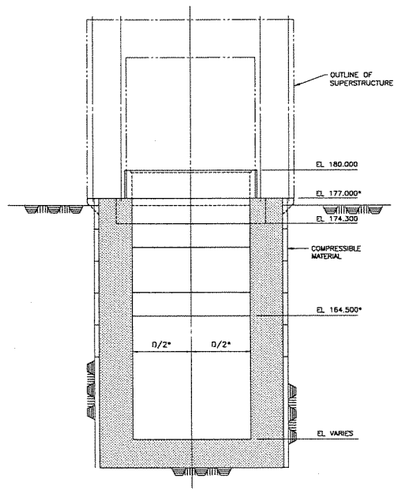
SECTION C–C
SCALE 1:200



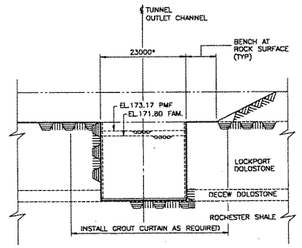
KEY PLAN
SCALE 1 : 50000



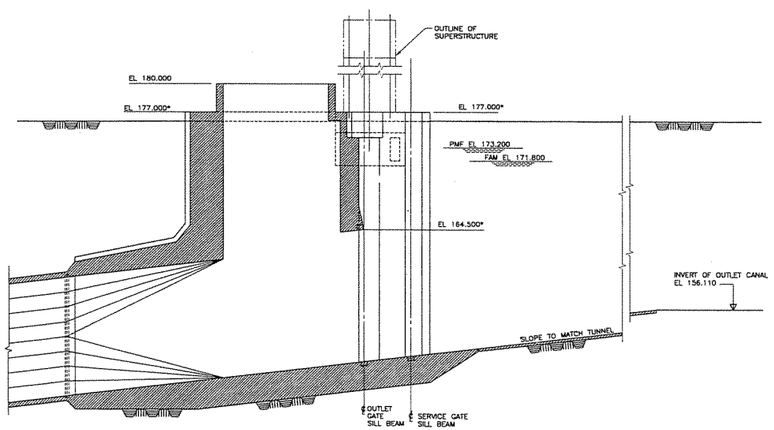
PLAN
SCALE 1:200



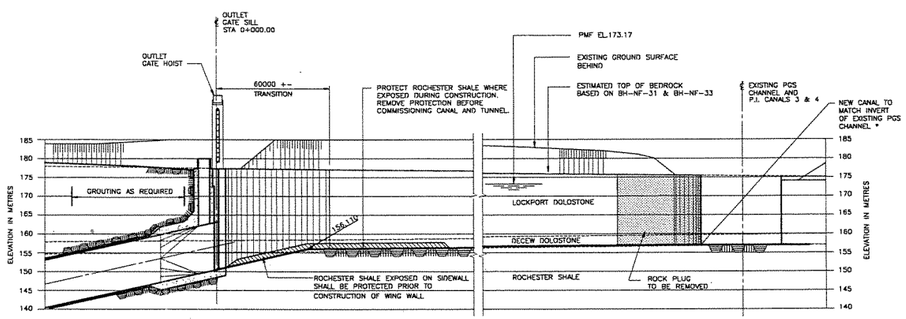
ELEVATION D–D
SCALE 1:200



SECTION A–A
SCALE 1:500



LONGITUDINAL SECTION
SCALE 1:200



PROFILE ALONG CENTRE LINE OF CANAL FROM DIVERSION TUNNEL
HORIZONTAL SCALE 1:1000
VERTICAL SCALE 1:500

1:200	0	4	8	12	16	20	m
1:500	0	10	20	30	40	50	m
1:1000	0	20	40	60	80	100	
1:2000	0	40	80	120	160	200	

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-D0E-29230-0015

rvl no/ number	ver no	date	particulars	dwn/ chkd	appd
	02	AUG 05 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	01	DEC 17 2004	ISSUED FOR PROPOSAL		
	00	NOV 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
OUTLET WORKS
OUTLET STRUCTURE AND CANAL ARRANGEMENT, PLAN AND SECTIONS

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

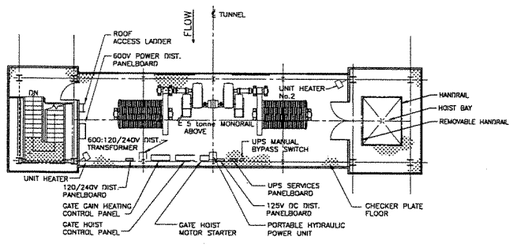
Hatch Mott MacDonald–Acres

drwn	designed by	rvl no	
chkd		ver no	
date yr/month/day	design approved	plot scale	1:1M
04/11/05		del. code	
scale	authorized	CAD file type	
AS SHOWN		DWG	
dwg no	NAW130-D0E-29710-0023	ver	02

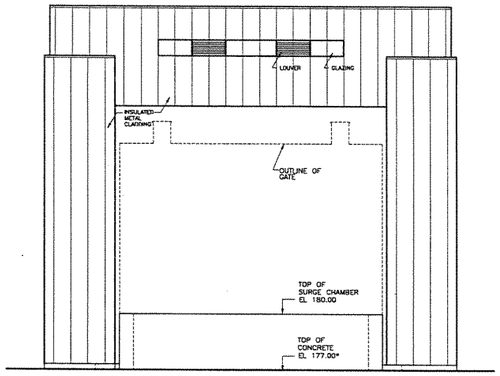
A0 (841 x 1189)

standard drawing number
NAW130-D0E-29270-0001

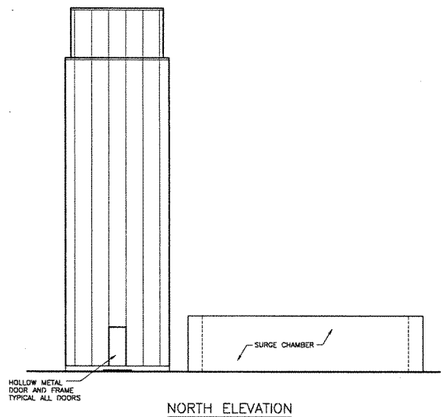
0 10 50 100 200 250 300 millimetres



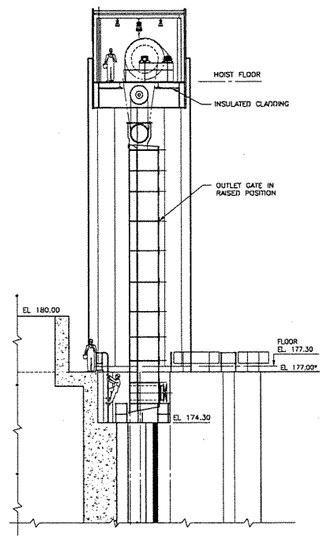
PLAN AT HOIST FLOOR
SCALE 1:100



WEST ELEVATION
SCALE 1:100



NORTH ELEVATION
SCALE 1:100

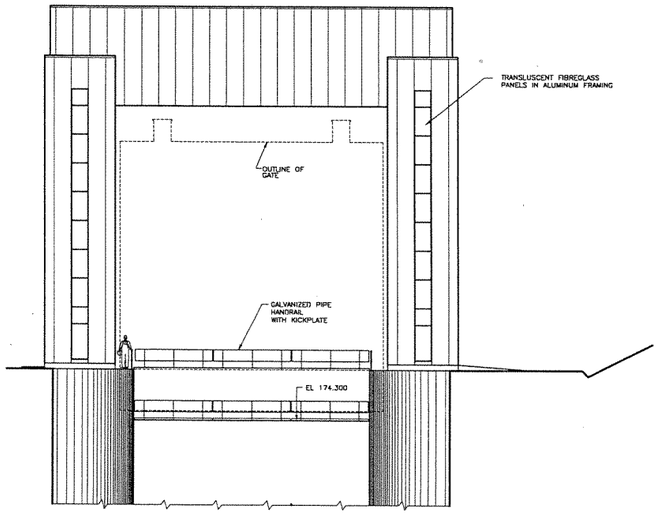


SECTION A–A
SCALE 1:100

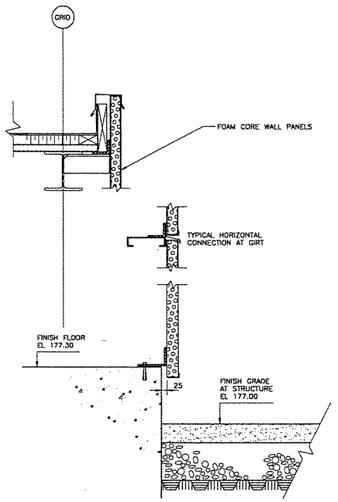
NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-DOE-29230-0015

PLAN AT FLOOR EL 177.30
SCALE 1:100



EAST ELEVATION
SCALE 1:100



TYPICAL WALL SECTION
SCALE 1:10

1:10 1:100 0 200 400 600 800 1000 mm; 0 2 4 6 8 10 m

CONCEPT DRAWING

	02	AUG 04 2005	ISSUED FOR INCLUSION IN AGREEMENT	
	01	DEC 17 2004	ISSUED FOR PROPOSAL	
	00	NOV 17 2004	ISSUED FOR REVIEW	
ref / rod number	rev no	date	particulars	dmn / chkd / code

NIAGARA TUNNEL FACILITY PROJECT
OUTLET WORKS
CLOSURE GATE HOIST STRUCTURE
ARCHITECTURAL ARRANGEMENT

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

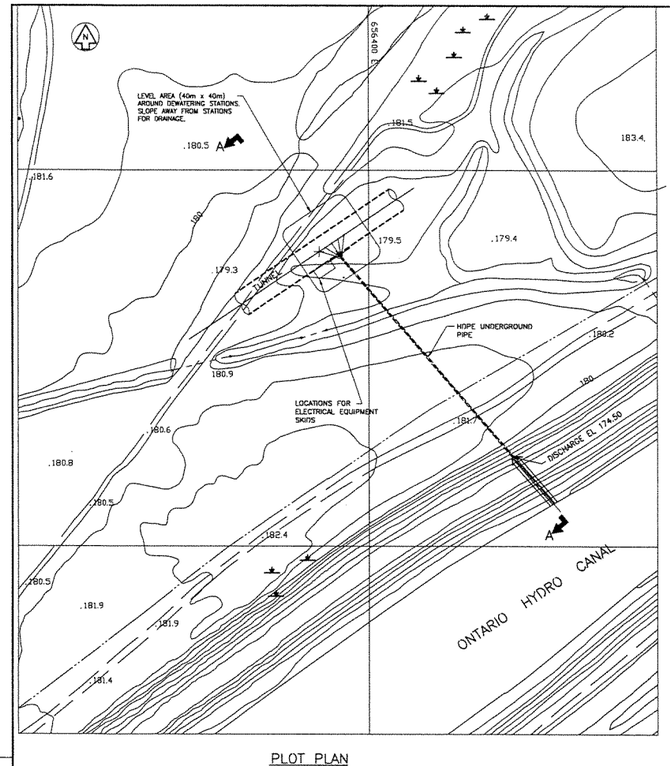
Hatch Mott MacDonald–Acres

dwn	designed by		cur stat
chkd			
date yr/month/day 04/11/02	design approved		print scale 1:1M
scale AS SHOWN	authorized		dist. code
		CAD file type DWG	
dwg no NAW130-DOE-29710-0024			ver 02

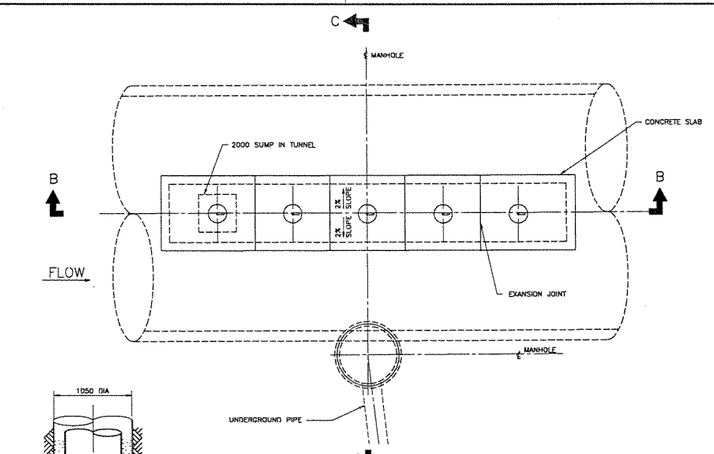
A0 (841 x 1189) standard drawing number NAW130-DOE-29710-0024

0 10 50 100 200 250 300 millimetres

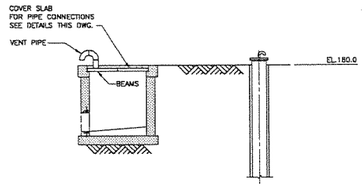
Plotted by: Ed Lee on 2005-11-03 at 1:08pm
Logo was Post-2003
Drawing Name: C:\Projects\NAW130\Drawings\Outlet Works\Closure Gate Hoist Structure\NAW130-DOE-29710-0024.dwg



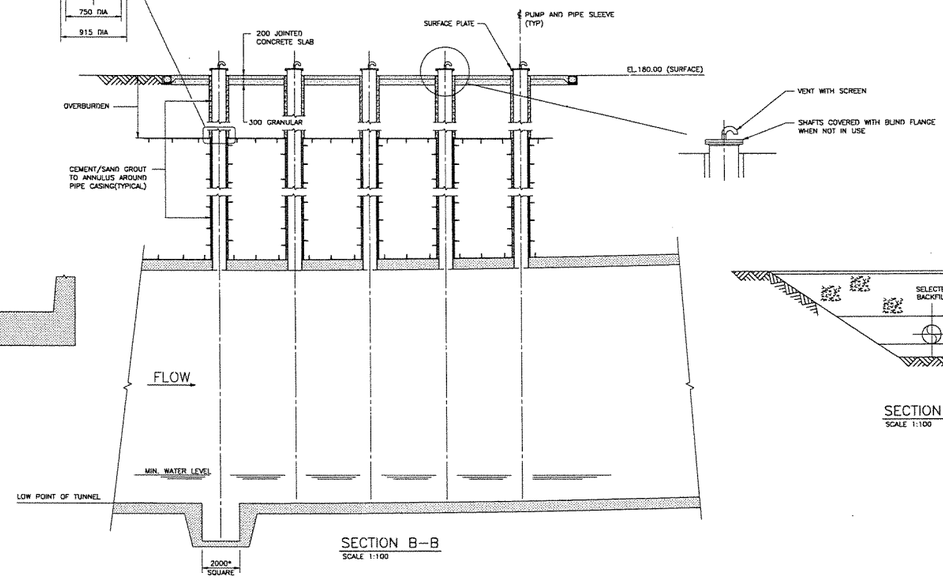
PLOT PLAN
SCALE 1:1000



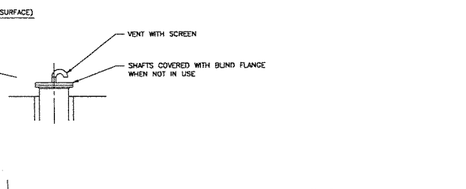
SURFACE PLAN
SCALE 1:100

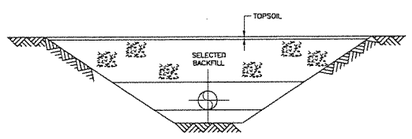


SECTION C–C
SCALE 1:100

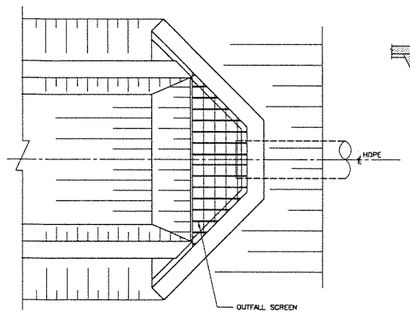


SECTION B–B
SCALE 1:100

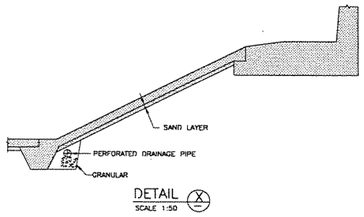




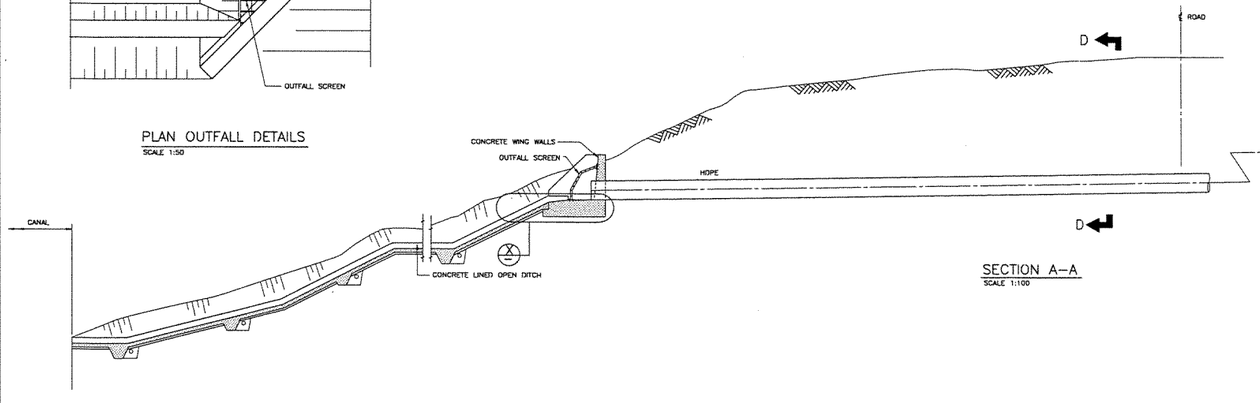
SECTION D–D
SCALE 1:100



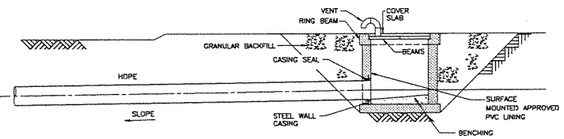
PLAN OUTFALL DETAILS
SCALE 1:50



DETAIL X
SCALE 1:50



SECTION A–A
SCALE 1:100



1:50 0 1 2 3 4 5 m
1:100 0 2 4 6 8 10 m
1:1000 0 20 40 60 80 100 m

0 10 50 100 200 250 300 millimetres

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-00E-29230-0015
3. INSTALL CONDUIT ON OUTSIDE OF CASING FOR CABLING FROM INSTRUMENTATION THAT IS TO BE INSTALLED IN TUNNEL LINER.
4. SUPPLY AND INSTALLATION OF PUMPS AND DISCHARGE PIPES, BY OTHERS.

CONCEPT DRAWING

mf / cd number	ver no	date	particulars	prep'd	appd
	02	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	01	DEC. 17 2004	ISSUED FOR PROPOSAL		
	00	NOV 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
DIVERSION TUNNEL
DEWATERING STATION
ARRANGEMENT, PLAN, SECTIONS AND DETAILS

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

dwn	designed by		
chkd			
date yr/month/day 04/11/02	design approved		plot scale 1:1 M
scale AS SHOWN	authorized		CAD file type DWG

dwg no NAW130–D0E–29270–0001 ver 02

A0 (841 x 1189) standard drawing number NAW130–D0E–29270–0001

Aug 03, 2005 - 1:33pm - Login name: Pohl (ATL)
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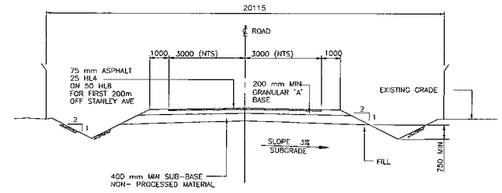
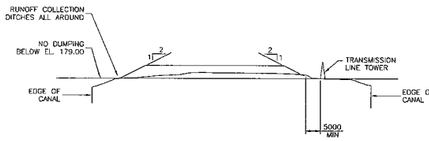


TYPICAL CONSTRUCTION ROAD SECTION

SCALE 1 : 100



SECTION A–A

SCALE 1 : 2000

IB COORDINATES

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2	N:4777395.661 E:655617.602
3	N:4777226.499 E:655715.462
6	N:4777220.957 E:655762.082
7	N:4777166.795 E:655796.943
8	N:4777172.383 E:655924.678
9	N:4777219.925 E:655922.328
10	N:4777221.076 E:655845.609
11	N:4777301.358 E:655949.340
12	N:4777357.918 E:656082.588
13	N:4777283.194 E:656152.017
14	N:4777232.132 E:656199.461
15	N:4777775.316 E:656258.408
16	N:4777648.788 E:655966.979
17	N:4777647.554 E:655941.232
18	N:4777630.568 E:655586.705
19	N:4777597.328 E:655588.251
20	N:4777608.129 E:655837.760
21	N:4777486.365 E:655843.617
22	N:4777758.284 E:656219.150

BOREHOLE COORDINATES		
I.D.	NORTHING	EASTING
SD6	4 777 177.33	656 221.05
SD7	4 777 255.15	656 236.26
SD8	4 777 277.17	656 153.06
SD9	4 777 235.48	656 201.38
NF30	4 777 365.49	656 351.89
GB1	4 777 231.74	656 118.74
GB2	4 777 345.82	656 187.43
GB3	4 777 350.25	656 238.17

CONCEPT DRAWING

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-DOE-2923G-0015
3. FENCE TO BE GROUNDED UNDERNEATH TRANSMISSION LINES.
4. THE OUTLET AREA SITE INCLUDES THE AREA DELINEATED BY "AREA AVAILABLE FOR CONTRACTOR", THE "ON SITE DISPOSAL AREA" AND THE "SITE MAIN ACCESS ROAD".
5. EXISTING OPG FENCES THAT ACT AS BOUNDARIES TO THE AREA AVAILBLE TO THE CONTRACTOR, SHALL BE UNDER THE CONTROL OF THE CONTRACTOR.
6. DIMENSIONS SHOWN IN MILLIMETRES AND ELEVATIONS SHOWN IN METERS.

LEGEND:

GPS SURVEY

AREA AVAILABLE FOR CONTRACTORS

PROTECTED AREA

DISPOSAL AREA

18" IRON BAR (IB) AND MARKER STAKE

BOREHOLE

1:100 0 2 4 6 8 10 m
1:200 0 4 8 12 16 20 m
1:2000 0 40 80 120 160 200 m

mf rpt number	ver no	date	particulars	dwn	chkd
	07	AUG 11 2006	ISSUED FOR AGREEMENT AMENDMENT 4		
	06	AUG 25 2005	FENCE MODIFICATIONS		
	05	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	04	APR 14 2005	ISSUED FOR AMENDMENT 4		
	03	MAR 16 2005	ISSUED FOR AMENDMENT 3		
	02	MAY 7 2005	ISSUED FOR AMENDMENT 2		
	01	DEC 17 2004	ISSUED FOR PROPOSAL		
	00	NOV 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
CONSTRUCTION FACILITIES
OUTLET AREA
WEST PLAN

ONTARIO POWER GENERATION

Hatch Mott MacDonald–Acres

dwn	designed by		
chkd			
date yr/month/day 05/09/05	design approved	plot scale 1:1 M	
scale 1:2000	authorized	CAD file type DWG	

dwg no NAW130-DOE-80000-0012 ver 07

AO (841 x 1189)

standard drawing number NAW130-DOE-80000-0012

Aug 29, 2007 9:50am
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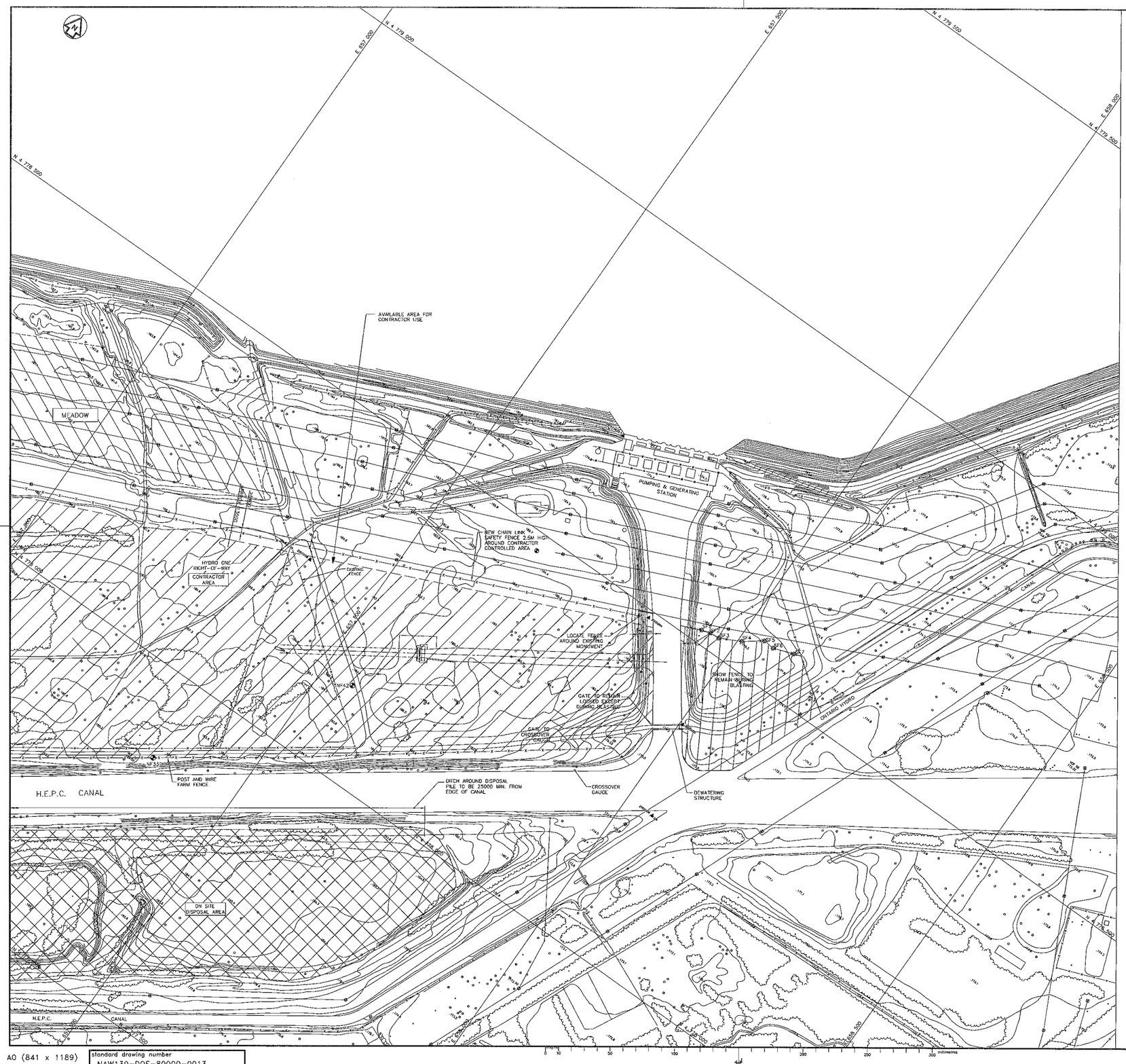

SNOW FENCE COORDINATES		
I.D.	NORTHING	EASTING
SF1	4 778 519.818	657 945.226
SF2	4 778 138.479	657 959.046
SF3	4 778 525.675	657 973.642
SF4	4 778 542.024	658 005.618
SF5	4 778 562.967	658 034.158
SF6	4 778 551.026	658 051.828
SF7	4 778 573.107	658 083.346

BOREHOLE COORDINATES		
I.D.	NORTHING	EASTING
NF33	4 777 869.840	657 362.530
NF42	4 778 138.479	657 551.309

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-DOE-29230-0015
3. FENCE TO BE GROUNDED UNDERNEATH TRANSMISSION LINES.
4. THE OUTLET AREA SITE INCLUDES THE AREA DELINEATED BY "AREA AVAILABLE FOR CONTRACTOR", THE "ON SITE DISPOSAL AREA" AND THE "SITE MAIN ACCESS ROAD"
5. EXISTING OPG FENCES THAT ACT AS BOUNDARIES TO THE AREA AVAILABLE TO THE CONTRACTOR, SHALL BE UNDER THE CONTROL OF THE CONTRACTOR.
6. DIMENSIONS SHOWN IN MILLIMETRES AND ELEVATIONS SHOWN IN METERS.

LEGEND:

GPS SURVEY

AREA AVAILABLE FOR CONTRACTOR

AREA AVAILABLE TO CONTRACTOR TO DELINEATE AND CONTROL SAFE DISTANCE DURING BLASTING

PROTECTED AREA

DISPOSAL AREA

CONTROL MONUMENT

BOREHOLE

SNOW FENCE COORDINATE

CONCEPT DRAWING

0 50 100 150 200 m
SCALE 1:2000

mf no/ number	rev no	date	particulars	des'd	appd
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	06	JAN. 25 2006	ISSUED FOR FCD NO. 006		
	05	AUG. 31 2005	FENCE MODIFICATIONS		
	04	AUG. 03 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	03	MAR. 18 2005	ISSUED FOR ADDENDUM 3		
	02	MAR. 7 2005	ISSUED FOR ADDENDUM 2		
	01	DEC. 17 2004	ISSUED FOR PROPOSAL		
	00	NOV. 17 2004	ISSUED FOR REVIEW		

NIAGARA TUNNEL FACILITY PROJECT
CONSTRUCTION FACILITIES
OUTLET AREA
EAST PLAN

ONTARIO POWER GENERATION

Hatch Mott MacDonald-Acres

drawn	designed by		
checked			
date yr/month/day 04/11/05	design approved	plot scale 1:1 M plot date	
scale 1:2000	authorised	DAG file type DWG	
dwg no NAW130-DOE-80000-0013			ver 07

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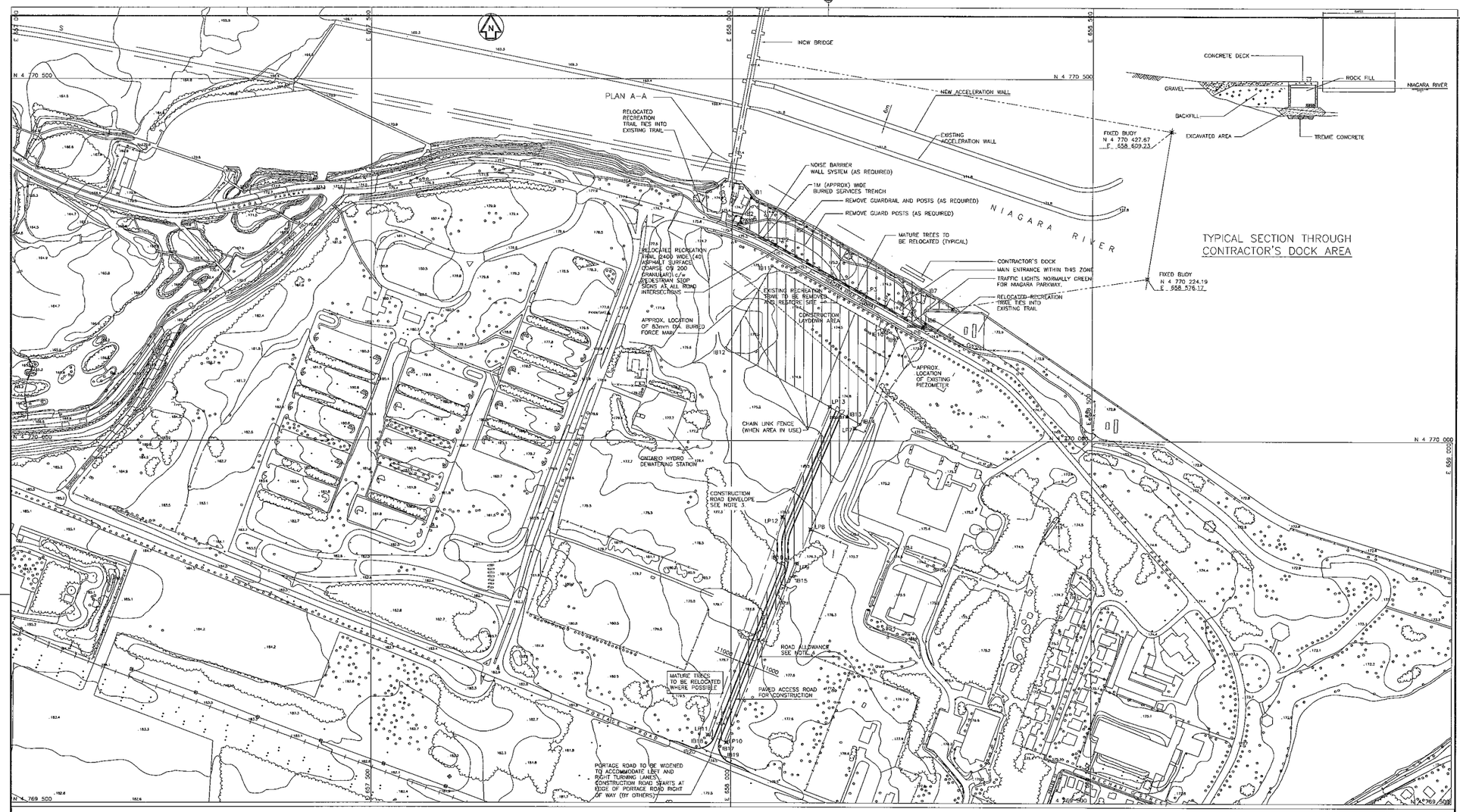
Layer name: Neg0529230

A0 (841 x 1189)

standard drawing number
NAW130-DOE-80000-0013



LAYOUT POINTS COORDINATES		
I.D.	NORTHING	EASTING
LP1	4 770 258.651	658 009.179
LP2	4 770 270.847	658 061.147
LP3	4 770 202.466	658 183.702
LP4	4 770 185.531	658 213.364
LP5	4 770 169.521	658 241.408
LP6	4 770 155.910	658 265.249
LP7	4 770 017.100	658 170.900
LP8	4 769 877.300	658 110.400
LP9	4 769 830.090	658 081.746
LP10	4 769 583.478	657 994.304
LP11	4 769 563.748	657 968.255
LP12	4 769 894.201	658 071.347
LP13	4 770 046.522	658 135.532

IRON BAR COORDINATES		
I.D.	NORTHING	EASTING
IB1	4 770 335.138	658 026.799
IB2	4 770 307.428	658 013.196
IB3	4 770 254.299	658 007.187
IB4	4 770 276.669	658 045.708
IB5	4 770 154.483	658 284.310
IB6	4 770 162.310	658 268.694
IB7	4 770 200.720	658 269.950
IB8	4 770 295.650	658 103.846
IB9	4 770 142.653	658 230.892
IB10	4 770 153.086	658 212.209
IB11	4 770 241.292	658 055.936
IB12	4 770 128.081	657 992.035
IB13	4 770 032.676	658 161.082
IB14	4 770 022.735	658 178.675
IB15	4 769 812.190	658 087.346
IB16	4 769 836.351	658 075.902
IB17	4 769 577.823	657 985.584
IB18	4 769 582.735	657 965.89
IB19	4 769 561.713	657 992.249
IB20	4 769 577.352	657 952.681

1:500 0 12.5 25 37.5 50 m
1:2000 0 50 100 150 200m

CONCEPT DRAWING

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS.
2. DURING CONSTRUCTION OF THE BURIED SERVICES TRENCH SOME IB'S MAY HAVE BEEN REMOVED.
3. ENVELOPE FOR ROAD LAYOUT.
4. FINAL ROAD ALLOWANCE USED FOR LEASING PURPOSES BY N.P.C. WILL BE BASED ON AN OFFSET FROM THE AS BUILT CENTER LINE OF ROAD.
5. INCORPORATES NAW130-SK-0009.

REFERENCE:

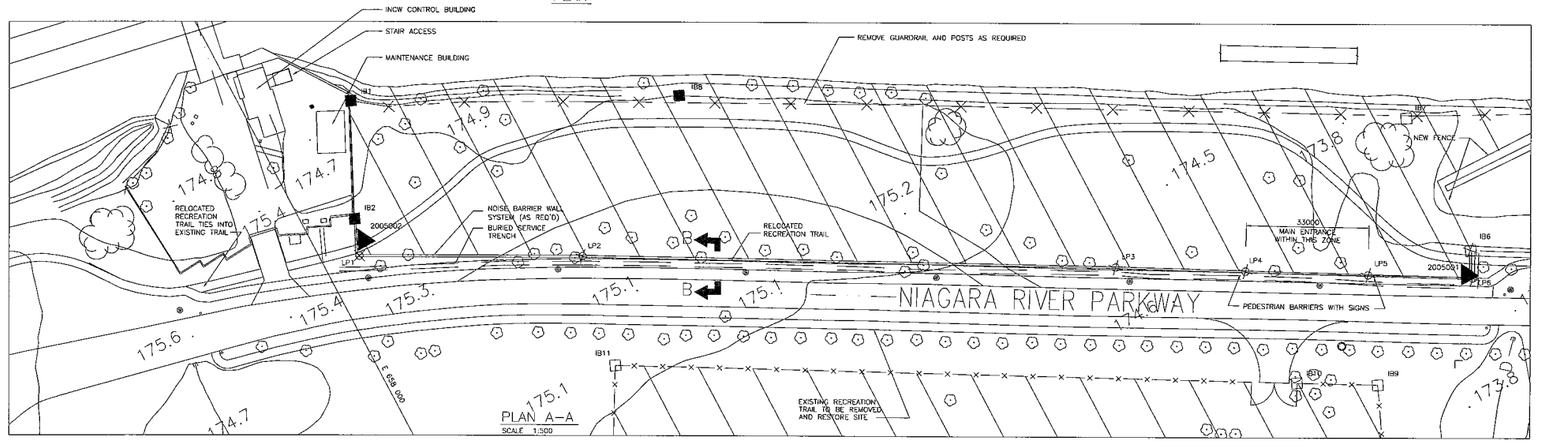
DRAWING NO. NS1999-003
RICHARD LAROCQUE LIMITED – ONTARIO LAND SURVEYORS & CONSULTANTS DATED OCTOBER 17, 2005

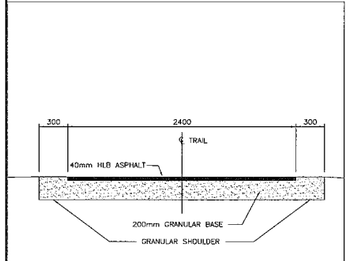
DRAWING NO. NS1999-0030-B
RICHARD LAROCQUE LIMITED – ONTARIO LAND SURVEYORS & CONSULTANTS DATED JANUARY 31, 2006

LEGEND:

AREA AVAILABLE FOR CONTRACTOR
CONTROL MONUMENT
EXISTING TUNNEL PIEZOMETER
IRON BARS IB4
AREA AVAILABLE FOR ROAD LAYOUT
LAYOUT POINTS LP10

PLAN





SECTION B–B
TYPICAL SECTION RECREATION TRAIL
SCALE 1:20

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	09	AUG 29 2007	ISSUED FOR AGREEMENT AMENDMENT 3		
	08	SEP 30 2006	ISSUED FOR PCD 0012		
	01	AUG 15 2006	REVISION CANCELLED		
	06	FEB 23 2005	PLAN SCALE AND SCALE BARS REVISED		
	05	FEB 17 2005	GENERAL REVISION ISSUED FOR PCD 0012		
	04	AUG 30 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	03	MAR 16 2005	ISSUED FOR AMENDMENT 3		

NIAGARA TUNNEL FACILITY PROJECT
CONSTRUCTION FACILITIES
INTAKE AREA
PLAN AND SECTION

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

dwn	designed by		
chkd		size	D
date yr/month/day 04/11/05	design approved	plot scale 1:1 M	
scale AS SHOWN	authorized	drwg. code	
		CAD file type DWG	
dwg no NAW130–D0E–80000–0014			ver 10

A0 (841 x 1189) standard drawing number NAW130-D0E-80000-0014

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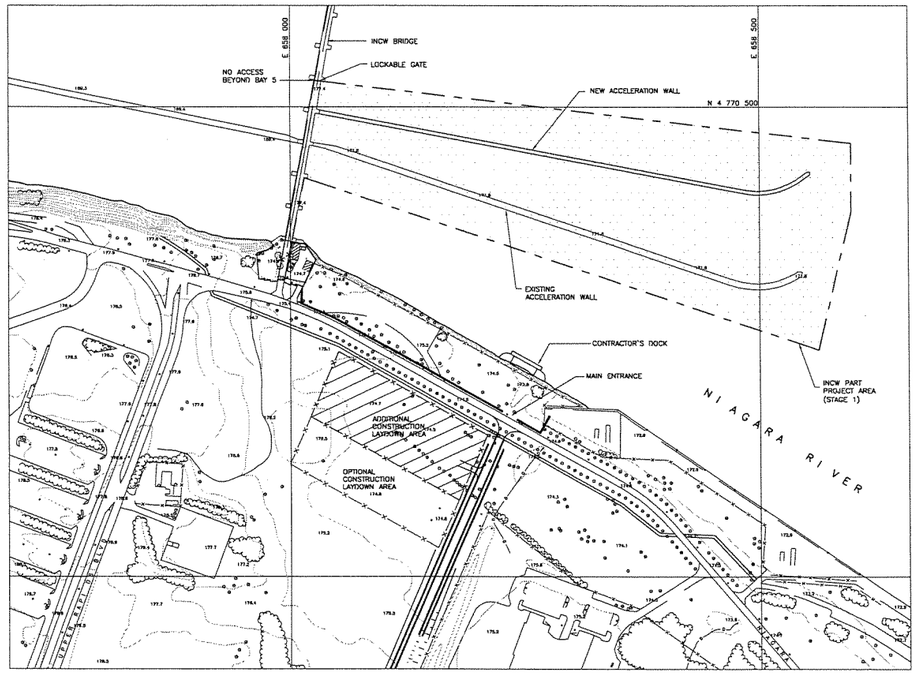
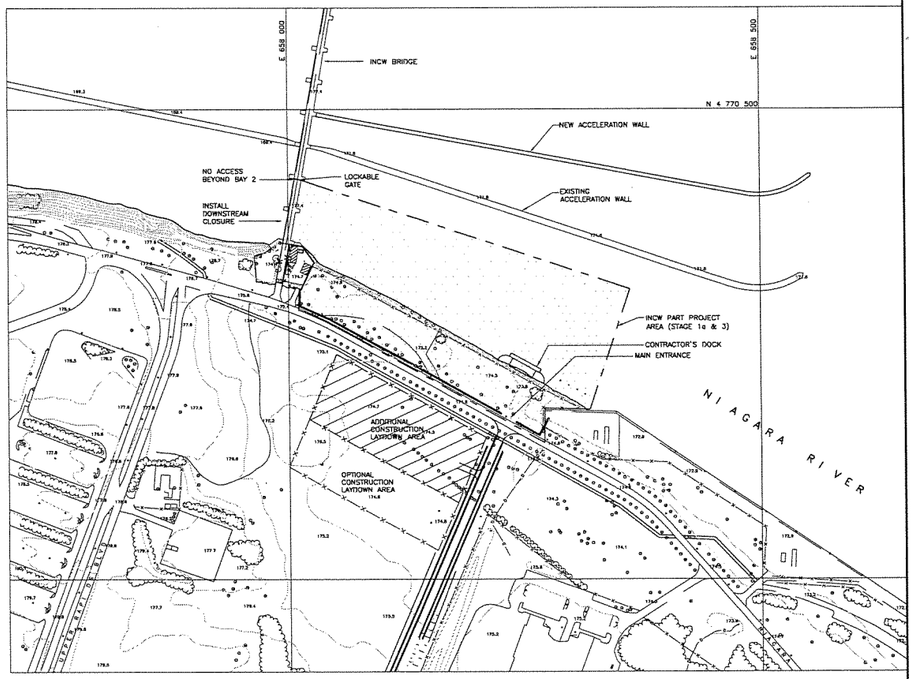
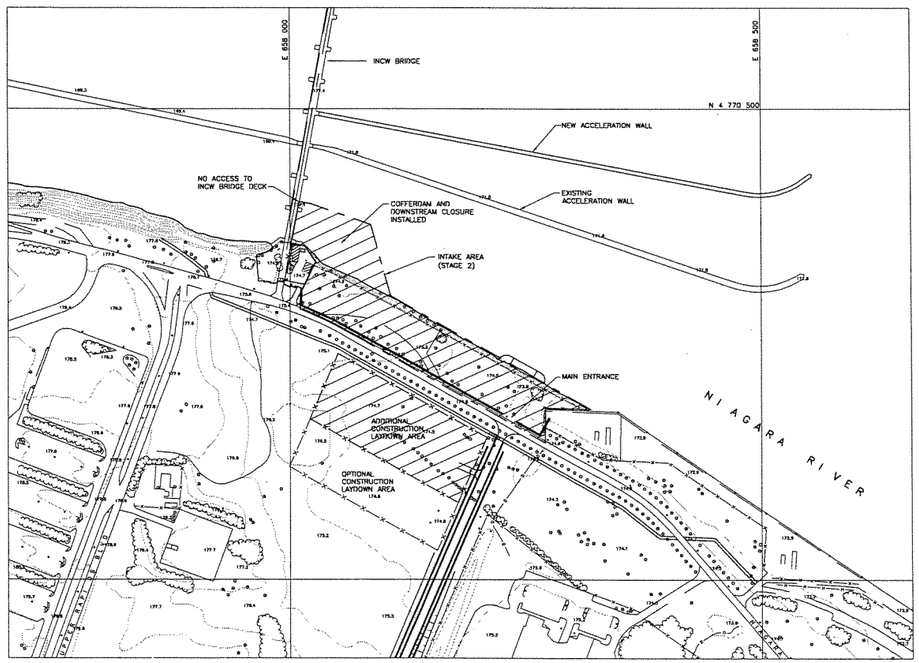


INCW PART PROJECT SITE
EXISTING AND NEW ACCELERATING WALL WORK (STAGE 1)
SCALE 1 : 2000



INCW PART PROJECT AREA SITE
COFFERDAM CONSTRUCTION, DOWNSTREAM CLOSURE AND IN-WATER EXCAVATION WORK (STAGE 1a)
COFFERDAM DISMANTLING AND REMOVAL (STAGE 3)
SCALE 1 : 2000



INTAKE AREA SITE
INTAKE CONSTRUCTION WORK (STAGE 2)
SCALE 1 : 2000

LEGEND:

INTAKE AREA
CONTRACTOR IS "CONSTRUCTOR" FOR WORK IN THIS AREA. NO IN-WATER WORK IS ALLOWED

INCW PART PROJECT AREA
OPG ASSUMES ROLE OF "CONSTRUCTOR" FOR WORK IN THIS AREA

mf no/ number	ver no	date	particulars	dsn chkd	appd
	01	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT		
	00	MAR 18 2005	ISSUED FOR AMENDMENT 3		

NIAGARA TUNNEL FACILITY PROJECT
CONSTRUCTION FACILITIES
INTAKE AREA AND
INCW PART PROJECT AREA
SITE PLANS

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

Hatch Mott MacDonald–Acres

dwn	designed by		
chkd			
date yr/month/day	design approved	plot. scale 1:1	
04/11/05		plot. date	
scale 1:2000	authorized	CAD file type DWG	
dwg no NAW130-D0E-80000-0015		ver 01	

A0 (841 x 1189)

standard drawing number
NAW130-D0E-80000-0015

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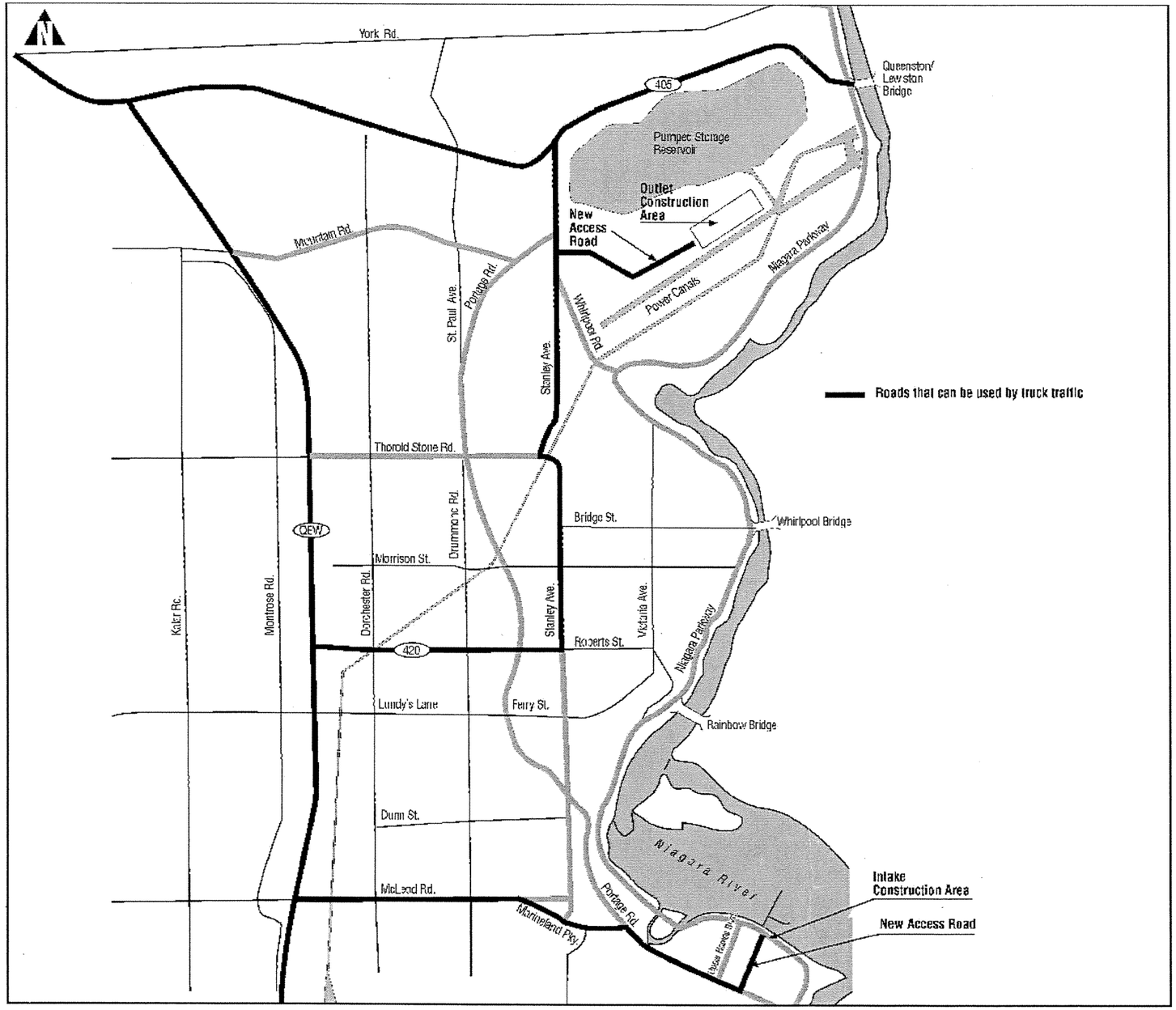
Aug 02, 2005 - 1:13pm
Drawing Name: K:\1000\Projects\00 NAW\80000 0015.dwg

NOTES:

1. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL RELEVANT CONCEPT DRAWINGS AND DOCUMENTS FOR THIS PROJECT AND ONTARIO POWER GENERATION DRAWINGS FOR THE EXISTING WORKS. DETAILS OF EXISTING CANALS AND SERVICES ARE NOT SHOWN, WHERE APPROPRIATE, FOR CLARITY.
2. FOR GENERAL NOTES, SEE DRAWING NAW130-DOE-29230-0015



	02	AUG 03 2005	ISSUED FOR INCLUSION IN AGREEMENT
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	00	DEC 17 2004	ISSUED FOR PROPOSAL
ont nat number	nat no	date	particulars

NIAGARA TUNNEL FACILITY PROJECT
CONSTRUCTION FACILITIES
DESIGNATED TRUCK ROUTES

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

Hatch Mott MacDonald-Acres

drawn	designed by		
chkd			
date yr/month/day 04/12/16	design approved	post scale 1:1M	
scale NTS	authorized	CAD file type DWG	
dwg no NAW130-DOE-84500-0001			rev 02

A0 (841 x 1189)

standard drawing number
NAW130-DOE-84500-0001

0 10 50 100 200 250 300 millimetres

Appendix 1.1(j)
INTENTIONALLY DELETED

Appendix 1.1(j) - INTENTIONALLY DELETED

Appendix 1.1(k)
Contract Schedule

Appendix 1.1(k) - Contract Schedule

Start Date:	September 1, 2005
TBM Breakthrough Date:	April 28, 2011
Substantial Completion Date:	June 15, 2013

Appendix 1.1(o)
Disallowance Advisory

Appendix 1.1(o) – Disallowance Advisory

Disallowance Advisory

To: **Strabag Inc.** 2520 Stanley Avenue, Niagara Falls, ON L2E 6S4 (the "**Contractor"**)	Contract: Amended Design/Build Agreement (the "**Agreement**") dated [***date***] between the Contractor and Ontario Power Generation Inc. ("**OPG**") Disallowance Advisory No.: [**#**] Date: [***date***]

Defined terms used in this Notice have the same meanings given to those terms in the Agreement as amended.

In accordance with Section 1.1(O)(1)(iii) of the Agreement, OPG hereby notifies the Contractor that any and all costs arising from, or incurred as a result of the future occurrence(s) of the actions, omissions or occurrences listed below will constitute a Disallowed Cost as defined in Section 1.1(O)(1).

Description of Future Actions, Omissions or Occurrences Deemed to be Disallowed Costs:

ONTARIO POWER GENERATION INC.

_____

Name:
Title:

Appendix 1.1(P)
Disallowed Cost Notice

Appendix 1.1(P) – Disallowed Cost Notice

Disallowed Cost Notice

To: **Strabag Inc.** 2520 Stanley Avenue, Niagara Falls, ON L2E 6S4 (the "**Contractor**")	Contract: Amended Design/Build Agreement (the "**Agreement**") dated [***date***] between the Contractor and Ontario Power Generation Inc. ("**OPG**") Disallowed Cost Notice No.: [**#**] Date: [***date***]

Defined terms used in this Notice have the same meanings given to those terms in the Agreement as amended.

In accordance with Section 1.1(O)(1) of the Agreement, OPG hereby notifies the Contractor that the costs arising from or incurred as a result of any of the following action(s), omission(s) or occurrence(s) constitute Disallowed Costs as defined in Section 1.1(O)(1). No such costs will be payable by OPG as Allowed Costs, and Contractor will not include such amounts in Allowed Costs in any current or future invoice or Application for Payment (including the invoice of [***date***]).

Description of Disallowed Cost Occurrence(s):

Under Section 1.1(O)(1)(i):

Under Section 1.1(O)(1)(ii):

Under Section 1.1(O)(1)(iii):

The following is OPG's calculation of all costs associated with the above occurrence(s) that are to be deducted from the payment of Allowed Costs:

Value of Disallowed Costs in this Notice:

Total to be deducted $ [###.##]

ONTARIO POWER GENERATION INC.

_____

Name:
Title:

Appendix 1.1(r)
Preliminary Design and Construction Approach

Appendix 1.1(r) - Preliminary Design and Construction Approach

[See attached]

MH-3001-00
Design Basis and Method Statements for Design and Construction of Intake Approach and Accelerating Walls

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-3001-00

Design Basis and Method Statements for Design and Construction of Intake Approach and Accelerating Walls

May 11, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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1.0 GENERAL

1.1 PROJECT OVERVIEW

The proposed Niagara Tunnel Facility aims to convey an inflow of about 500 m^3/s from the Niagara River to the Ontario Power Generation power canal system. This new additional system shall be capable of directing the desired flow under all operating conditions and subject to the specified environmental restraints.

This document shall be read in conjunction with the document titled "Structural Design Analysis" for the two structural component covered by this document, namely the intake approach wall and the accelerating wall.

1.2 DEFINITION OF SYSTEM

The proposed project, layout of which is given in Concept Drawings provided by OPG, will consist of the following key component structures:

(a) Intake Channel and Approach Wall
(b) Accelerating Wall
(c) Intake Structure
(d) Diversion Tunnel
(e) Dewatering Station and associated work
(f) Outlet Structure

1.3 SCOPE

This Draft Design Basis and Method Statements document is for the specific elements (a) and (b), namely the Intake Approach Wall and the Accelerating Wall only.

This document covers the main aspects for design and construction of these structures including the following:

- Preliminary layout of works
- Design approach
- Codes and standards
- Outline specifications
- Construction techniques
- Layout of construction equipment to install the walls
- Sequencing of the work

The Design Basis and Method Statements for the remaining elements of the Niagara Tunnel Facility Project will be addressed by other relevant documents elsewhere in the Proposal submission.

2.0 INTERFACING SYSTEM

The Intake Approach and Accelerating Walls are to interface with and connect to existing structures and facilities as a part of the intake system structures. The Intake Approach Wall and the Accelerating Wall are to be joined to the designated piers of the INCW with minor modification and extension of the structure. The Intake Approach Wall shall be blended into the existing SAB2 intake wall.

The Intake Structure and Outlet Structure will provide control for the water flow between the diversion tunnel and the existing power canal.

Service gates will be located in the Intake and Outlet Structures for dewatering the diversion tunnel.

3.0 FUNCTIONAL REQUIREMENTS

3.1 FUNCTIONAL OBJECTIVES

The Intake Approach and Accelerating Walls shall be capable of directing smoothly continuous supply of water to the Intake Structure to meet the designed flow, while meeting the specified hydraulic and environmental requirements under all operational conditions.

3.2. DAM SAFETY REQUIREMENTS

The structures shall be capable of retaining the stored volume and to pass flows around and through the structure in a controlled manner.

There could be a number of modes of failure of the wall but the probability of such is extremely remote if properly designed. It is expected that failure, if occurring, should be limited to minor displacement or tilting of walls at which instance it could be easily detected and remedied accordingly. The need to close the tunnel in those situations is highly unlikely.

The potential hazard resulting from failure of the Intake Approach and Accelerating Walls appears to be very low as it is unlikely that there is any loss of life resulting from its failure and that the economic value of other losses will also be minimal outside the loss of power generation.

4.0 PERFORMANCE REQUIREMENTS

4.1 LAYOUT DESIGN

The layout design shall:

1. Direct the prescribed quantity of water (about 500 m^3/s) drawn from the Niagara River to the existing power canal system under operating conditions, with minimum head loss and high structural reliability;

2. Ensure an uninterrupted flow of water under all adverse climatic and environmental conditions (i.e. shall provide satisfactory performance for both open water and ice conditions),
3. Satisfy all conditions imposed by the hydraulic, environmental, operational and economic requirements;
4. Consider all safety requirements,
5. Allow provisions for periodic inspection, maintenance and ease of repair or even replacement of structural modules under operating conditions if necessary,
6. Allow construction of the structures, within the limit of the scheduled construction period, in a logical sequence,
7. Permit suitable means of foundation preparation with minimum time required for underwater and in-river operations,
8. Take into account the restrictions on marine construction scheduling as imposed by the Ministry of Environment (MOE).

4.2 DESIGN AND SERVICE LIFE

The tunnel lining system, intake structure and outlet structure shall be designed for a service life of 90 years. Other elements, such as the accelerating wall, approach wall and the intake channel, which are not specifically required to be designed for a 90-year service life, shall be designed to applicable and appropriate codes, guidelines and standards that are commensurate with their intended purpose.

5.0 SAFETY REQUIREMENTS

5.1 STRUCTURAL INTEGRITY

The structure shall be designed in accordance with the Codes and Standards listed in Section 14.0 to ensure adequate structural integrity and safety for all the conditions under which the system is intended to function.

5.2 INDUSTRIAL SAFETY

During underwater construction, in-service inspection and maintenance of the structures, safety of the divers or personnel shall be ensured. The diving operation shall be conducted in a safe manner according to CSA Z275.2.

The layout design of the structures shall take into account the safety of the operating and maintenance personnel.

5.2 SAFETY BY DESIGN

Improving the safety environment of the construction site will reduce worker injuries and save time and cost. But, safety practices alone are not enough to reduce accidents because they are unable to remove hazards inherent in a facility's design or required construction sequences.

Safety measures considered and incorporated in the schematic and design development phase will have direct impact to improve the safety environment of construction workers on the job site. Many designer decisions could also impact the safety of end users, maintenance and repair workers.

In addition to reduction of construction worker injuries and associated costs, pre-project safety planning is also important to implement design features to reduce re-design, rebuild, maintenance, and operating costs.

A safety analysis conducted during design phase is an effective means of identifying unnecessary hazards in the project design. Many of these hazards may be "designed out" through the use of alternative components, systems, or construction methods. Design suggestions will be used to control or to eliminate the hazards.

A computerized design aid may be used to conduct a comprehensive and systematic construction safety analysis during the design phases of the project. The following should be investigated:

1. identification of construction hazard
2. summarize and prioritize hazards
3. investigate lessons learnt and design solutions
4. document project hazard related decisions
5. report on hazard tracking, owner acceptance and residual risk

It is also important to utilize a management tool to ensure comprehensive design team involvement.

As the design proceeds, the contractor and specialist contractors will be included in the design process to ensure that due consideration for constructability, especially for in-water works, will be made in the design and detailing of the work. The input from the contractors will also enable any construction in the water to be carried out safely and will comply with the best and most up-to-date construction practice for these works. The design will be completed through an iterative process that includes these parties.

6.0 STRUCTURAL REQUIREMENTS

6.1 LOADS

The structure shall be designed to withstand all temporary, permanent, construction, environmental, normal, unusual and extreme loads, in all possible combinations.

All structural components shall have adequate capacity to safely sustain the prescribed design loads.

6.1.1 Design Loads

The types of loads for which the structures are to be designed include the following:

(a) Dead Loads (D)
All permanent masses of the structural components, all permanent construction materials, including the permanently located attachments and equipment systems, if any.

(b) Operating Water Pressures (H)
The external water pressure exerted by water above ground is governed by the specified maximum water levels. When used as stabilizing force acting on the structure in a stability analysis, these forces must be conservatively estimated.

(c) Design Flood (F)
The water level under inflow flood scenario varies between the 200-year flood and the Probable Maximum Flood (PMF) as prescribed in the OPG Invitation document.

(d) Hydrostatic Uplift (U)
Uplift pressure exists through cross section within the wall structure, at the interface between the wall structure and the foundation, and within the foundation below the base.

(e) Soil and Silt Pressures (S)
Earth pressures against the structure may occur where backfill is deposited in the exaction. However, it was stipulated by OPG that Passive pressure due to backfill shall not be considered. Silt pressures are considered in the design if suspended sediment measurements indicate that such pressures are expected.

(f) Wind Load (W)
Wind loads applicable at the site location should be computed based on a sufficient low probability factor. For construction design condition (e.g. prior to backfill), wind pressure acting on the structure may be based on a higher probability factor. Usually, wind load is not a governing factor for massive concrete structures.

(g) Ice Load (I)
The structure is to be designed to withstand the forces generated by ice movement against it. Ice forces may include dynamic loads generated by ice floes striking the structure, and static loads generated by thermal expansion or contraction of the ice and by fluctuations in the water levels.
The magnitude of thermal ice load is governed by a number of controlling factors such as ice thickness, shoreline confinement, water velocity, water level fluctuation, rate of temperature rise, etc.

(h) Seismic Loads (E)
The earthquake loadings used in the design of the structure are based on design earthquakes and associated ground motion parameters determined from seismological evaluation for the specific site. Where site specific study has not been conducted, seismic zone maps of the National Building Code proposed for the 2005 revision are to be used.

Two levels of seismic loads are usually considered for the design: (a) the Maximum Design Earthquake (MDE) having an extremely low probability of annual exceedence, and (b) the

Operating Basis Earthquake (OBE) used in conjunction with ice loading and having a probability of annual exceedence of 1 in 200.

(i) Hydrodynamic Loading (H_D)
Hydrodynamic loading includes the effects of the maximum transient heads in the tunnel during the gate closure. Loads due to water hammer shall be provided by a hydraulic study. Unlike the Intake Structure and the Outlet Structure, the Intake Approach and Accelerating Walls are not subject to such dynamic transient loads.

(j) Construction Loads (C)
Construction lifting loads shall be dead weights in air or under water plus 50% for impact allowance during handling, lowering, barging, launching and controlled sinking operations of the precast modules. Construction loads due to mobile or tower cranes will also be considered where appropriate.

(k) Other Loads
In general, loads induced by other factors such as temperature are not significant in mass concrete gravity structures. Hence, these may only be considered where deemed necessary.

6.1.2 Load Combinations

All combinations of loads that may act simultaneously during construction, normal plant operation or abnormal environmental conditions shall be considered.

The loading conditions considered in concrete structure designs and overall structural stability analysis shall include but not limited to the following:

1. Loading Case No. 1 – normal loading condition – Construction
   Any combination of loads that may act simultaneously during the construction period, including lifting and handling loads, crane loads for construction activities, etc.
2. Loading Case No. 2 – normal loading condition – Summer Operating
   Any combination of loads that may act simultaneously during normal operation.
3. Loading Case No. 3 – normal loading condition – Ice Load
   Any combination of loads that may act simultaneously due to ice loading effects on the structural components.
4. Loading Case No. 4 – normal loading condition – De-watering
   Any combination of loads that may act simultaneously during planned dewatering or emergency shutdowns of the tunnel facilities.
5. Loading Case No. 5 – unusual loading condition – IDF[1]
   Any combination of loads that may act simultaneously during a 200-year flood.
6. Loading Case No. 6 - extreme loading condition – PMF[2]
   Any combination of loads that may act simultaneously during this extreme environmental event which has a low probability occurrence.

[1] IDF = Inflow Design Flood

7. Loading Case No. 7 – extreme loading condition – MDE[3]
   The Intake Approach and Accelerating Walls, being a conventional structure (i.e. not dam safety related), shall be designed to satisfy the requirements stipulated in the National Building Code of Canada.
8. Loading Case No. 8 – extreme loading condition – Ice Load and OBE[4]
   Any combination of loads that may act simultaneously in an unlikely event that an earth tremor occurs during peak winter season. As the probability of the combination of these two environmental events occurring simultaneously is low, the earthquake load is decreased appropriately.

The most critical design condition for various loading cases shall be assumed.

6.2 DESIGN CRITERIA

6.2.1 Stability Requirement

Sliding stability of the structures shall be verified by limit equilibrium method using un-factored loads. The computed factors of safety against sliding, and resulting stresses along any critical sections within the structure or at the base shall not exceed the minimum acceptable factors of safety and allowable working stresses specified for the normal, unusual and extreme load combinations.

6.2.2 Required Strength

The reinforced concrete hydraulic structures shall be designed in accordance with the Strength Design Method. The structural members will have a required strength to resist design loads and the factored load combinations specified in Sub-Section 6.1.1 and 6.1.2.

The load factors as prescribed in CSA A23.3 shall be applied and the total factored design load shall be increased by the hydraulic factor $H_f = 1.3$. The hydraulic factor is used to improve crack control for massive hydraulic structures which usually are lightly reinforced.

The hydraulic factor is not applicable for sliding or overturning stability analysis.

6.2.3 Design Strength

The strength of a structure or individual member must exceed the demand (required strength) for all foreseeable loads without failure or significant distress. The nominal strength must be reduced by a resistance factor to account for the variability in the strength. For this purpose, the resistance factors prescribed in CSA A23.3-94 shall be applied.

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[2] PMF = Probable Maximum Flood

[3] MDE = Maximum Design Earthquake

[4] OBE = Operating Basis Earthquake

6.2.4 Serviceability Requirement

An adequate uninterrupted supply of water to the intake tunnel must be assured. Structural members shall be proportioned to minimize deflection limit and the foundation will be designed and constructed with adequate measures to minimize possible settlement.

7.0 DESIGN CONSTRAINTS

The location, dimensional geometry, and transitional shape of the Intake Approach and Accelerating Wall systems are fixed as defined on the Concept Drawings. Extension of the respective INCW piers to connect these two walls will be adjusted during the final design stage as determined by the final tunnel configuration and other more accurate survey data at the site.

For design purpose, OPG stipulated the following limitations:

1. Passive pressure due to backfill shall not be considered.
2. Cohesion at the concrete rock interface shall not be assumed.
3. Rock anchors shall not be used to provide the required stability of gravity structures.

8.0 DESCRIPTION OF TYPE OF STRUCTURES

The Intake Channel, and Approach and Accelerating Walls are positioned upstream of the INCW Structure. The dimensional geometry, alignment, and top elevations of these walls are fixed as defined in the Concept Drawings provided by OPG.

The Intake Approach and Accelerating Walls shall be mainly composed of a series of structurally independent reinforced concrete modules, filled with rock-fill materials and capped with concrete cover slab. Transitional sections to the existing INCW Structure and to the gravity wall of the existing tunnel no. 2 shall be cast-in-place concrete wall sections.

The precast concrete modules shall be designed to have vertical keys for interlocking with adjacent modules to improve retaining back-fill materials and overall lateral stability.

These precast wall units shall be arranged in such an alignment to form a smooth surface to direct the flow of water into the Intake Structure.

9.0 CONSTRUCTABILITY REQUIREMENTS

9.1 CONSTRUCTION METHODS

The effects of construction sequence and methods shall be considered including the following:

1. Application of conventional design and construction methods, if all possible, shall be considered.
2. The effects of special construction material handling methods and equipment including floatation assistance systems, large capacity crane, etc. shall be evaluated.

3. The effects on the structural system due to the maximum variance in degree of levelling of foundation pads shall be taken into account in the design.
4. The timing and method employed for demolition of the existing accelerating wall and disposal of materials shall be carefully considered to minimize environmental impact and off-site disposal.
5. During the design process the contractors and key subconstractors will be involved on an on-going basis to ensure that designs are developed that are practical, constructable and meeting standards. Worker safety will also be a key design consideration.
6. Marine construction period should be kept to a practical minimum in accordance with the restrictions on the marine construction scheduling imposed by MOE.
7. Construction activities at the Intake Channel, and the Approach and Accelerating Walls must not hinder the efficient movement of ice in the vicinity of the INCW.
8. The cofferdam arrangement shall be designed to minimize the interference into Bay 2 of the INCW.
9. Blasting where needed shall be controlled to ensure that the rock beyond the excavation limits is not damaged or de-stabilized by the blasting operation. Blasting velocities shall be carefully monitored to ensure operation of existing equipment will not be affected.
10. Most importantly, the integrity of the foundation of the INCW structure must be fully secured during the blasting activities for the Intake Channel, as well as for the excavation associated with the construction of the Intake Structure and the extension of Piers 1, 2 and 5.

9.2 CONDITION SURVEYS

Through careful planning and use of proper construction techniques, the impact on existing structures and systems by the performance of the construction work should be minimal.

For verify the impact with specific data, condition surveys of existing structures in the near vicinity of the construction sites will be conducted before and after the construction work is complete. These condition surveys will be undertaken by independent qualified consultants employed by OPG.

Adjustment of construction methods may be necessary upon review of some preliminary condition survey reports.

9.3 HYDROGRAPHIC SURVEYS

The preliminary design of the walls is based on lakebed survey results or as shown on drawings provided by OPG. To permit detailed design to proceed, an accurate measurement of the lakebed at suitably close intervals must be carried out. The information provided from dipping or sonar measurements should enable the engineer to ascertain the actual lake bottom along the alignments of the walls. By this the cement sandbag padding requirements as well as the sizes of the precast wall elements can be finalized and any alteration or customization could be made to the concrete blocks prior to them being manufactured, and the engineer and the contractor could act accordingly.

10.0 MAINTAINABILITY REQUIREMENTS

The targets stipulated for these structures will ensure that the maintenance requirements are reduced to the practical minimum.

The layout design shall ensure suitable means of access for personnel and materials for the purpose of efficient operation, maintenance and inspection.

11.0 CONCRETE CONSTRUCTION

The concrete material to be used for the construction of these structures shall be in accordance with the appropriate specification, standards and manuals listed in Sub-Section 12.1 and 12.2.

All concrete is to have the specified 28 days compression strength, water cementing material ratio, and air content in accordance with the requirements of CSA Standard A23.1-00.

11.1 DURABILITY REQUIREMENTS

Concrete in water passage shall be designed to be resistant to the abrasive action of water flow, entrained ice and debris. Hence, concrete with low water/cementitious materials ratio and having adequate strength shall be used.

Based on information provided, it is understood that concrete made with a cement that provides sulphate resistance is only required for the annular grout and reinforced concrete lining, but not these concrete structures.

11.2 CONSTRUCTION TECHNIQUES AND EQUIPMENT

Construction of the walls will generally include the padding of the lakebed and level the placement areas with cement stabilized sandbag, which may involve the use of divers. After confirmation of the stability and accuracy of the padding layer the first layer of precast wall units will be installed. The bottom of the wall, including the void within the padding sandbags will be filled with mass concrete infill to the level shown on the drawings. The remaining layer(s) of the wall will then be installed and rockfill placed inside the voids in the wall, and reinforced concrete capping will be installed. It is expected that construction using barges (in-water activities) and cranes (land activities) will be required to construct the various components of the walls. Where barge is used, appropriate docking and storage facilities should be constructed at the site, and all extra loadings arising from such shall be included in the design of the walls if an impact is identified.

There are areas along the walls where mass concrete infill will be required, primarily to stabilize the bottom of the wall and the sandbag base on which the precast units will be installed.

Prior to the placement of mass concrete in-fill, the area shall be cleaned of silt and debris.

When the mass concrete in-fill area cannot be kept water free, procedures for underwater concreting shall be established to include concrete mix design, appropriate admixtures,

placement schemes, inspection plan, and concrete sampling plan to ensure concrete placed is competent. When the concrete surface has been brought above the water line, all the laitance must be removed from the surface of the concrete before normal concrete placing continues.

For constructing extension of concrete structural elements, the surfaces of the existing component shall be thoroughly scaled. And, prior to placement of new concrete, the concrete surfaces shall first be cleaned by sandblasting, followed by an air-water jet to remove all loose and adhering contaminants to ensure full bonding will be achieved.

During construction the contractor shall adhere to all environmental requirements as stated elsewhere in the contract, and comply with necessary restrictions that may be in place for working near a tourist site. Any area disturbed by construction operations shall be reinstated properly as shown on the drawing, as directed by OPG, or to the pre-construction conditions.

12.0 CODES AND STANDARDS

12.1 CODES, REGULATIONS AND LAWS

The requirements of the following codes, regulations and laws shall be referred to, where applicable:

1. National Building Code of Canada (1995)
2. The Building Code of Ontario (1997)
3. CSA Standard CAN3-A23.3-94: Design of Concrete Structures
4. Lakes and Rivers Improvement Act, Government of Ontario (1986)
5. Dam Safety Regulation under the Lakes and Rivers Improvement Act (Proposed Draft), Ministry of Natural Resources (November 2001)

12.2 OPG SPECIFICATIONS, STANDARDS AND MANUALS

The structure shall be designed and constructed in accordance with the following standards and specifications:

1. Niagara Tunnel Facility Project - Invitation to submit Design/Build Proposals, Ontario Power Generation (Amendment 1, February 2005)
2. Dam Safety Guidelines, Canadian Dam Association (January 1999)
3. Guidelines and Criteria for Approval under the Lakes and Rivers Improvement Act, Ministry of Natural Resources (Draft, May 1997)
4. CSA Standard CAN3-A23.1-94: Concrete Materials and Method of Concrete Construction
5. CSA Standard CAN3-A23.2-94: Methods of Test for Concrete
6. USACE EM1110-2-2000: Standard Practice for Concrete for Civil Works Structures, US Army Corps of Engineers (March 2001)
7. USACE EM1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures, US Army Corps of Engineers (August 2003)

8. USACE EM1110-2-2200: Engineering and Design – Gravity Dam Design, US Army Corps of Engineers (June 1995)
9. USACE EM1110-2-2502: Engineering and Design – Retaining and Flood Walls, US Army Corps of Engineers (September 1989)
10. US Bureau of Reclamation Handbook – Design of Gravity Dams, US Bureau of Reclamation (1976)

13.0 PRELIMINARY DESIGN DESCRIPTION

13.1 GENERAL

The Intake Approach and Accelerating Walls have been developed based on the precast reinforced concrete modular system concept. For each module, the basic structural system is an open rectangular box structure. The size of these units is determined mainly based on practical and economical limitations related to transportation requirements. Specifically, the governing factors are the maximum width and gross weight of each modular unit.

The respective wall will be constructed by stacking up either two or three units. The stacked modules are to be filled with rock-fill materials and subsequently fully covered with a concrete slab on the top of the wall.

13.2 FABRICATION

The Intake Approach and Accelerating Wall concrete modules shall be prefabricated under controlled environment in the dry.

13.3 FOUNDATION PREPARATION

The overburden at the Intake Approach and Accelerating Wall foundation location shall be excavated to ensure all loose materials are removed to the exposed rock level.

13.4 PLACEMENT OF SUPPORT PAD

Cemented sand bags used for the supporting pad shall be placed in such a manner that the allowable degree of levelling will be achieved. The variation in the top surface elevation for adjoining interlocking modules shall be less than 40 mm. The maximum relative elevation difference in the finished top surface of the entire wall shall be less than 150 mm.

13.5 ROCK-FILL

Rock-fill materials to be placed within the precast concrete modular units shall consist of clean rock fragments and shall be free from organic materials.

Rock-fill shall be uniformly graded in size up to a maximum size appropriate for this application.

13.6 CONCRETE COVER SLAB

The Intake Approach and Accelerating Walls shall be fully covered with a concrete slab. These cover slabs may be cast-in-place or precast units.

13.7 BACK-FILL

Back-fill materials behind the Intake Approach Wall shall be clean rock fragments and shall be free-draining. No back-fill shall be placed behind any concrete modular unit until it is fully rock-filled first.

Back-fill to form the final prescribed slope shall be placed only after the concrete cover slab is well in place.

14.0 DESIGN ANALYSIS

14.1 CODES, STANDARDS AND SPECIFICATIONS

The Intake Approach and Accelerating Walls will be designed in compliance with the codes, standards and specifications listed in Section 12.

14.2 DESIGN METHODS AND PROCEDURES

The structural systems will be designed by using recognized methods and procedures, which include the established and coded computer software in performing the structural analysis as appropriate for the design.

14.3 STABILITY ANALYSIS

Stability is evaluated in a manner similar to a conventional gravity retaining wall. For stability calculations the interlocking precast concrete modular system is assumed to behave as a coherent block. The system must be stable against sliding along the base of the structure, overturning about the toe of the wall, and bearing capacity failure of the foundation.

15.0 INTAKE CHANNEL

15.1 EXCAVATION

The excavation of the sides of the Intake Channel shall be done by employing line-drilled and controlled blasting to ensure that the surrounding rock beyond the excavation limits is not damaged or de-stabilized. Any rock outside the requisite excavation lines which may be damaged by the construction works shall be removed and backfilled with sound concrete sufficiently anchored back to integral solid rock.

Excavation of the Intake Channel shall be done in two stages. The first stage consists of excavation of the two shallow approach sections in the wet up to designated elevation. The second and final stage will be done in the dry condition provided by a cofferdam.

For the deep excavation area, multiple grout curtains will likely be required to ensure that the area is sufficiently dry throughout the period of excavation and construction of the Intake Structure. If found necessary, rock anchors may be installed to assure no detrimental effects on the rock foundation of the INCW Structure will occur.

15.2 EFFECTS ON INCW STRUCTURE AND SYSTEMS

Excavation by blasting at close proximity of the INCW Structure shall be carefully planned and close control shall be exercised to ensure that the integrity of the control structure and its foundation will be maintained.

In general, ground vibration from construction sources such as blasting will depend on the blasting method and the seismic propagation characteristics of the site. Vibration-induced damage thresholds are usually expressed in terms of peak particle displacement, velocity or acceleration, and sometimes include a frequency-dependent factor.

It is most usual for peak particle velocity to be used, because it has been found to be the best correlated with case history data of damage occurrence and because it has a theoretical underpinned inasmuch as the strain induced in the ground is proportional to the particle velocity.

For this reason, strategically located measurements will be made to monitor the vibration level on the existing structures. The recorded data will be assessed against appropriate vibration damage thresholds to be established by expert judgement based on specific site knowledge and previous case history data.

If necessary, trial blasts should be carried out where initial desk studies show that nearby structures could be at risk or that the sensitivity of system is high. The trials should be designed with a clear concern for the factors that will influence the induced peak particle velocity during the excavation works.

16.0 DEMOLITION OF EXISTING ACCELERATING WALL

16.1 REFERENCE DRAWINGS

Typical details of the existing Accelerating Wall which is to be demolished and removed are shown in reference drawings provided by OPG.

Field survey and inspection of the existing conditions to verify all details and dimensions will be conducted prior to execution of the demolition work.

16.2 Demolition Sequence

Means and methods used in demolition of the existing timber-cribbed Accelerating Wall shall be such as to minimize impact on the operation of the INCW. All in-river activities shall meet all the environmental requirements and safety program established by OPG.

Demolition of the timber-cribbed structure shall be undertaken section by section starting from the far end working towards the INCW structure.

For each section, demolition will begin with breaking and removing the concrete cover slab. After rock-fill is removed to designated level or as agreed by the engineer, the timber cribs will be saw cut across the mid height. The top half will then be lifted and removed. The same procedure is followed for removing the bottom half. Throughout the removal process the timber crib wall must be stabilized by rockfill against being washed away in the current. All remaining rockfill left after the timber is removed shall also be picked up immediately.

16.3 DISPOSAL

All structural materials of the existing Accelerating Wall shall be removed from the Niagara River and disposed to sites approved by OPG. Rock fill materials of good qualities may be re-used for construction of the new Accelerating Wall subject to approval by OPG.

17.0 SEQUENCING OF WORK

The recommended sequences of construction as presently envisage are as follows:

1. The existing Accelerating Wall is removed.
2. The new Accelerating Wall is constructed.
3. Part of the east Intake Approach Wall is constructed.
4. Concurrently with the above activities, excavation of the two shallow sections of the Intake Channel is carried out in the wet.
5. After the completion of the new Accelerating Wall, a cofferdam is installed at the location where the last deep section of the Intake Channel is to be excavated. An ice protection groyne is constructed.
6. The excavation of the last deep section of the Intake Channel is done in the dry, followed by the construction of the extension of the INCW pier 1 and 2.
7. Part of the west Approach Wall is constructed in the dry.
8. After the sectional service gates for the Intake are in place and with balanced water pressure on each side of the cofferdam, the groyne and the cofferdam are removed.
9. The construction of the Intake Approach Wall is complete with backfill to the desired level and slope defined.

The above construction sequencing is feasible given the information and preliminary requirements known to-date. The Contractor shall verify all details and dimensions of the existing site, adjacent structures prior to execution of the site work. If during the course of work, existing conditions are found to deviate from those assumed for design, the engineering consultants shall be notified. Additional analysis or alternate design may be necessary before proceeding further with the work.

MH-3002-00
Drafting Design and Method Statements for Temporary Construction Facilities at the Intake and Outlet Areas

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-3002-00

Drafting Design and Method Statements for Temporary Construction Facilities at the Intake and Outlet Areas

May 11, 2005
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MORRISON HERSHFIELD

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1.0 GENERAL

1.1 PROJECT OVERVIEW

The proposed Niagara Tunnel Facility aims to convey an inflow of about 500 m^3/s from the Niagara River to the Ontario Power Generation power canal system. These associated works will provide the necessary infrastructure to support the construction of the tunnel and access shafts, the intake structure, outlet structure and other associated works.

1.2 GENERAL DEFINITION OF CIVIL REQUIREMENT

The proposed project, layout of which is given in Concept Drawings provided by OPG. The civil components of this project covered under this document consist of the following:

1. Temporary Facilities, including all Laydown Areas;
2. Roads and Parking Areas;
3. Fencing and gates; and
4. Stockpiles.

This document will also cover the following work components as they are not covered in other sections of this proposal:

5. Demolition and disposal of the Dewatering Structure at the Pump Generation Station (PGS); and
6. Relocation of the waterline as a result of the removal of the dewatering structure.

1.3 SCOPE

ThiS Design Basis and Method Statements document is for the above-named work components for the contractor's works areas, the Intake and Outlet construction staging areas as well as the final stockpile area. Also covered is the works related to the removal of the dewatering structure outside the PGS.

The following aspects of design and construction will be covered

1. Layout of works;
2. Design Approach;
3. Codes and standards; and
4. Outline specifications

2.0 FUNCTIONAL REQUIREMENTS

2.1 GENERAL

The following is a summary of the various elements of the civil and miscellaneous works for the construction staging areas at the intake and outlet structures.

2.1.1 Temporary Facilities

At the intake a construction laydown area will be placed to the south of Niagara Parkway. This facility will be used in conjunction with all associated works at the intake.

At the outlet the construction offices will be located adjacent north south portion of the temporary access road. This site will be fully serviced by temporary utilities from Stanley Avenue. In addition Material Yards will be placed throughout the site within designated areas and will be fully accessible. All areas to be used as works areas or storage will be entirely within the properties of OPG. Areas identified as reserve areas or within prohibited zones (such as those under the overhead power lines) will remain untouched and protected.

2.1.2 Roads and Parking Areas

At the intake site a temporary roadway is being constructed to allow access to the site from Portage Road to the construction laydown area and across Niagara Parkway to the construction area at the intake and will eliminate any need for construction traffic to utilize Niagara Parkway.

At the outlet site a new permanent paved access road is being construction form Stanley Avenue that could be used to service the works area at the part of the site. However only approximately 180 m of this road will be built and will remain in-place until past the end of construction of this project. Beyond the limit of this pave road a temporary roadway is to be constructed to provide access to the material stockpiling area and all areas at the outlet location.

Parking at location near site offices will be provided, as shown on drawings MH-6008 and MH-6009, including potential areas that may be expanded to be used for this purpose. These areas may or may not be paved.

Relocation of recreation trails at the intake areas will be completed also as per drawing no. MH-6008.

2.1.3 Fencing

Fencing will be chain link for all construction and any other areas to eliminate interference between the public and the construction activity.

Hoardings will be placed at locations designated as being close to pedestrians primarily along the Niagara Parkway, as shown on drawing MH-6008.

2.1.4 Stockpiles

During the excavation of the tunnel approximately 2.0 million cubic metres of material will be stockpiled between the two power canals as shown on MH-6009. These stockpiles will be

approximately 5 to 6m in height with 1 (vertical) to 2.5 (horizontal) side slopes and with the top surface level and graded.

According to the Draft Design/Build Agreement and Concept Drawings, specifications for the excavated material potentially contaminated with BTEX are provided. This material is to be placed on a temporary storage pad until chemical testing is completed to determine how this material is to be managed. The temporary storage pad is located in the northeast corner of the main disposal area. Accordingly, runoff in this area will be sent to the retention pond and treated after sampling, if required. The Draft Design/Build Agreement further states the height, compaction, drainage, setback and slope requirements. However, OPG's "Management of Excavated Material" dated December 2004 and OPG's "Management Plan for BTEX" dated December 2004, provides more detail for the permanent and temporary stockpiling of specific rock formations. In particular, the Draft Design/Build Agreement requires a temporary storage area for material potentially contaminated with BTEX and the "Management of excavated Material" requires that the material potentially contaminated with BTEX be permanently stored without temporary storage requirements.

2.1.5 Demolition of Dewatering Structure at Pump Generation Station

As part of the project the Contractor will remove the existing reinforced concrete structure located at the PGS canal including all equipment associated with the gate. The removal of the structure will open up the channel cross section and will increase the flow capacity of the channel to accommodate the additional water brought through the new tunnel. Information regarding the existing dewatering structure include as-built drawings, are provided by OPG.

2.1.6 Relocation of the Waterline

An existing waterline currently crosses the PGS Canal via the dewatering structure, and mounted on the deck surface of the structure. Due to removal of the structure, the waterline has to be re-routed along the west bank of the canal and cross the canal via the road outside the PGS, and reconnected to the section of the waterline on the east bank of the canal. An alternate solution of installing a utility bridge will be considered and evaluated along with the OPG staff to develop the most cost effective and constructable solution.

As the waterline is owned by OPG, discussion with OPG has to be carried out to ensure that any supply disruption, timing of the disruption, temporary cut-off and reconnect arrangements, work inspection and the like are to be conducted properly and with sufficient advance notice.

3.0 REQUIREMENTS

3.1 GENERAL

The following is a detailed summary of the requirements that guided the development of the design of the temporary facilities.

3.1.1 Layout Design

The layout design shall:

1. Provide safe and reliable access to each of the intake and outlet construction staging areas, with proper intersection layout with main public roads and highways.
2. Ensure a safe and reliable stockpiling area for all excavated materials from the tunnel.
3. Ensure that all environmental protection requirements are complied with such as during clearing and tree removal, and that no deleterious materials are introduced into the water and subsoil systems.
4. Take into account all restrictions placed on the excavated materials and ensure compliance with all agree to regulatory measures.
5. Consider all safety and security requirements, including those to trespassers.
6. Allow provisions for periodic inspection, maintenance and ease of repair or even replacement of any of the temporary works if necessary.
7. Allow construction of all temporary works within the limit of the scheduled construction period, in a logical sequence and prior to the core works.
8. Actively involves the contractor throughout the design process to ensure that all their requirements, such as sufficiency of areas, construction production rates, and the like, are duly addressed and updated from time to time.

4.0 CONSTRUCTION RELATED ISSUES

4.1 CONSTRUCTABILITY AND CONSTRUCTION METHODS

The effects of construction sequence and methods shall be considered including the following:

1. Application of conventional design and construction methods, if all possible, shall be considered.
2. Movement off all construction and excavated materials shall ensure the necessary containment and mitigation of any contamination of the existing ground and the canal system and shall be in compliance with the Environmental Management Plan.
3. Tire washing facilities, noise abating devices, properly painted hoarding, and the like, should be in place to avoid any adverse impact to the neighbouring road, residents and visitors.
4. The removal of the dewatering structure requires significant planning and coordination with OPG staff, and observing all the environmental requirements of working in the water. The need to remove construction debris from the canal would probably dictate the use of specialized equipment that would generate as little small fragment of construction debris as possible.

4.2 CONSTRUCTION EQUIPMENT

Only conventional construction equipment are expected to be used in all civil engineering works, except due consideration of the environmental protection should be made when removing the dewatering structure. Collecting device may be considered in the deck removal to minimize contamination of the water resulting from the demolition work, and the intention is to have large block of the structure removed and lifted off instead of fine breaking processes.

The use of barge stationed in the canal as a working platform will be considered, and discussion will be held with OPG to ensure all issues are resolved if this method is to be adopted.

5.0 MAINTAINABILITY REQUIREMENTS

Most civil works are required to be in place and function throughout the entire construction period and therefore must be properly maintained. The targets for all works will ensure that the maintenance requirements are reduced to the practical minimum. The layout design shall ensure suitable means of access for personnel and materials for the purpose of efficient operation, maintenance and inspection of all works.

6.0 CODES AND STANDARDS

6.1 GENERAL

The following is a detailed summary of the regulations and laws that govern the design development and the commitment to the safety.

6.1.1 Codes, Regulations and Laws

The requirements of the following codes, regulations and laws shall be referred to, where applicable:

1. OPSS (Ontario Provincial Standard Specifications)
2. CSA Standard Z107.0-00 (Standard for Certification of Noise Barriers February 2000)
3. CAN/CSA-S6-00 (Canadian Highway Bridge Code)
4. Other CAN standards, see applicable specifications included
5. Other CSA Standards, see applicable specifications included

6.1.2 OPG Specifications, Standards and Manuals

The shall be designed and constructed in accordance with the following standards and specifications:

1. Niagara Tunnel Facility Project - Invitation to submit Design/Build Proposals, Ontario Power Generation (Amendment 1, February 2005)
2. Ontario Provincial Standard Drawings (OPSD)

6.1.3 Conditions of Approval

Generally, during design, construction and post-construction activities, the Contractor shall work in a manner that protects health and the environment and in compliance with the following:

1. The requirements of the Niagara River Hydroelectric Development Environmental Assessment, dated March 1991 including update of July 13, 1992 and amendment dated June 3, 1993;

2. The requirements of the Environmental Assessment Approval, dated October, 14, 1998;
3. The requirements of Approvals obtained by OPG;
4. The requirements of the Environmental Approvals and Third Party Information, dated March 2005;
5. The requirements of Approvals to be obtained by OPG or the Contractor;
6. The requirements of the Draft Design/Build Agreement;
7. The requirements of the Community Impact Agreement, dated December 22, 1993;
8. This Environmental Management Plan;
9. Plans submitted to OPG as outlined in this document and Draft Design/Build Agreement;
10. Applicable statutes, laws and regulations;
11. OPG's Environmental Management System; and,
12. The requirements of federal, provincial and municipal agencies.

In order to meet all of the environmental requirements for the Project, as outlined above, compliance plan has been developed. This plan provides the specific procedures that will be completed during all phases of the Project to ensure compliance with the Draft Design/Build Agreement, Community Impact Agreement, Environmental Assessment, applicable laws, regulations and guidelines, approvals, agency requirements and applicable Project documentation. To effectively document and explain the compliance procedures, this section has been divided into the three phases of the Project: design, construction and post-construction. The compliance plan utilizes procedures such as environmental audits, risk management analysis, quality assurance/quality control, and environmental inspection, monitoring and training, to ensure compliance.

7.0 PRELIMINARY DESIGN DESCRIPTION

7.1 GENERAL

The preliminary design and development of plans for the temporary civil works, which in this case also include the removal of the dewatering structure at the outlet PGS Canal and the relocation of the waterline, have been developed based on the requirements given in the drawings provided by OPG, particularly the Owner's Mandatory Requirements and subsequent clarifications, as well as applicable standards as outlined in the specifications attached herewith.

7.1.1 Temporary Facilities

- Intake Temporary Facilities:

  At the intake a construction laydown area will be placed to the south of Niagara Parkway. This facility will be used in conjunction with all associated works at the intake. This site will be approximately 182 m x 76 m. It will be fenced and a lockable gate provided for security. Their surface will be graded stone and maintained throughout the project life. The facing side to Niagara Parkway of the lay down area shall also have a screen wall erected to downplay the activity within the compound and the public activity along the parkway. For additional reference, refer to Drawing No. MH-6008-00.

- Outlet Temporary Facilities:

  At the outlet the construction offices will be located adjacent north south portion of the temporary access road. This area is fully fenced and will be approximately 400 m x 50 m. This site will be fully serviced by temporary utilities from Stanley Avenue. In addition Material Yards will be placed throughout the site and will be fully accessible and within the fenced construction area. Their surface will be graded stone and maintained throughout the project life. For additional reference, refer to Drawing No. MH-6009-00.

7.1.2 Roadways

- Intake Roadways:

  At the intake site a temporary roadway is being constructed to allow access to the site from Portage Road to the construction laydown area and across Niagara Parkway to the construction area at the intake. This will eliminate any need for construction traffic to utilize Niagara Parkway. Roadside ditches will be provided to carry any surface water generated from the roadway into the existing and natural drainage system. A temporary traffic signal will be installed at the intersection of the Access Road and Niagara Parkway to alleviate conflict with construction traffic crossing Niagara Parkway. For additional reference, refer to Drawing No. MH-6008-00.

  The existing recreation trail will be relocated to a new location as shown on the drawing to minimize interference of visitors to the area and the construction.

- Outlet Roadways:

  At the outlet site a new permanent paved access road is being construction form Stanley Avenue to provide access to the work zones. However only a 180 m section of this road will be built, and beyond this section a temporary roadway is being constructed to provide access to the material stockpiling area and the outlet location. These roadways will be in place until the end of the project and then removed and the area restored to original conditions. Roadside ditches will be provided along these roadways to carry surface drainage from the roadway and other site locations to a detention/settling basin for eventual discharge into the canal system. For additional reference, refer to Drawing No. MH-6009-00.

  All roadway design, horizontal and vertical alignments, road widths, surface details, drainage, intersection details, and the like, will comply with highway design requirement appropriate to the class of the road as provided in the above-quoted references.

7.1.3 Fencing

Fencing providing boundary separation and security to the sites will be primarily chain link fences. This will help to eliminate any potential interference between the public and the construction activities. At the intake area, some of the work zones will be fenced off using full height hoardings to afford even better separation and minimize the impact on the appearance of this tourist area.

For additional reference and specific locations, refer to Drawing Nos. MH-6008 and MH 6009.

7.1.4 Stockpiles

During the excavation of the tunnel a large quantity of material primarily rock will be stockpiled between the two power canals as shown on MH-6009. These stockpiles will be between approximately 5 m to 6 m in height with proper and safe side slopes and with the top surface level and graded.

The stockpiles shall be piled in lifts of not more than 300 mm. The stockpile will be setback at a minimum 20 m from the canals and a perimeter trench will be implemented to gather any surface runoff from the stockpiles, collected in a settling basin and discharged through filter cloth into the canal. The ditch surface shall be protected by seeding, and strawbale flow-checks will be provided at 250 m intervals, and before every culvert and intersecting ditch. When the grade of the ditch is steeper than 10%, rockfill check dam will be installed. No stockpile is within 5 m from any part of the tower structures or the location in plan of the overhead transmission lines. A temporary construction pad will be provided for holding materials suspect of contamination. The runoff will be suitably treated prior to discharge. Excavated materials suitable for aggregate production or other uses will be stockpiled separately.

As stated previously, the specifications for stockpiles are located in the Draft Design/Build Agreement and Concept Drawings and also in OPG's "Management of Excavated Material" dated December 2004 and OPG's "Management Plan for BTEX" dated December 2004. If the specifications in the Draft Design/Build Agreement and Concept Drawings prevail, then the following will be implemented. A temporary stockpile will be located between the canals and a runoff pond provide for runoff from the excavated materials. This will be used for specific contaminated materials from the tunnel excavation. The runoff will be pumped to the water treatment facility prior to final discharge. The runoff pond and the temporary stockpile will be lined with synthetic material or a minimum of an impervious material to eliminate ground contamination.

If the design is to meet the requirements in OPG's "Management of Excavated Material" and "Management Plan for BTEX", then certain rock formations have specific temporary and/or permanent storage requirements based on the information provided by the Reuse of Excavated Materials Committee. The limestones/dolomites above the Rochester Shale formation are to be segregated and stockpiled separately for reuse by the Project. The shales potentially containing BTEX (Rochester, Grimsby and Power Glen formations) are to be isolated permanently in the main disposal area with a perimeter drain leading to the retention pond. The Queenston Shale may be used by the clay/brick industry at a later date and therefore should be stored in the main disposal area separate from the other rock for easy access when required. All other rocks are to be placed in the main disposal area for permanent disposal separately from the other in this area.

The storage area for the excavated material potentially contaminated with BTEX will be approximately 400 m long by 100 m wide and will either have a compacted clay base or impermeable geotextile. Within this area, there will be a 10 m wide buffer area around the perimeter which will contain the drainage ditch/outside berm. The shale will be stockpiled in lifts less than 300 mm and the slope will be no greater than two horizontal to one vertical (2:1). The run-off will be directed towards the retention pond for treatment, if required.

7.1.5 Demolition of the Dewatering Structure

The existing dewatering structure at the PGS Canal is a 45 m long, 6 span reinforced concrete structure, with a 6.7 m wide walking surface on the top. The 5 piers in the water are tall concrete piers with a wide base but tapering up towards the top but all are up to 17 m in height and are sitting on the rock surface of the bottom of the canal, including some embedment into the rock stratum. It is not known whether the structure is manufactured from precast units, but from the information provided, there is definitely a possibility of this and as such it may help to remove the component in convenient chunks instead of breaking into small debris using a concrete breaker.

The 6 span openings are actually gate openings used to close the canal from the main HEP canal for dewatering purposes, though according to information provided to the Proponent, the structure has not been used. OPG provided additional information on the condition of the structure through inspection reports, and suggested that there are damages to certain parts of the structure especially at the abutments and one of the piers (pier 1), and does not use the structure for vehicular traffic anymore.

The method of demolition will be such as to minimize impact on the operation of the PGS and coordination with the timing and duration, as well as the proposed method of removal, will be discussed with OPG and agreed prior to implementation. Sufficient advance notification will be provided to ensure all preparative work be made and all affected personnel informed of the impending work.

The entire superstructure will be removed and the remaining abutment and exposed rock surface stabilized where necessary and where confirmed by the engineer. The pier will be removed up except the last 300 mm which should be intact and firmly fixed into the rock.

Debris catching device will be implemented together with use of barges, at the endorsement of OPG, to minimize concrete debris falling into the water. All sawcutting operations will be controlled and effluent removed using vacuum machine. Large cut reinforced concrete chunk will be removed by lifting from the banks and carting away in truck to designated disposal areas.

7.1.6 Waterline Relocation

During construction an existing waterline will be relocated from the existing PGS dewatering structure prior to the demolition of the structure. The relocation can either be a surface laid/ buried waterline laid along the banks of the PGS Canal, and cross the canal at the roadway located outside the PGS station, or on a new utility bridge over the canal at its existing location. Both alternatives will be evaluated, considering cost, timing, impact to other work, etc., and discussed with OPG staff prior to selecting the suitable approach.

The relocated waterline will be constructed to the same standards and details as the existing waterline.

7.1.7 Disposal

The disposal will be conducted in compliance with the Owner's Mandatory Requirements, section 3.

As stated above, the specifications for stockpiles are located in the Draft Design/Build Agreement and Concept Drawings and also in OPG's "Management of Excavated Material" dated December 2004 and OPG's "Management Plan for BTEX" dated December 2004. On-site permanent disposal of excavated material is required for rock from the Rochester, Grimsby and Power Glen formations and rock other than Queenston formation and limestones/dolomites. The Queenston shale will be temporarily stored at the main disposal area and the limestones/ dolomites will be reused. The section of the permanent disposal area storing the Rochester, Grimsby and Power Glen formations will be either lined with clay or geotextile to reduce potential soil and groundwater contamination. Runoff will be pumped back across the conveyor bridge to the water treatment facility prior to final discharge. The run off pond will be lined with synthetic material or a minimum of an impervious material to eliminate ground contamination.

Any excavated materials suitable for aggregate production will be stockpiled separately and used where applicable. Any surplus will be removed from the site at the end of the contract. No excavated material or discharge of water prior to treatment will be spilled or placed into any watercourse at the site.

8.0 DESIGN ANALYSIS

8.1 CODES, STANDARDS AND SPECIFICATIONS

The facilities will be designed in compliance with the codes, standards and specifications listed in Section 6 above.

8.2 DESIGN METHODS AND PROCEDURES

The civil works will be designed by using recognized methods and procedures, which include the established and industry standard software in performing in the installation of all work.

9.0 SEQUENCING OF THE WORK

The sequence of construction will be in compliance to the overall schedule provided with the submission. The construction of the temporary facilities will be prior to most activities taking place in support of the tunnel excavation and the intake and outlet structures.

10.0 CONSTRUCTION TECHNIQUES AND EQUIPMENT

The work will be completed utilizing standard construction methods. The use of excavators for grading, trucks for transportation of good and excavated materials when required. A conveyor system will be used to transport excavated materials from the outlet of the tunnel to the temporary and surcharge stockpiles. A water treatment facility will be used on site to treat any and all ground water generated for all construction activity. All equipment and their operation will be in compliance with the EMR and the OMR.

The equipment used for the demolition of the PGS dewatering structure include the use of sawcutting or flame cutting equipment, barges, lifting equipment and debris collecting setup. When necessary, underwater work may be required to retrieve concrete components submerged in the water at the bottom of the canal.

MH-3003-01
Outline Design Basis for Intake Sectional Service and Outlet Closure Gates, Hoists, and Guides

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project
Proposal No.: Tunnel Facility Project-001

Document: MH-3003-01

(Revised August 12, 2005)

Outline Design Basis for Intake Sectional Service and Outlet Closure Gates, Hoists, and Guides

August 12, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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1.0 INTAKE SECTIONAL SERVICE AND OUTLET

1.1 GENERAL

1.1.1 Intake Stop Log

1. One set of sectional service gates (Stop-Logs) with embedded parts and anchor bolts is to be installed inside the intake structure.
2. The embedded part is of two (2) parts design set in the secondary concrete in the intake structure. The load bearing face, seal face and top of the seal beam are type 304 stainless steel, machined after fabrication.
3. Six stop-Logs are required to close off the opening. They are to be lifted in place (or removed) by mobile crane. One (1) follower assembly for handling the stop-log will also be supplied. The stop-logs are to isolate the tunnel from upper Niagara River GIP at the INCW to facilitate tunnel dewatering by OPG.
4. Two (2) 350 mm valves are installed on the top log for use to fill the tunnel.
5. Installation facilities for the intake stop log to enable installation work to be performed above water will include a custom-designed follower structure (as above), as well as a guiding system to permit accurate installation of each intake stop log using a mobile crane. The design of the guiding system will be finalized during the detailed design stage, but the following 2 options will be considered:
   a. Modification of the existing frames for the INCW stop logs to include external top and bottom guiding beams, and provision of new guiding slots in new approach walls and pier extensions to accommodate these modified structure. The details of the existing stop log will be carefully studied to ensure the modified INCW stop logs can function both as a stop log for the INCW gate, as well as a guide for installation of the new tunnel intake stop logs. This method has the advantage of minimizing the storage requirements by OPG.
   b. A specially fabricated steel guide structure complete with walkways to be bolt-connected to the top of the slot in the roof of the intake structure for insertion of the stop logs. This structure will rise above water level to allow workers / OPG employees to control the stop log installation process from the surface.

1.1.2 Outlet Closure Gate, Hoists and Structure

1. One vertical lift, wheeled outlet closure gate with heated embedded parts and anchor bolts will be installed inside the discharge structure. This gate is stop the flow in the tunnel and to prevent admission of water from the canal into the tunnel during dewatering.
2. The embedded parts are of the two-part design that will be set in the secondary concrete. One bolted splice will be installed in the roller path. The roller path is fabricated of hardened stainless steel ASTM A693, Type 630 H1100 and machined after fabrication. The vertical and lintel seal face are type 304 stainless steel, machined after fabrication. Six (6) heaters per gain will be installed down to elevation 163.50 m.

3. The outlet closure gate is a five (5) sections, articulated type, vertical lift gate with four (4) wheels per section. The embedded track is heated with gain heating elements embedded inside the concrete structure.
4. A dual drum wire rope hoist, driven by one 7.5 kW (10 hp) electrical motor is installed to operate this gate. The cable hoist is located inside a hoist bridge and housing mounted on top of two steel tower structures (one stair tower and one maintenance service bay tower). The steel structure is erected above the outlet structure. One air brake is also installed allowing the gate to be lowered, un-powered, under gravity and at regulated speed.
5. One 5-ton hoist and monorail will be supplied and installed in the maintenance tower and hoist bridge.
6. Insulated metal cladding, doors, louvers, windows, translucent panels and associated hardware will be supplied and installed. Roof will be sloped metal deck.

1.1.3 Outlet Stop-Log (Embedded Part Only)

1. One set of Stop-Log embedded parts with anchor bolts (embedded inside the discharge structure) is to be installed downstream of the discharge gate. Stop-Logs will not be supplied for this gate. The embedded parts are installed in case there is a need to stop water entering the tunnel from the canal.
2. The embedded part is of two (2) parts design set in the secondary concrete in the outlet structure. The load bearing face, seal face and top of the seal beam are type 304 stainless steel, machined after fabrication.

1.1.4 Miscellaneous

1. All sealing surfaces and gate roller paths are stainless steel. All three sets of embedded parts are two-part design and to be set in secondary concrete. The load bearing face and seal face, the lintel and the top of the sill beams are of type 304 stainless steel.
2. The outlet closure gate proposed is a 5-part articulated gate. All 5 individual gates are completely shop assembled including seals. The sections will be field connected by link bars and pins. With this arrangement, the top gate can be lifted against downstream pressure by approximately 200 mm to fill the tunnel.
3. The gate structure material will be made of grade 300 and/or 350 WT Cat. 1 structural steel. The wheels are forged 4145 material, crowned and fitted with 'Timken' tapered roller bearing. Guide shoes will be installed instead of guide wheels.
4. The outlet gate will be sealed against pressure from either side with rubber seal applied on all four sides. The J seal on the sides and the double stem seal on the lintel are Teflon covered. The seals are bolted on with galvanized steel clamp bars and stainless steel bolts. The bottom of the skin plate and all seal mounting faces are machined. Holes for the axels are bored.
5. The hoist bridge and towers are covered with insulated metal sidings with windows, service door; personnel door, steel stair will be installed on the towers for access to the hoist tower.
6. Access ladders and railing around the outlet gate and stop-log opening will also be installed.
7. Electrical control panels for hoist and heaters will be installed inside the hoist house.

8. The intake and outlet gates will be sandblasted to bare metal and shop painted after fabrication.
9. The hoist house interior will be heated and ventilated per Ontario Ministry of Labour, ASHRAE and NFPA standards and requirements.
10. Adequate lighting will be installed inside the hoist house, stairs, tower, and on the outside walls of the tower structure.

1.2 DESIGN PARAMETERS

1.2.1 General

The design of the intake stop-log and the discharge control gate is in accordance with Section 7 of the Owner's Mandatory Requirements as part of the Proposal Invitation document.

1.2.2 Basic Design Parameters

Basic design parameter are outlined as follows:

1. Intake Stop-Log

Tunnel Internal Width	=	12.78 m
Lintel Elevation	=	147.03 m
Sill Elevation	=	132.27 m
Opening Height	=	14.55 m
Normal Maximum Water Level	=	171.65 m
Normal Minimum Water Level	=	170.74 m
200 Years Flood Level	=	172.11 m
PMF	=	173.17 m

2. Outlet Closure Gate

Tunnel Internal Width	=	12.78 m
Lintel Elevation	=	164.50 m
Sill Elevation	=	148.62 m
Opening Height	=	15.88 m
Normal Maximum Water Level	=	169.80 m
Normal Minimum Water Level	=	164.20 m
200 Years Flood Level	=	172.11 m
PMF	=	173.17 m
Surge Water Level at Discharge	=	180.00 m

3. Wire Rope Hoist

Rated Capacity	=	1,560 kN

		(350,000 lb)
Lifting Speed	=	0.16 m/min.
Lowering Speed (Powered)	=	0.16 m/min.
Lowering Speed (Un-powered/Fan)	=	0.31 m/min.
Motor	=	7.5 kW (10 hp), TEFC
Brake	=	Drum Brake
Reducer	=	Flender
Rope	=	30 mm (1-1/2") dia. EIPS GALV. IRWC
Rope Breaking Load	=	890.75 kN (200,000 lb)
Rope Factor of Safety	=	9.70 @ Rated Capacity @ maximum Motor Torque
Drum Diameter	=	1219 mm (48")
Sheave Diameter	=	914 mm (36")

4. Hoist Control

One control panel will be supplied and installed inside the hoist housing. Controls include:

- Raised/Stop/Lower and Emergency Lower Push Button
- One Local/Remote/Maintenance selector switch
- Pilot light for Power On; Gate Raising; Gate Lowering; Gate Close; Gate Fully Open
- Limit Switches for Lower Position (rotary type); Upper Limit; Dogging Position; Anti-Creep;
- Slack Rope and Power Over-Travel Switches

1.3 INSTALLATION AND COMMISSIONING

1.3.1 Embedded Parts

1. Three (3) sets of embedded parts with anchor bolts will be shipped to site for installation in the intake and discharge concrete structure. The installation will be the responsibility of the gate manufacturer and supplier.
2. The gate supplier will also apply secondary concrete ensuring proper alignment of the embedded parts.

1.3.2 Intake Stop-Log

The Stop-Log sections will be dry tested. They will be lifted in place and removed under dry condition. Upon completion of the construction and after the tunnel is filled and the gate is submerged, the gate manufacturer will assist in lifting the Stop-Log sections, removing them from the inlet structure. The gate supplier will also assist to install the slot cover after removing the Stop-Log.

1.3.3 Outlet Closure Gate

The outlet closure gate, along with the hoist structure; housing; access ladders; railing and heater and hoist controls will be installed by the gate supplier. The gate supplier will also commission the gate hoist ensuring proper operations of the closure gate.

1.4 SHOP DRAWINGS AND O/M MANUALS

1.4.1 Shop Drawings

Manufacturer's Shop Drawings indicating details of the gate design and construction will be provided by the gate manufacturer and submitted to OPG for review, acceptance and records. Prior to the completion of the project, Operating and Maintenance manuals will be submitted to OPG for records.

1.4.2 Codes and Standards

OBC	Ontario Building Code
AISC	American Standards Association
	Specification for Structural Steel Building
AISE	The Association for Iron & Steel Technology, Technical Report 6
CSA	Canadian Standards Association
	STD B167 – Safety Standard for Maintenance and Inspection of Overhead Crane
AGMA	American Gear Manufacturing Association STD 6010-F97 – Method for Specifying the Geometry of Spur and Helical Gear, and Standard 420.04
CMAA	Crane Manufacturers Association of America, Specifications 70

The design shall also comply with the Owner's Mandatory Requirement as provided during preparation of proposal of the project.

MH-3004-01
Outline Design Basis for Electrical and Mechanical Services

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-3004-01

Outline Design Basis for Electrical and Mechanical Services

May 11, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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1.0 ELECTRICAL SERVICES

1.1 POWER SUPPLY

1.1.1 Supply To Outlet Structure – Permanent Service (Hoist Tower)

Power Sources

1. Power to the site can be provided from one of the existing overhead lines installed in proximity of the site. One of the lines is a 27.6 kV circuit assumed to have sufficient capacity to carry the permanent electrical load of the outlet shaft structure.
2. The line referred to runs in a north-south direction, approx. 1.5 km west of the site of the proposed outlet shaft.

Transmission

1. Power needs to be brought to the site of the proposed outlet shaft via a three-phase pole line, approximately 1.5 km long. Spacing of the poles is anticipated to be approx. 60 m, resulting in a total number of approximately 26 poles. Connection of the spur line to the 27.6 kV supply line shall be carried out by OPG/Hydro One.

Termination

It is proposed that a pad-mounted transformer be provided at the site of the outlet shaft. The transformer shall be rated 225 kVA, 27.6 kV – 600/347V, 3-phase. Transformer's feeders shall as follows:

Primary:

- 3 fuse cut-outs at the dip pole
- 3 lightning arresters, pole mounted
- 3 cable terminations
- 3-#1 AWG, 28 kV, concentric neutral cables in 3-100 mm PVC conduits – cca. 25 m

Secondary:

- 4-350 MCM RW90, 1000 V insulation, in 100 mm rigid PVC conduit, cca. 10 m

1.1.2 Supply To Tunnel Outlet Shaft Portal – Construction Power Service

Power Source

It is proposed that the construction power service be derived from the 110 kV line available at the south of the site. Approximate location of connection point is 500 m south-east of the site of the outlet shaft. Given the proximity to the transformer station where the line originates, it is assumed that ample capacity exists in this feeder to provide for the construction power

requirements, estimated at 13.3 MW. This shall be verified by the Contractor at the commencement of the construction.

Termination

An on site (temporary) substation shall be constructed and shall contain the following components:

- 2-7.5 MVA, 110 kV-4.16/2.4 kV power transformers, outdoor, pad mounted
- Supporting structure for incoming protection & metering equipment
- 5 kV Class secondary switchgear, c/w:
  - 2 main (incoming) switches
  - 1 tie switch
  - 6 feeder switches (tunnelling equipment & support systems + site support/services systems)
- 1-2000 kVA, 4.16 kV-600/347 V pad mounted transformer
- 600/347 V, 2500A low voltage switchgear, outdoor type (or installed in a container/shed), c/w:
  - 2500 a main breaker
  - 6-1600 A/800 AT breakers (for WTP, site office/store, crane, cooling water system etc.)

2.0 MECHANICAL SERVICES

2.1 HEATING AND VENTILATION (HOIST TOWER)

2.1.1 Heating

1. Heating in the form of electric baseboard heaters and wall mounted electric cabinet heaters with built-in thermostatic control will be installed inside the outlet closure gate hoist tower and housing.
2. The heating system will be designed to maintain the indoor temperature at 10^{o}C (50^{o}F) during the heating seasons. This feature is in compliance with the OBC requirements, and to prevent freezing inside the hoist house. Heating will also prevent condensation on electrical and mechanical equipment and ensuring reliable operations of the electrical and mechanical equipment.

2.1.2 Ventilation

Gravity ventilation in the form of strategically located, and appropriately sized louvers will be installed in the hoist house. Sufficient air is designed to circulate through the hoist house maintaining the indoor air temperature at not higher than 6ºC (10ºF) above the outdoor air temperature in the cooling seasons. The feature is to avoid possible accumulation of foul gas and/or odour.

2.1.3 Design Conditions

Indoor Conditions:

- Heating Seasons 10ºC (50ºF) Maximum

- Cooling Seasons 6ºC (10ºF) Higher than Outdoor Air Temperature

Ambient (Outdoor) Conditions:

- Heating Seasons -5ºC (23ºF) ASHRAE 99.6%
- Cooling Seasons 28ºC (82ºF) DB ASHRAE 0.4%
  21ºC (70ºF) MWB

2.1.4 Plumbing And Drainage

1. Provision is made for the installation of one washroom inside the hoist house.
2. The facility will include one water closet, one lavatory and one electric hot water heater.
3. Domestic water pipe shall be installed connecting the washroom to a nearest Municipal domestic water main. We will also install sanitary drain line connecting the washroom to a nearest Municipal sanitary main.
4. Vent stack and trap-seal-primer will be installed preventing sewer gas from migrating into the washroom.

2.1.5 Code And Standards

1. OBC - Ontario Building Code
2. ASHRAE - American Society of Heating, Refrigerating and Air Conditioning Engineers
3. AMCA – Air Movement and Control Association International
4. ANSI – American National Standards Institute
5. AWWA – American Water Works Association
6. CSA – Canadian Standards Association
7. NFPA – National Fire Protection Association
8. SMACNA – Sheet Metal and Air Conditioning Contractors' National Association

2.2 CONSTRUCTION/SEQUENCING OF THE WORK

The construction will be undertaken using standard construction techniques and standards for the industry. The sequencing will be established to support the overall scheduling of the project.

PR-00-3001, Rev 1
Outline Design Basis and Method Statements

ONTARIO POWER GENERATION
OPG

NIAGARA TUNNEL FACILITY PROJECT

Outline Design Basis and Method Statements

August 2005

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REVISION

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Rev.	Date	Issue, Modification	Prepared	Checked	Approved

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1 GENERAL

1.1 General Project Overview

Ontario Power Generation (OPG) is implementing the Niagara Tunnel Facility Project aiming to bring water from the Niagara River to an existing storage reservoir. The key elements of the project are:

- Intake Structure and Channel
  approx. 200 m long
  approx. 20 m wide
  up to 30 m deep

- Delivery Tunnel
  approx. 10.4 km long
  approx. 12 m internal diameter

- Outlet Structure and Canal
  approx. 400 m long
  approx. 20 m wide
  up to 35 m deep

In addition a dewatering system consisting of 5 vertical shafts with approx. 0.8 m internal diameter, dewatering pipe and culvert is planned. The tunnel shall also be monitored by piezometers and extensometers during operation. Gates are to be situated at the Intake and Outlet. Also new guiding walls are required in the river upstream of the Intake.

It is planned to transfer 500 m^3/s of water with the tunnel facility to the reservoir. The operational time of the facility will be 90 years. It shall be capable of being opened and closed as required. Also dewatering of the facility shall be feasible at unspecified intervals to facilitate maintenance. The intake and outlet structures of the Niagara Tunnel facility are to be located at fixed points. A corridor is provided in plan for the New Diversion Tunnel (No.3), which basically runs parallel with the two existing Diversion Tunnels No. 1 and 2. One other constraint is for the New Diversion Tunnel (No. 3), that subject to the Environmental Assessment Approval no permission is currently given for crossing through the buried St.' David's Gorge. The alignment grade for the tunnel is to be selected such, that crossing under the gorge is realized. At least 100 m of ground overburden have to be considered as a result of such deep alignment. In addition regional swelling and squeezing phenomena and highly aggressive saline groundwater have to be taken into account for implementation of all structures associated with the project.

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1.2 Scope

The outline design basis and method statement covers primarily aspects of tunnel design (hydraulic design, geotechnical design, civil design, structural design etc.) and the design of associated structures, which are

- Diversion Tunnel
- Intake Structure
- Outlet Structure
- Outlet Canal
- Dewatering Shafts, Pipe and Culvert
- Permanent Instrumentation (i.e. tunnel piezometers and extensometers)

Design basis and method statements associated with

- accelerating walls at the intake
- temporary facilities
- roads and parking areas
- rail road trackage and sidings at the outlet area
- fencing, gates and barriers
- stockpiles and water treatment facilities
- cofferdams and temporary docks
- demolition and disposal

are covered elsewhere in the Proposal.

The following aspects of design and construction shall be covered with this document:

- layout of works
- design approach
- codes and standards
- specifications
- construction techniques

Construction aspects associated with

- equipment
- sequencing of the Work and
- layout of construction facilities

are covered elsewhere in the Proposal.

Emphasis is given, that the design basis and construction methodology specified herein is organized such to address the Owner's Mandatory Requirements.

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1.3 Preliminary Design and Construction Considerations for the Diversion Tunnel

1.3.1 Diversion Tunnel Alignment

The Proposal design follows the concept alignment in principle. Only below the buried St' David's Gorge, the alignment is slightly relocated to the north-west to gain maximum rock cover, which is predicted close to the location of geotechnical borehole SD-8. Horizontal and vertical curvature is arranged such to maintain a min. 1000 m radius for to facilitate muck transportation by conveyor belt systems. In addition the alignment close to the existing outlet structure is moved away from underneath the existing Delivery Tunnel No. 1, to facilitate the drilling of the borehole for tunnel piezometers.

The overall depth of the tunnel has been slightly reduced as compared to the concept design. The inclination of fall and raise of the grade near the outlet and intake of the facility is arranged slightly shallower as in the concept design. The dewatering structure has also been moved further away from the buried St' David's gorge as compared to the concept design. A potential fourth Diversion Tunnel may be arranged in parallel to the proposed alignment route.

1.3.2 Diversion Tunnel Lining

Originally two lining alternatives for the Diversion Tunnel have been investigated by the Proponent:

- Single shell lining with precast concrete segments
- Double shell lining with an initial lining of shotcrete, ribs and rock bolts and a final lining of cast in place concrete. Both linings being separated by a waterproofing membrane system.

Although easier to apply in combination with a Tunnel Boring Machine (TBM), the single shell lining alternative has been abandoned for the following reasons:

- The surface roughness of precast segments (K_s = 75 – 80) is inferior to cast in place concrete (K_s = 85 – 90) according to Strickler (see chapter 2.3).
- Although compressible annular grouting mortar is available to compensate deformations resulting from rock squeeze, it is not possible to hold the operational internal water pressure in segmental lining rings. Water could escape through segment joints at pressures up to 14 bar and could adversely affect the rock of formations, which are sensitive to water. High swelling pressures or even worse, erosion of ground around the tunnel would be the undesirable result.
- It cannot be guaranteed, that uniform grouting of the annulus around the segmental lining ring is achieved, since rocks falling from behind the shield of the TBM into the

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annular gap may caurse shadowing and voids when grout is injected. No controlled prestress of the segmental lining ring is possible.

- Many lining segments can be damaged during fabrication, transportation and erection. Either an economical loss or restrictions in durability are the result of rejected segments or massive repairwork.

For such reasons the double shell lining option is the preferred proposal. The cast in place lining solution provides also the following advantages:

- Flexibility with respect to internal diameter. With an expandable steel formwork, sections of minimum rock support requirements may be utilized to adjust the tunnel diameter to provide maximum flow rates.
- The arrangement of a waterproofing membrane between initial lining and final lining prevents the aggressive groundwater to get in contact with the final lining concrete.
- The installation of a comprehensive interface grouting system enables to compress the final concrete lining such, that internal water pressure is held without the lining concrete being cracked in tension. Hence the requirement of steel reinforcement can be eliminated for the final lining. The tunnel structure is tightly embedded into the rock and the enormous interactive load bearing capacity of ground and structure is consequently mobilized.

1.4 Durability Aspects

1.4.1 Service Life and Constraints

The operational design life for the Niagara Tunnel Facility Project shall be 90 years. No outage of the Diversion Tunnel shall occur during such period. The tunnel lining has to resist

- acid and sulphate attack from an unfavourable environment
- high internal and external pressures from ground and water
- the abrasive action of water, ice and debris

within this operational time period.

1.4.2 Design and Construction for 90 Years Service Life

In vision of the extraordinary challenge to meet the specified requirements for a service life of 90 years, the following design aspects have been determined to serve the purpose:

- Construction of a double shell lining instead of a single shell lining. The initial rock support is timely separated from final lining erection, which improves the quality of the final structure in total.

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- Separation of the final lining from the aggressive environment by a waterproofing membrane system. The waterproofing system is vacuum tested to ensure reliable performance. Any exchange of water or chloride between inside and outside of the tunnel is inhibited.

- Tight connection between final structure and the surrounding rock mass to mobilize the load bearing capacity of the rock for the 90 year operation requirement. By no means it shall be allowed that rocks and debris is washed out and voids behind the lining are created. The tight connection is achieved by contact grouting, interface grouting and cavity grouting where required.

- Prestressing of the final lining to create a compressed concrete support ring, which is able to sustain internal waterpressure without steel reinforcement being required. The risk of corrosion for reinforcement within the 90 years design life is such eliminated. The prestressing of the tunnel with interface grouting takes the rock mass surrounding the tunnel close to its original stress state and reduces or eliminates adverse time dependent deformations of the rock mass.

- Design of the concrete structures against uplift uses the self weight of the structure only. Long term rock deformations, which cannot be controlled by stress resistance of the concrete structure are compensated without exerting additional load by a compressible material placed between structure and rock. Overstressing of the concrete during the 90 years of specified operation is therefore avoided.

- In general materials shall be used, which are
  -- recorded over a design life of 90 years (i.e. concrete, grout etc.)
  -- tested to serve over a design life of 90 years (i.e. membrane materials, coated steel etc.) in accordance with OMR requirements
  -- easy to maintain or exchange if necessary (i.e. sill gates, tunnel piezometers, etc.)

1.4.3 Comprehensive Durability Testing

The testing of materials will be phased in

- testing by the manufacturer against specified performance criteria (base product quality)

- testing on site against particular application criteria (applied product quality)

- testing of sections of the completed structure or product where possible (final product quality).

Hence a high degree of quality assurance will be ensured to achieve the specified product quality required for the 90 years design life of the facility.

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2 HYDRAULIC DESIGN

2.1 Water Surface Elevations

Water surface elevations to be prepared on the basis of NAD 83.

2.2 Hydraulic Design Approach

The hydraulic conveyance system extends from the intake structure at the GIP to the outlet water level gauge in the outlet canal and includes the intake channel, the intake structure, the tunnel, the outlet structure and the outlet canal to the point immediately upstream from the transition at the junction with the PGS channel. The discharge of the conveyance system will be measured and calibrated considering the head of energy losses between the upstream and downstream level gauges.

The tunnel conveyance system will be designed, detailed and constructed to provide the optimum hydraulic efficiency. This is valid also for the construction of the inlet- and outlet structure and for the outlet canal.

The tunnel will be capable of delivering a GFA with the hydraulic head and energy grade design level defined in Appendix 1.1(aa) to the Design/Build Agreement considering the hydraulic conveyance system defined in Section 8.2(1).

Transient load analysis has been performed based on powered and unpowered closure rates for outlet gate and appropriate intake and outlet water levels. The analysis is provided in chapter 2.4 of this document.

Loads determined from the transient load analysis will be used for input into the design of the outlet gate and structures and tunnel liner. The outlet surge shaft will be sized to limit the transient load while retaining the upsurge water level within the confines of the shaft.

2.3 Steady Flow Conditions

2.3.1 References

For calculation of the steady flow conditions the following literature has been used:

[2.1] Press, Schröder: Hydromechanik im Wasserbau, 1966, Verlag W. Ernst&Sohn

[2.2] Gerhard Seeber: Druckstollen und Druckschächte, 1999, Georg Thieme Verlag

[2.3] Schneider: Bautabellen für Ingenieure, 11. Auflage, 1994, Werner Verlag

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[2.4] Bemessungsblätter (tables for calculation) by TIWAG (Tyrolean Hydro Power Company)

[2.5] Ven Te Chow, Open Channel Hydraulics, McGraw-Hill Book Company, 1959

2.3.2 Diversion Tunnel

2.3.2.1 Selection of the formula for calculation of the flow losses in the tunnel section

Acc. to [2.2], the flow losses in pressure tunnels are mostly calculated using the formula of Strickler, but if it is in the range of application, the calculations would be more exactly using the formula of Prandtl-Colebrook.

Using the basis data for the tunnel of the Niagara project, it can be shown, that the formula of Prandtl-Colebrook reached its limit and gives wrongly sometimes negative roughness coefficients.

Hence the Strickler-Formula is better used for calculations of flow losses in such cases.

Therefore the formula of Strickler has been applied for the calculation of flow losses in the Diversion Tunnel.

2.3.2.2 Roughness coefficients as given in the literature

The literature provides the following coefficients for the Strickler formula for tunnels with final concrete lining:

a) In [2.1] Table 17, page 281, coefficients acc. to Strickler formula:

- Geschliffener Zementputz größter Glätte K = 100
  (polished cement liner, maximum smoothness)
- Betonstollen und Eisenbetondruckrohrleitungen, glatt, sehr sorgfältige Ausführung, unversehrter Glattputz K = 85 bis 95
  (concrete lined tunnels and concrete pressure pipes, smooth, very thorough finish)
- Betonstollen von weniger sorgfältiger Ausführung k = 70 bis 80
  (concrete lined tunnel, less thorough finish)

b) In [2.2] page 22, coefficients acc. to Strickler formula:

- Spritzbeton, je nach Dicke und Ausbruchsart, mechanisch Kst = 50 bis 65
  (shotcrete, depending on thickness and excavation type, mechan.)
- Schalbeton (Stahlschalung) Kst = 80 bis 90
  (concrete with steel formwork)
- Panzerung mit Anstrich Kst = 90 bis 110
  (steel lining with painting)

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c) In [2.3], page 13.21, table Manning-Strickler coefficients:

- **Beton: Druckstollen, sorgfältige Ausführung: Kst = 85 bis 95**
  (pressure tunnel with concrete inner lining, thorough finish)

d) In [2.4] Calculation diagrams of the TIWAG (Tyrolean Hydro Power Company)

- Reibungsverluste für Kreisprofile nach Strickler, Ks = 85 (Betonauskleidung, Stollen)
  (Friction losses for tunnels, concrete inner lining)
- Reibungsverluste für Kreisprofile nach Strickler, Ks = 100 (Stahlauskleidung, Schächte)
  (Friction losses for shafts, steel lining)

e) In [2.5], table 5-6, values of the roughness coefficient „n":

- Concrete, "finished" "n" between 0.011 and 0.014, typical = 0.014

"n" means 1/Kst, therefore the coefficient Kst is between 71 and 91, typical 83

2.3.2.3 Roughness coefficients used for calculation

Summary for the coefficients as given in the literature

Literature	Description	Roughness Coefficient
[2.1]	Tunnel, concrete inner lining, smooth, very thorough finish	Kst = 85 to 95
[2.2]	Pressure tunnel with steel formwork	Kst = 80 to 90
[2.3]	Pressure tunnel with concrete lining, thorough finish	Kst = 85 to 95
[2.4]	Tunnel with concrete lining	Kst = 85
[2.5]	Concrete "finished"	Kst = 71 to 91, typical = 83

It is assumed, that according to these coefficients (given in the literature) the Contractor will certainly achieve a roughness coefficient of Kst = 85 in the concrete lined Diversion Tunnel when using a steel formwork with a thorough finish. Depending on other parameters like the length of the formwork section and the thorough execution of the transition from one formwork section to the other, perhaps a higher coefficient could be achieved (range up to Kst = 90)

But as a conservative approach, the roughness coefficient of Kst = 85 is applied to the tunnel section.

2.3.2.4 Transition at change of thickness of inner lining

According to [2.1] the losses for a gradual dilatation into a larger cross section can be calculated as:

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$z = c \times (1-(F2/F1))^2$

Whereas c = Correction factor (at 8° degree: 0.15 to 0.20)
and F1 and F2 is the area of cross section before and after the dilatation.

Example for a dilatation of the inner ling of 0.2m:

- D1 = 12.00m, F1 = 113.1m2
- D2 = 12.40m, F2 = 120.8m2
- Flow assumed 500 m3/s, therefore at F2 flow velocity v = 4.14 m/s
- c = 0.20

Result: z = 0.0009 and the flow losses hv = 0.0008m, which is negligible.

For a gradual dilatation into a smaller cross section the flow losses are negligible (acc. to [2.1])

Conclusion: If the dilatation is gradually and slow (e.g. does not exceed 8°), the losses at the transition can be neglected.

2.3.3 Channels

2.3.3.1 Formula for calculation of the flow losses in the intake channel and the outlet canal

For the calculation of the hydraulics of the channel the formula of Strickler has been used.

2.3.3.2 Roughness coefficients given in the literature

a) In [2.5], page 110, table 5-6, the roughness coefficients "n" (which is 1/Kst) are provided for:

Channel, Rock cuts:

- smooth and uniform: "n" = minimum 0.025, typical 0.035, maximum 0.04
- Jagged and irregular: "n" = minimum 0.035, typical 0.040, maximum 0.05

This results in Kst-coefficient for the Strickler formula of:

- smooth and uniform: Kst = minimum 25, typical 28.6, maximum 40
- Jagged and irregular: Kst = minimum 20, typical 25, maximum 28.6

b) In [2.3], page 13.21, the following roughness coefficients are listed for rock excavations:

- Rough excavation: Kst = 15 to 20
- Medium rough excavation: Kst = 25 to 30
- Rock excavation, well cut or bored: Kst = 45 to 50

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2.3.3.3 Roughness coefficients used for calculation

It is assume that the excavation will be smooth and uniform and with respect to [2.3] considered a well prepared "medium rough excavation"

Therefore we assume that the excavation for the outlet canal can be modelled with a coefficient of Kst = 30 acc. to the Strickler formula.

The flow at the intake channel is actually 3-dimensional, which is not considered by the formula of Strickler. Therefore a reduced coefficient of Kst = 25 (instead of Kst = 30) is applied at the intake channel to consider possible additional losses in this section.

(Flow losses are 4 cm at Kst = 30 compared to 6 cm for Kst = 25 at the intake channel).

2.3.4 Intake- and Outlet Structure

2.3.4.1 Formula for calculation of the flow losses

For the calculation of hydraulics in the intake- and outlet structures, again the formula of Strickler is used. The calculations have been performed on vertical cross sections.

2.3.4.2 Roughness coefficients presented in the literature

a) In [2.1], page 281, table 17, the following roughness coefficients are presented for concrete.

"Smooth and undamaged liner, smooth concrete with high content of cement: Kst = 80"

b) In [2.3], page 13.21, the following roughness coefficients are listed for concrete:

- Concrete, wood formwork: Kst = 65 to 70
- Concrete, steel formwork: Kst = 90 to 100

2.3.4.3 Roughness coefficients used for calculation

The assumption is, that the surface of the structures can be cast smoothly although some of the surfaces are not flat but curved.

Therefore we assume that the surfaces of the intake- and outlet structures can be modeled with a coefficient of Kst = 80 for the Strickler formula.

2.3.5 Summary of Roughness Coefficients

The formula of Strickler has been used for the calculation of the flow losses for steady flow conditions for the entire water transfer facility. The calculations acc. to Strickler are carried out using vertical cross sections. It has to be noted, that with the used mathematical model (based on the Strickler formula) 3D- flow and associated losses are not considered. However

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the calculation results are still suitable to represent the flow of water, since the losses, which are not considered will be comparatively small and therefore negligible.

The following roughness coefficients are used:

Intake Channel:	Kst = 25
Intake Structure:	Kst = 80
Diversion Tunnel:	Kst = 85
Outlet Structure:	Kst = 80
Outlet Channel:	Kst = 30

Since the transition between different thicknesses of final lining is gradually and slow (e.g. does not exceed 8 ° of opening angle between two cross sections of different size), the flow losses due to the transition are neglected in the tunnel section.

2.3.6 Hydraulic Analysis for Steady Flow Conditions For the Entire Conveyance System

The entire conveyance system has been calculated by computer using the formula of Strickler and the roughness coefficients as stated before.

The base data for the steady flow conditions are:

- H_{ref} (as defined in Appendix 1.1(aa) to the Design/Build Agreement) = 5.60 m.
- The layout of the conveyance system is defined in the Proposal Drawings.
- Roughness as defined in the previous chapters.

The result of the calculations is a discharge of 502 m^3/s for the Proposal.

The printout of the computer calculation results is included in the Appendix 2.1.

2.4 Unsteady Flow Conditions (Transient Load Analysis)

2.4.1 General

For unsteady flow conditions in the conveyance system the operation of the gate in the outlet structure has to be investigated. For lowering the gate two load cases have to be investigated: the powered lowering (max. speed 0.16m/min) and unpowered lowering (max. speed 0.31 m/min). Additionally the load case for raising the gate (max. speed 0.16m/min) has been investigated.

To cover also unfavourable load cases, the maximum discharge for calculation of the unsteady flow conditions was assumed with 550 m^3/s.

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The aim of the calculations is to prove that the assumed lowering and raising times and the closing laws of the gate are suitable to retain the upsurge water level within the confines of the surge shaft at the outlet structure.

It has to be noted that for the calculation for the unsteady flow, the closing characteristics for the gate has been assumed. In the detailed design phase the unsteady flow calculations have to be repeated using the manufacturer's real characteristics of the gate which will be installed.

2.4.2 Computation Method, Software

The transient analyses have been performed using computer software developed by ILF, the efficiency of which has been proven in numerous projects. Large water transmission systems, hydropower stations as well as crude oil and products pipelines have been studied.

The computer software is based on the "method of characteristics".

2.4.3 Computation Procedure

In general the following procedure is adopted:

Starting from a pre-defined steady state condition, the hydraulic behaviour of the system is calculated reviewing different events which might disturb the steady state condition.

Possible disturbances might comprise:

- Scheduled or unscheduled gate valve closure during operation
- Scheduled system shut-down
- Scheduled system start-up
- etc.

The load cases selected for this report were those which result in maximum or minimum pressures in the system, or show special behaviour of the system under transient conditions.

The computations always comprise the entire hydraulically active system.

2.4.4 Mathematical Model

The hydraulically active system has been converted into a numerical (= mathematical) model which conduces as input model for the computer software. The mathematical model includes respectively describes all necessary system parameters like tunnel diameter distribution, liquid properties, levels and stations, e.g. as well as characteristics for all hydraulic relevant equipment like surge shafts, valves, etc.

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2.4.5 Presentation of Computation Results

The computation results are presented by:

- Computer Prints, Hydraulic Profiles, "Situation at Time"
  The printouts show the actual flow rate, the actual minimum and maximum pressures for the system nodes and the actual status of equipment at a precise time point.
- Computer Prints, "History of Events"
  The printouts show the development of pre-selected values during the calculation

2.4.6 Load case 1: "Gate Hoist Lowering Powered (max. speed = 0.16 m/min)"

2.4.6.1 Basic Data

The following basic data have been used:

Maximum speed of lowering:	0.16m/min
Discharge at start of the calculations:	550 m^3/s
Roughness of tunnel lining:	ks = 0.028 mm (acc. to Prandtl Colebrook) (corresp. K=85 acc. to Strickler at the given conditions)
Valve type:	gate valve
Valve inside diameter:	15.88 m
Valve design pressure:	ASME 150

2.4.6.2 Result

For to retain the upsurge water level within the confines of the surge shaft at the outlet structure a two-speed closure has to be considered.

Closing speed 1:	5955 sec
Point of speed change:	12% remaining open position
Closing speed 2:	38830 sec
Closing time 1 (100% to 12%)	5240.4 sec
Closing time 2 (12% to 0%)	4659.6 sec
Total closing time (100% to 0%)	9900 sec = 165 min
Max. water level in the surge shaft:	179.52 m
Min. water level in the surge shaft:	167.49 m

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2.4.6.3 Computer Printout's of the Computation Results

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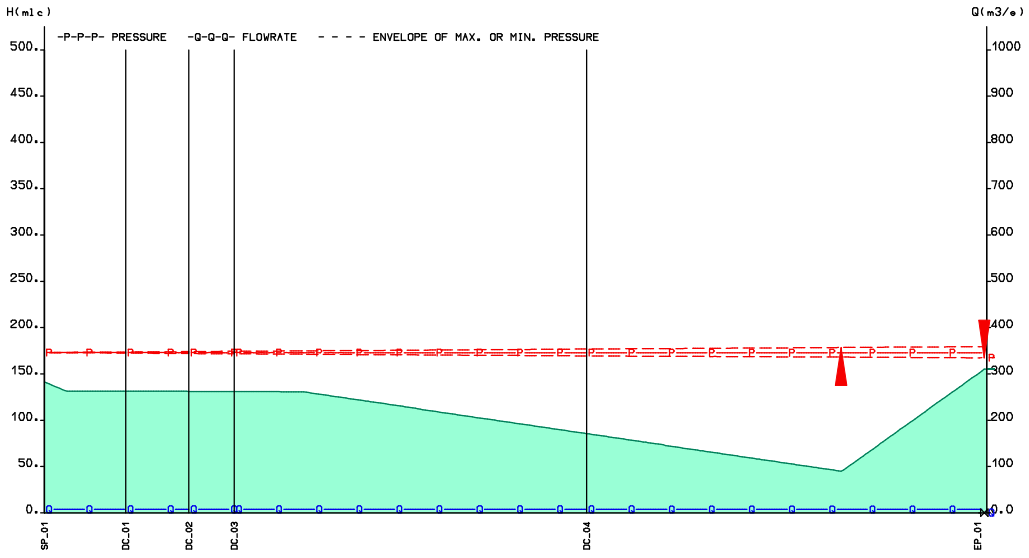
TRANSIENT HYDRAULIC STUDY, ILF 19-04-2005, A.HEINZ



Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING POWERED (max. 0.16m/min)

TIME(SEC): 10000.01

MAOP-pmax:km= 8.815 ,MAOP= 399.45,pmax= 13.08,%MAOP= 3.27
pmin-ELEV:km=10.400 ,ELEV=155.03 ,pmin=1.15

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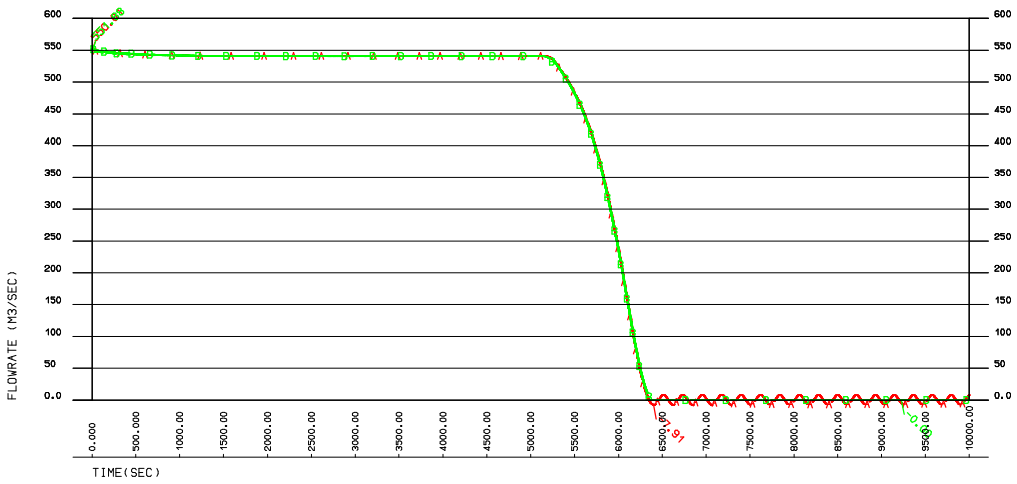
NIAGARA TUNNEL FACILITY PROJECT
TRANSIENT HYDRAULIC STUDY, ILF 19-04-2005, A.HEINZ



HISTORY OF FLOWRATES

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING POWERED (max. 0.16m/min)

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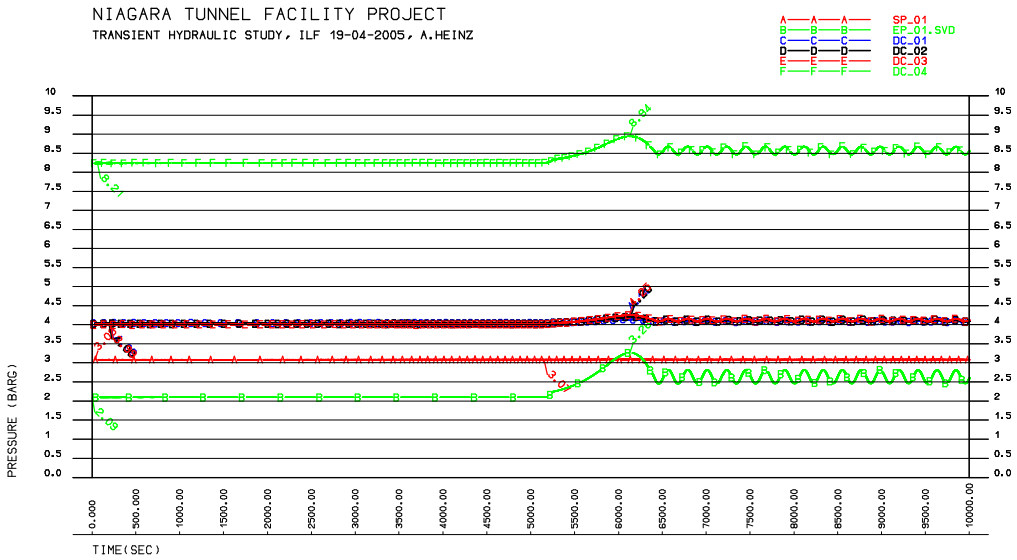

HISTORY OF PRESSURES

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING POWERED (max. 0.16m/min)

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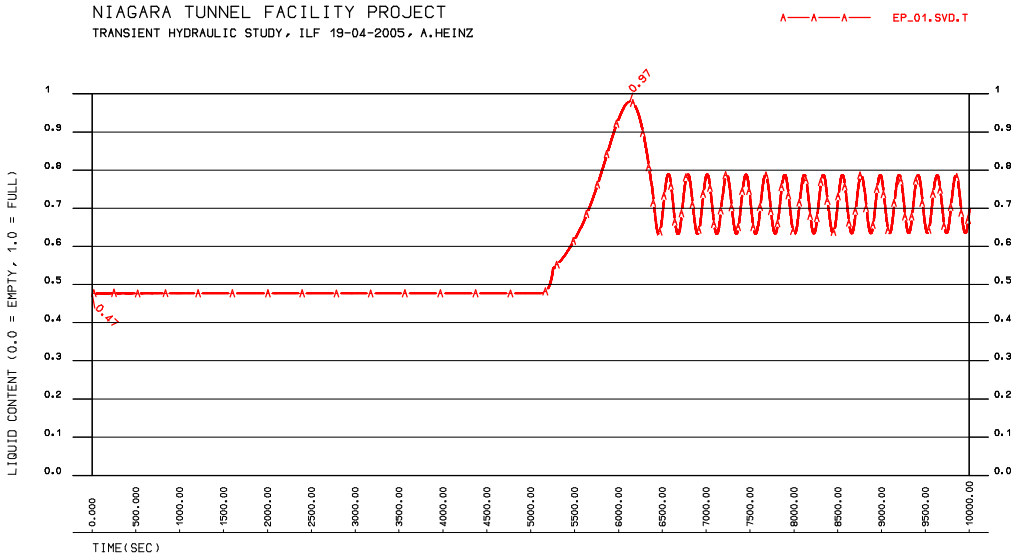

HISTORY OF SURGE VESSEL LIQUID CONTENT

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING POWERED (max. 0.16m/min)

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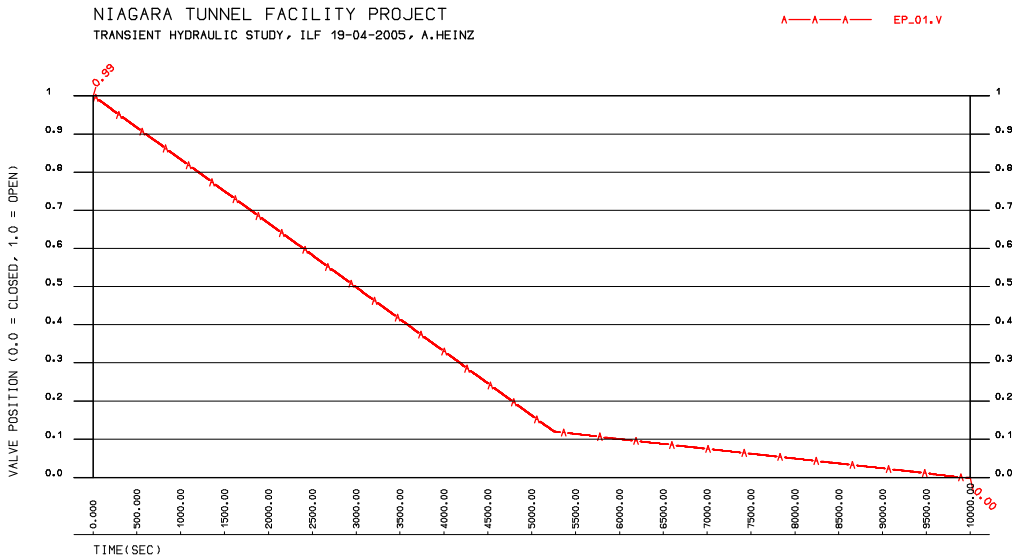

2.4.7 Load case 2: "Gate Hoist Lowering Unpowered (max. speed = 0.31 m/min)"

2.4.7.1 Basic Data

The following basic data have been used:

Maximum speed of lowering:	0.31m/min
Discharge at start of the calculations:	550 m^3/s
Roughness of tunnel lining:	ks = 0.028 mm (acc. to Prandtl Colebrook)
Valve type:	gate valve
Valve inside diameter:	15.88 m
Valve design pressure:	ASME 150

2.4.7.2 Result

For to retain the upsurge water level within the confines of the surge shaft at the outlet structure a two-speed closure has to be considered.

Closing speed 1:	3073.55 sec
Point of speed change:	12% remaining open position
Closing speed 2:	38830 sec
Closing time 1 (100% to 12%)	2704.7 sec
Closing time 2 (12% to 0%)	4659.6 sec

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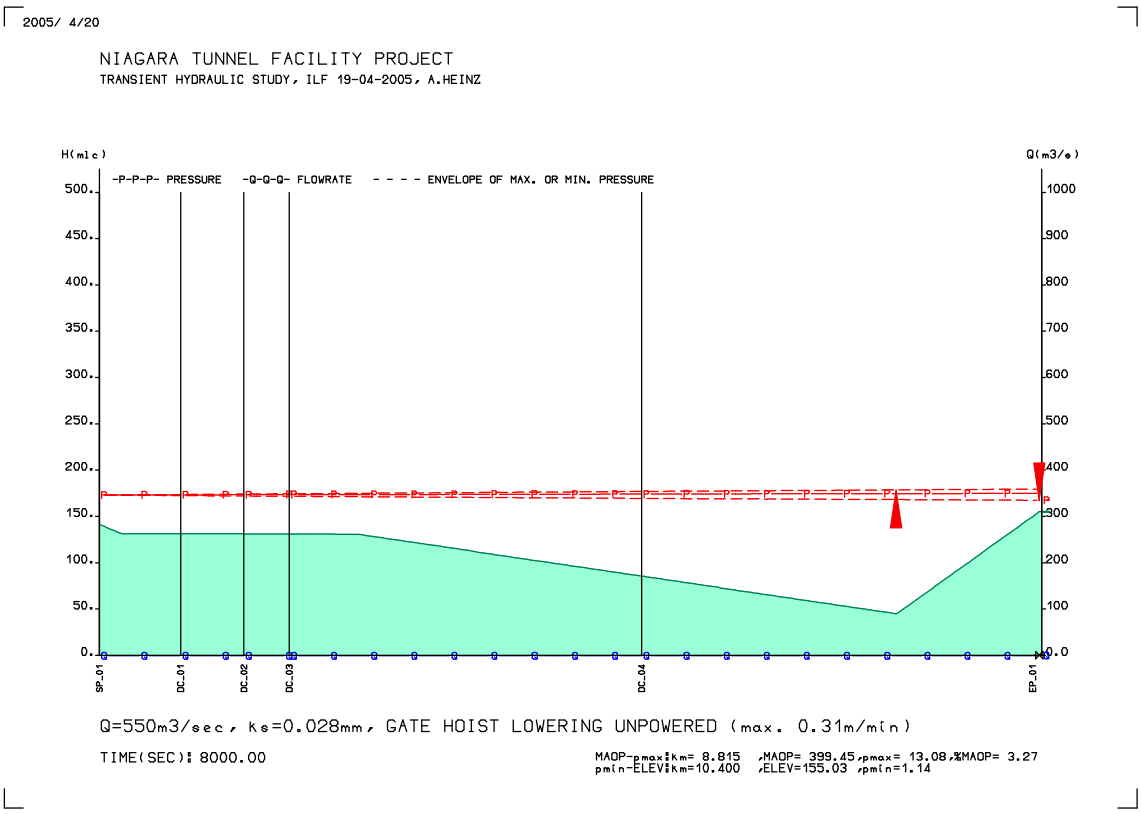
Total closing time (100% to 0%)	7364.32 sec = 122.7 min
Max. water level in the surge shaft:	179.61 m
Min. water level in the surge shaft:	167.49 m

2.4.7.3 Computer Printout's of the Computation Results



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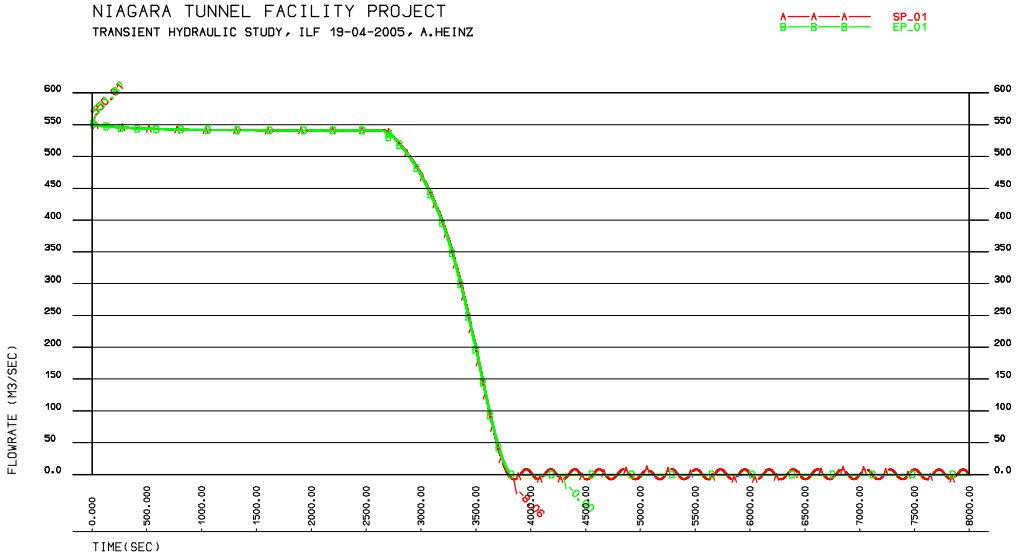

HISTORY OF FLOWRATES

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING UNPOWERED (max. 0.31m/min)

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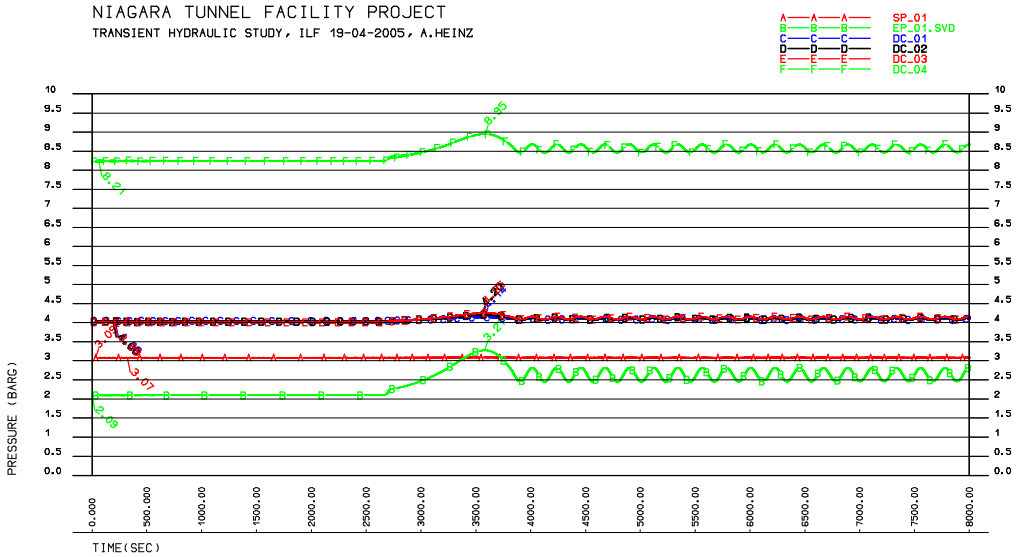

HISTORY OF PRESSURES

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING UNPOWERED (max. 0.31m/min)

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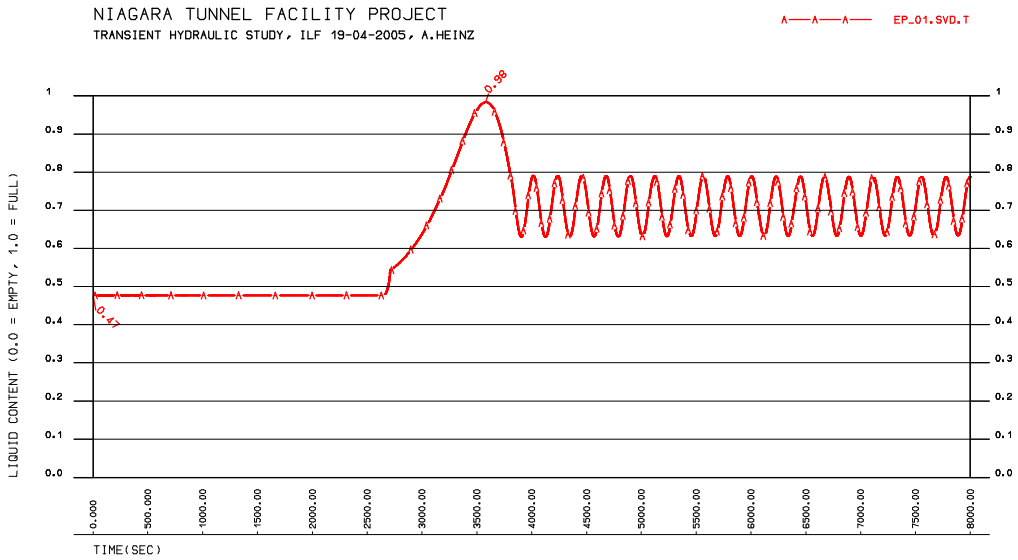

HISTORY OF SURGE VESSEL LIQUID CONTENT

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING UNPOWERED (max. 0.31m/min)

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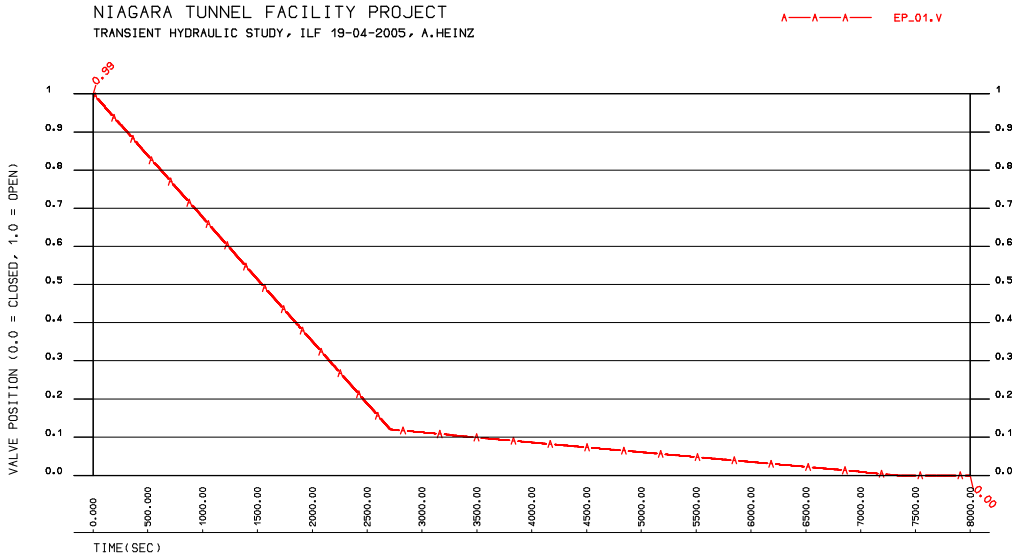

HISTORY OF VALVE POSITIONS

Q=550m3/sec, ks=0.028mm, GATE HOIST LOWERING UNPOWERED (max. 0.31m/min)

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2.4.8 Load case 3: "Gate Hoist Raising (max. speed = 0.16 m/min)"

2.4.8.1 Basic Data

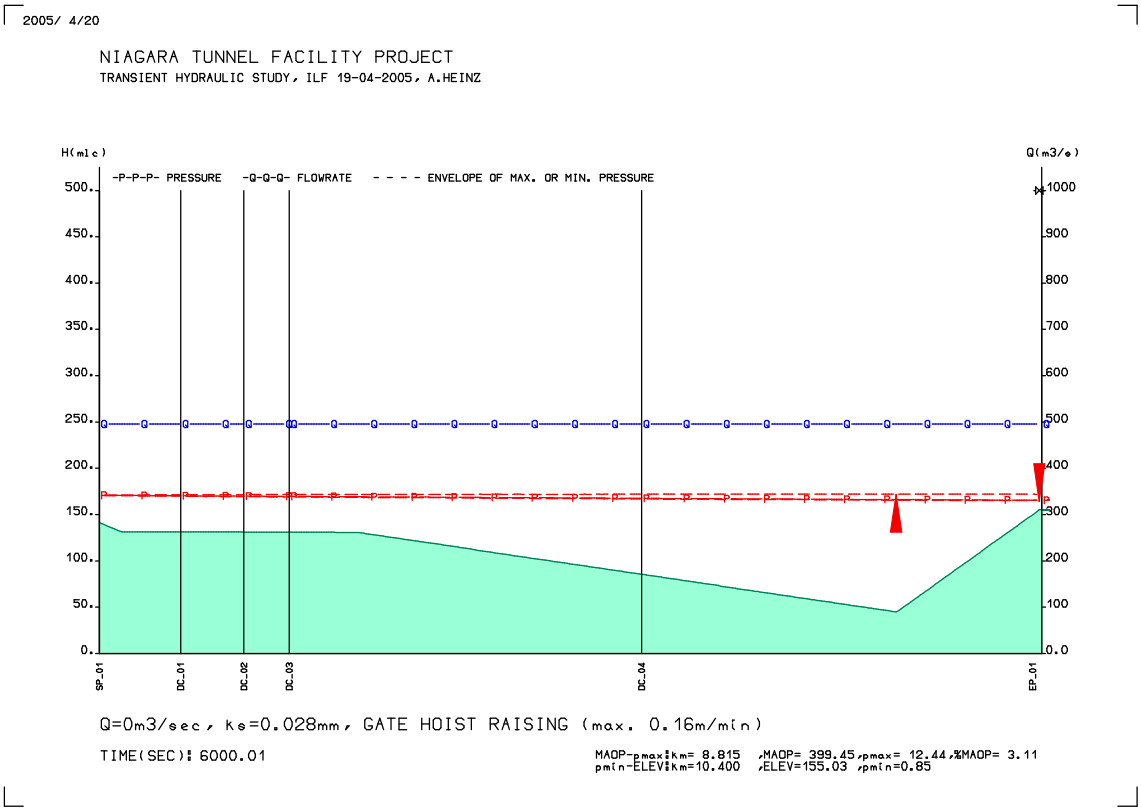
The following basic data have been used:

Maximum speed of raising:	0.16m/min
Discharge at start of the calculations:	0 m^3/s
Roughness of tunnel lining:	ks = 0.028 mm (acc. to Prandtl Colebrook)
Valve type:	gate valve
Valve inside diameter:	15.88 m
Valve design pressure:	ASME 150

2.4.8.2 Result

Raising speed:	5955 sec
Total raising time (0% to 100%)	5955 sec = 99.3 min
Max. water level in the surge shaft:	171.69 m
Min. water level in the surge shaft:	165.39 m

2.4.8.3 Computer Printout's of the Computation Results



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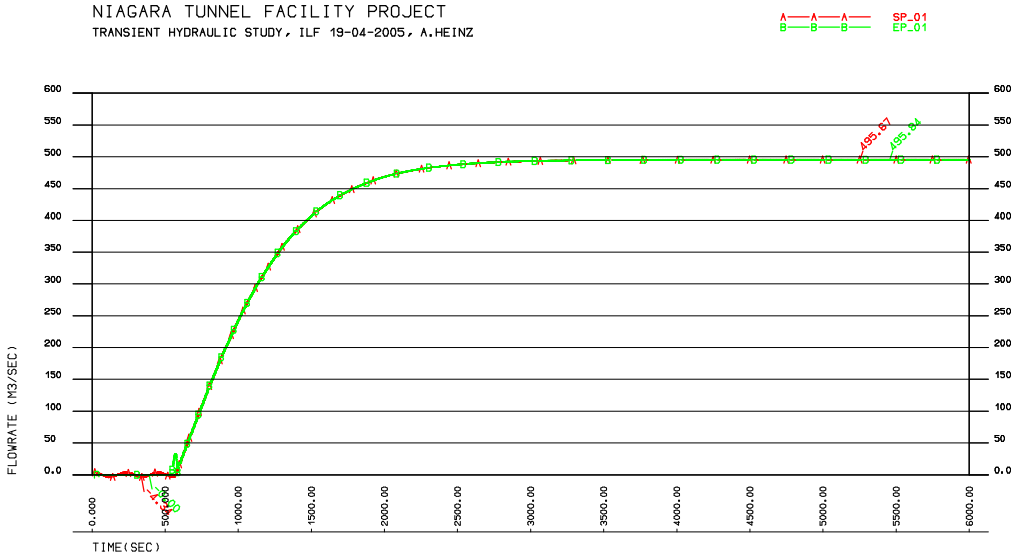

HISTORY OF FLOWRATES

Q=0m3/sec, ks=0.028mm, GATE HOIST RAISING (max. 0.16m/min)

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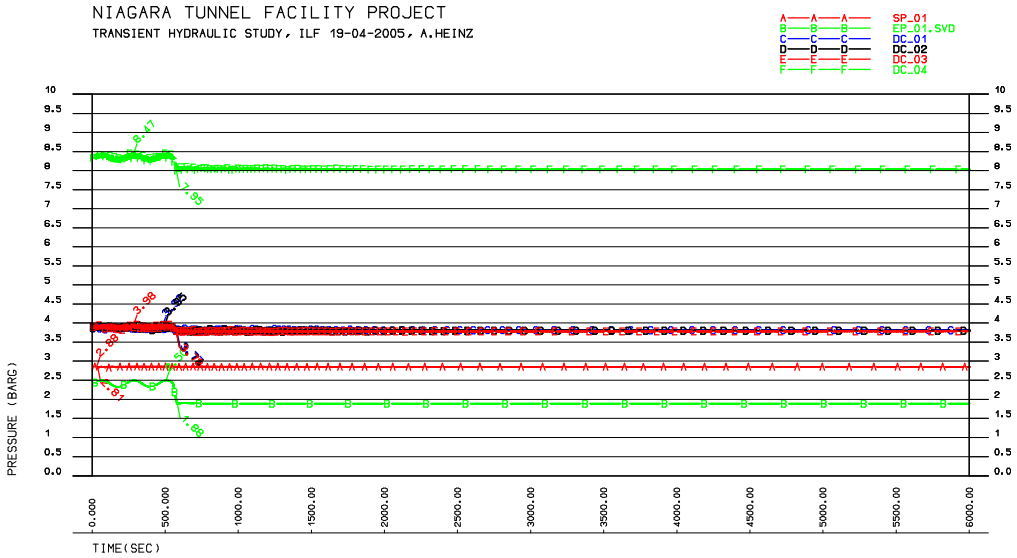

HISTORY OF PRESSURES

Q=0m3/sec, ks=0.028mm, GATE HOIST RAISING (max. 0.16m/min)

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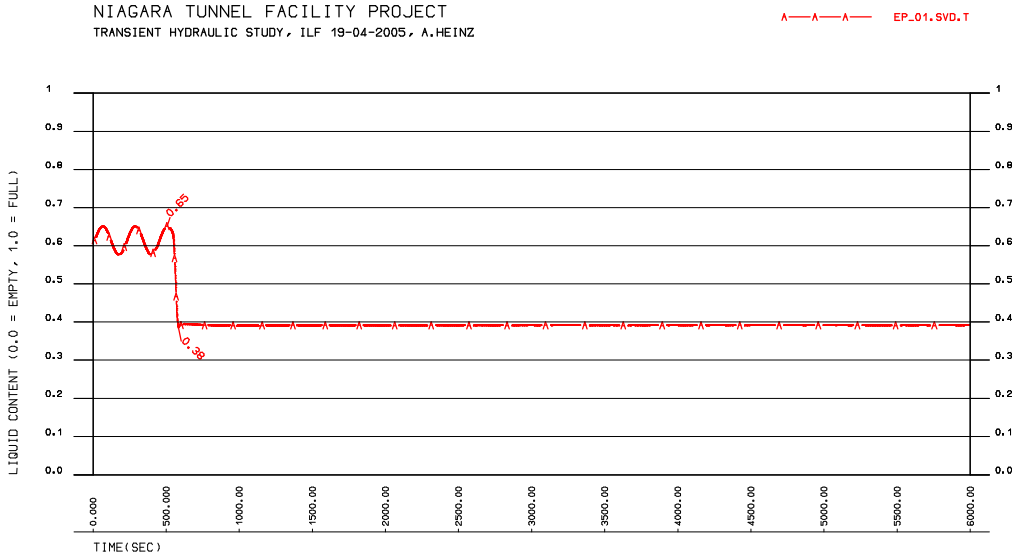

HISTORY OF SURGE VESSEL LIQUID CONTENT

Q=0m3/sec, Ks=0.028mm, GATE HOIST RAISING (max. 0.16m/min)

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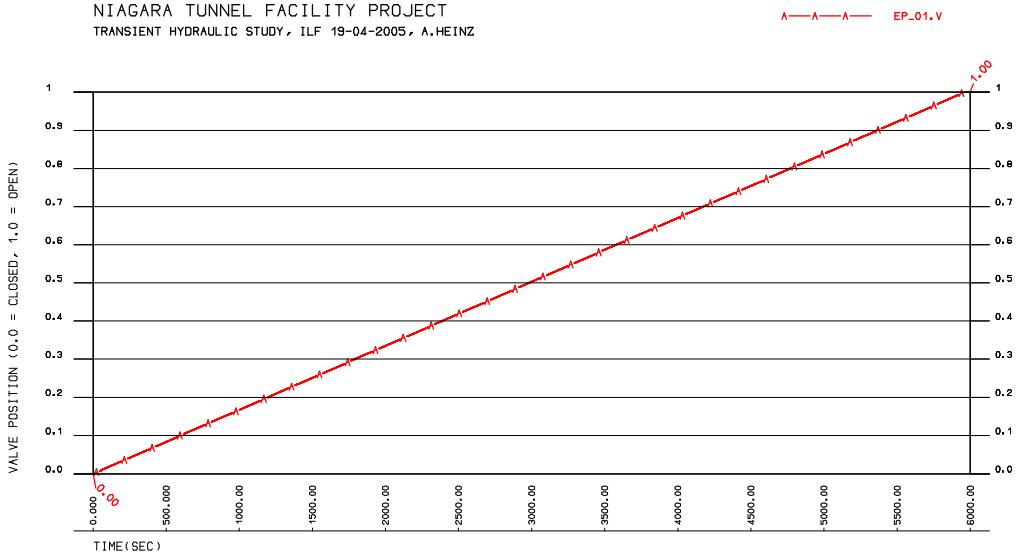

HISTORY OF VALVE POSITIONS

Q=0m3/sec, Ks=0.028mm, GATE HOIST RAISING (max. 0.16m/min)

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2.4.9 Computation Results

The above performed hydraulic transient computations lead to the following closing characteristics for the tunnel system endpoint gate valve:

- Total closing time gate valve, powered (max. speed = 0.16 m/min) 165.0 min
- Total closing time gate valve, unpowered (max. speed = 0.31 m/min) 122.7 min
- Total raising time gate valve (max. speed = 0.16 m/min) 99.3 min

As already mentioned above, the computations of these three load cases are strongly influenced by the gate valve zeta v, Kv or Cv characteristics. For the present computations only standard characteristics which provide conservative results have been used. During detail design phase the gate valve manufacturer has to supply the real characteristics and the computations have to be repeated accordingly.
In addition it has to be stated, that during the closing process standard gate valves are hydraulically not active until they reach the set point of approx. 15 to 10 % remaining open position (depends on type and construction of valve). During the first period up to approx. 85 % closure of the gate, when the valve is hydraulically inactive and no pressure surges will be produced, the valve could be operated at a faster closing speed. This fact would minimize the total closing time of the gate. To confirm this statement the mechanical boundary conditions, like size and possible speed of gate actuators, etc., have to be considered as well.

2.5 Preliminary watering up procedure

Construction stage before start of watering up:
- Tunnel, intake- and outlet structures are built
- Cofferdam at intake and rock plug at outlet canal is in place
- Gates are tested dry and wet by the manufacturer in the factory
- Gates are in place and tested in dry condition

Step 1, filling of outlet canal
- closure of outlet gate
- fill of outlet canal (by temporary filling culvert to PGS channel)

Step 2, rock plug removaloutlet gate
- removal of rock plug in wet excavation

Step 3, filling of Tunnel (approx. 20 m3/s , approx. 1 day filling time)
- opening of the outlet gate (adjust percentage of opening in relation to fill-state of tunnel)
- filling of water from outlet canal / PGS channel into the tunnel (escape of air through intake)

Step 4, removal of cofferdam and ice groyne
- closure of outlet gate

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- closure of INCW-gates close to intake
- removal of cofferdam and ice groyne in wet condition

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3 GEOTECHNICAL DESIGN AND CIVIL DESIGN

3.1 Survey

3.1.1 Survey Datum

Drawings and survey relevant data is prepared in NAD North American Datum (NAD83).

3.2 Civil Design Diversion Tunnel

3.2.1 General

The tunnel dimension, the surfaces of linings and lining transitions are designed to deliver the anticipated GFA. The tunnel is capable of being dewatered within a specified time of 3 weeks and the tunnel lining are designed to resisting all internal and external loads that are anticipated during the service life of the Diversion Tunnel.

The final lining concrete is protected by a waterproofing membrane system from the highly aggressive groundwater attack as identified in the GBR.

3.2.2 Tunnel Alignment

The alignment of the Proposal is described in chapter 1.3.1. It shall be noted, that the alignment of the tunnel satisfies the following requirements:

(a) the submerged intake of the tunnel is located beneath Gate 1 of the INCW at approximate location N 4 770 373.110 and E 658 118.470. The tunnel axis starts with a straight line in plan perpendicular to the centre line of the bridge and at the centre line of Bay 1 as indicated on the Concept Drawings.
(b) the outlet structure of the tunnel is located on the northwest side of the SAB2 Canal as indicated on the Concept Drawings. The Diversion Tunnel ends at the location N 4 778 230.990 and E 657 595.510.
(c) the horizontal alignment of the tunnel does remain within the subsurface right of way for the existing tunnels as indicated on the Concept Drawings
(d) the tunnel alignment does allow a future construction of a tunnel similar to the concept design with an intake beneath Gate 4 of the INCW and an outlet structure parallel and located south of the new tunnel outlet structure. The tunnel alignment indicated in the Proposal does allow a future construction of a tunnel also in parallel to the proposed Diversion Tunnel.
(e) the tunnel alignment does not cause severe stresses and strains to the lining of the existing tunnels or to the Toronto Power Generation Station building, wheel pit and dewatering tunnels as determined by numerical analyses. The alignment of the Proposal

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is crossing the wheel pit and the existing tunnels at a depth, where no influence on the existing structures is to be expected.

(f) a dewatering station is provided at the low point of the tunnel. The shafts are located on the Owner's land approx. 50 m east of the eastern rim of the buried St. David's Gorge.

3.2.3 Tunnel Lining Design

1 The tunnel lining consists of

(a) initial shotcrete lining – depending on the excavation and support type applicable for a particular section of tunnel, shotcrete, steel wire mesh, steel ribs and rock dowels are installed for temporary support of ground within adequate time after excavation.

(b) final cast in place concrete lining – which will be capable of accepting all permanent loads.

(c) waterproofing membrane system – which prevents seepage between inside and outside of the Diversion Tunnel and acts as a suitable corrosion protection for the final lining

(d) high pressure interface grouting system – which is designed to prestress the final concrete lining and the surrounding rock such, that no reinforcement of the final concrete lining is required.

Hence the final tunnel lining is watertight under normal operating conditions, rock swelling effects do not occur and the highly corrosive environment that exists along the tunnel alignment does not affect the final tunnel lining.

3.2.4 Tunnel Excavation and Construction

The tunnel will be excavated by means of a TBM starting from the outlet end of the tunnel. The TBM is erected in the flat section of the Outlet canal, pushed into the launch chamber where tunnel boring commences.
At the intake, which is excavated by the time, the TBM arrives, the TBM is dismanteled when leaving the tunnel and taken out of the construction pit in parts.

The use of drill and blast method of excavation will be limited to:

(a) intake structure
(b) intake channel
(c) outlet structure and
(d) outlet canal.

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Two short sections of mined tunnel will also be excavated by drill and blast. These tunnel sections are adjacent to the intake and outlet structures and 12 m and 20 m long respectively. The mined tunnel section at the outlet is used for TBM launch.

The dewatering shafts and tunnel piezometer holes will be drilled from the ground surface by standard boring techniques.

3.2.5 Tunnel Lining Installation

The tunnel initial lining will be installed in due time after excavation from behind the cutter head and from the working platform of the TBM. It consists of steel wire mesh, rock dowels, steel ribs and shotcrete as defined by the applicable support type. The initial lining is installed for the protection of personnel working in the tunnel and used for rock support and drainage of seepage water until the final lining is in place.

Within the TBM backup precast concrete invert segments are placed for to facilitate supply of the TBM advance. The invert segments are placed on a waterproofing membrane layer, which is adequately protected and they are grouted with mortar to be held in place properly. The invert segments serve as a foundation for the formwork of the cast in place final lining and are incorporated in the final lining.

Before the final lining is installed, the preset rings for interface grouting and a waterproofing membrane system consisting of regulating shotcrete, waterproofing membrane and plastic-backed geotextile fleece are fixed to the tunnel surface.

A steel shutter is used to pour the final lining consisting of cast in place concrete in approx. 12 m long sections. Adjustable formwork segments allow to vary the internal diameter of the Diversion Tunnel. Hence, depending on the internal and final lining thickness, maximum flow rates can be accommodated for water transfer. Changes of the internal tunnel diameter as a result of variable lining thickness and adjustable formwork are smoothened by a short transition section to minimize flow losses.

Eventually the final lining of cast in place concrete is prestressed by interface grouting applied between the initial lining and the waterproofing membrane system. The compressed final lining concrete resists the internal water pressure without cracking. The method has been successfully applied in pressure tunnels and shafts of hydro power schemes before (Appendix 3.4).

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3.3 Geotechnical Design Approach

3.3.1 Introduction

Tunnel design is governed by the fact that "Rock masses are so variable in nature that the chance for ever finding a common set of parameters and a common set of constitutive equations valid for all rock masses is quite remote." [3.15]. Therefore it has to be taken into account that, prior to tunnelling, any design represents a prediction which is either (a) verified on site in the event that all design assumptions are confirmed or (b) adjusted in situ to suit actual conditions. Figure 3.1 indicates the design approach which has been adopted. The design procedure is based on the guideline for the geomechanical design of underground structures [3.9] developed by the Austrian Society for Geomechanics. The first step of the design procedure is to establish geological data in those sections along the tunnel profile with consistent characteristics and then to summarize the geological series with similar mechanical properties. Further, the boundary conditions such as virgin stresses, size, shape and orientation of the opening have to be taken into account in order to establish a possible failure mechanism, thereby establishing the behaviour of the opening. Different failure mechanisms require different support measures as well as models of analysis to design the support measures. In order to simplify procedures at the site, support types are established which are applicable for the various types of behaviour of the opening.

The subject chapter deals with the determination of rock mass types including characteristic rock mass parameters and the allocation of rock mass behaviour types for the Niagara Tunnel Facility.

Note: It is assumed that all geotechnical parameters with a range derived from [3.19] were determined according to chapter 1 clause 9 of [3.19]. Therefore no further modifications of the values were carried out by the Proponent. If no range was given the range was calculated according to chapter 1 clause 8 of [3.19].

All geotechnical and hydrological findings for the project are summarized on drawing PD-01-1002 "Diversion Tunnel, Geotechnical Longitudinal Section" in a condensed form.

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3.3.3 Summary of Geologic Conditions

Twelve stratigraphic formations are identified in the project area, which consist of sequences of sedimentary rock of Ordovician to Devonian age. These are namely the Guelph, Lockport, De Cew, Rochester, Irondequoit, Reynales, Neahga, Grimsby, Power Glen, Whirlpool and Queenston formations. Some of these are only a few meters thick. Eleven of the mentioned formations are expected to be encountered along the tunnel. The uppermost Guelph formation will not intersect with the proposed tunnel alignment. The lithological spectrum of the encountered formation covers limestone, dolostone, sandstone and shale.

The rock formations dip gently towards south at an average rate of 5m/km. Major faults are not reported from the project area. However minor faults exist, forming thin shears parallel to bedding, up to a maximum thickness of 100mm and consisting of fine and coarse crushed material. It is assumed that these structures are related to stress relief, common in the Niagara region. Regional joint measurements revealed the existence of 4 major joint sets. The prevailing strike direction are 5°, 85°, 135° and 45°, all dipping at a high angle or vertical.

In situ stress conditions in southern Ontario are characterised by high horizontal stress, exceeding vertical stresses in parts significantly. The stress field is reported to be relatively consistent trending in a north-eastern direction. However the magnitudes of stress and the direction of the maximum stress can vary significantly depending on lithology, depth and topographical features.

Three major groundwater flow regimes are encountered in the rock formations of the project area. The uppermost occurs in the Guelph, Lockport and De Cew formations. These strata form the uppermost aquifer of the project area and are connected to surface water. This aquifer shows the highest permeability of the entire sequence. A second flow regime is associated with the low permeability strata of the Rochester, Neahga, Power Glen and Queenston formations, forming a system of aquitards. A third flow regime is associated with the deeper, higher permeable strata of the Irondequoit, Reynales, Thorold, Grimsby, Whirlpool and upper Queenston formations. These strata form deep lying aquifers. Groundwater elevations are reported to vary significantly from stratum to stratum and from location to location. Some groundwater heads encountered showed artesic behaviour with pressure heads above ground level. It is assumed that these characteristics are associated with the occurrence of natural gas. Water of the two lower flow regimes is reported to be highly corrosive and concrete aggressive, containing relevant amounts of chloride and sulphate. Chemical properties of the uppermost flow regime vary significantly depending on the influence of surface water.

Natural gas occurrence is common on the Niagara Peninsula. However the amounts of gas encountered during previous tunnel constructions were limited.

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Geological/geotechnical input data have been derived from OPG documents [3.10]. Based on this data the Rock Mass Types and Rock Mass Behaviour Types have been defined.

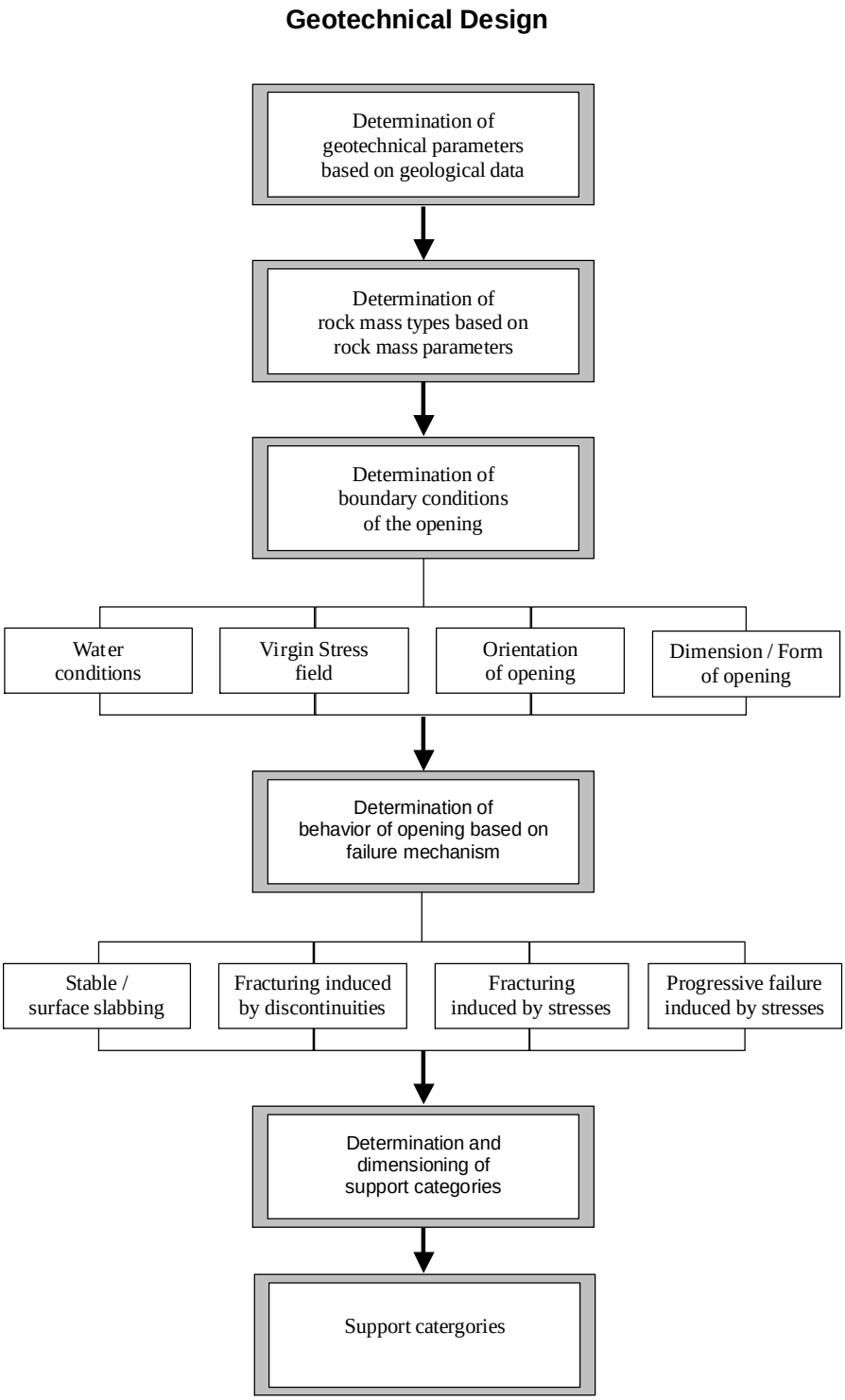

Figure 3.1: Flowchart for the Geotechnical Design of Initial Support

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3.3.4 Rock Mass Types

The rock mass types (RT) are defined using relevant geotechnical rock volumes including lithology, discontinuities and tectonic structures. The characteristics of the rock mass types are governed by:

- Lithology
- Properties of discontinuities
- Strength parameters of intact rock
- Conditions affecting parameters of intact rock and of rock mass

Six characteristic geotechnical parameters are used to define thirteen rock mass types for the Niagara Facility Tunnel project which are summarized in the following table 3.1.

3.3.5 Geotechnical Parameters

The geotechnical rock mass parameters are derived based on Hoek-Brown's mass law described in detail in [3.6]. The general form of the Hoek-Brown's failure criterion is:

$$\sigma_1 = \sigma_3 + \sigma_{ci} \cdot \left(m_b \cdot \frac{\sigma_3}{\sigma_{ci}} + s \right)^a$$

σ_1, σ_3 are the major and minor principal effective stresses

m_b is the Hoek-Brown constant for rock masses

s, a are parameters describing rock mass properties

σ_{ci} is the uniaxial compressive strength of the intact rock (obtained from [3.19], table 6.3)

The Hoek-Brown criterion thus establishes a connection between the principal effective stresses. The effective stresses will take into account 100% of the pore water pressure in the rock. The calculation of rock mass strength will be based on confining pressures that account for effective stresses.

The rock mass parameters m_b, *a* and *s* can be derived by means of the following parameters:

- Hoek-Brown constant for intact rock *mi*
- Geological Strength Index *GSI*

Values for Hoek-Brown constant *mi* were derived using the *mi*-chart provided with the software RocLab [3.12]. The *GSI* is a parameter introduced by Hoek in 1994, providing a numerical rating of the rock masses based on the structure and discontinuity surfaces of the rock mass. The *GSI* values were derived by evaluating average joint spacing and surface

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conditions of the individual rock formations, using the *GSI*-chart provided in [3.1] (see also Appendix 3.2).

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Table 3.1: Rock mass types

	Rock Mass Types (RT)						
	RT-1	RT-2	RT-3	RT-4	RT-5	RT-6	RT-7
Formation	Lockport	De Cew	Rochester	Irondequoit	Reynales	Neahga	Thorold
Thickness [m]	43-45	2-3	17-19	2,5-4	3,5-4,5	1,5-2	2-3,5
Lithology	Dolostone, thin to thick bedded, irregular shale partings in the Goat Island member, vugs common, chert nodules common, slightly fractured, gas pockets in upper section	Dolostone, thin to thick bedded, irregular shale partings, zones and nodules of gypsum, moderate to slightly fractured	shale with interbeds of limestone and dolostone, laminated, thin to thick bedded, pyrite and gypsum partings, slightly fractured, gas pockets	limestone, medium bedded to massive, wavy irregular shale partings, few vugs and small pores, slightly fractured, gas producing	Dolostone turing to limestone with depth, argillaceous and siliceous zones, numerous wavy shale partings, slightly fractured	shale, laminated, fissile to thick bedded, pyrite and gypsum partings, slakes during wet-dry cycles, moderately fractured	fine to medium grained sandstone, thin to thick bedded, irregular shale partings, moderately fractured, gas producing
Weathering	slightly weathered	fresh	slightly weathered	slightly weathered	fresh	fresh to slightly weathered	fresh to slightly weathered
Spacing of Discontinuities [m]	0,5	0,5	0,4	0,7	0,5	0,2	0,3
Roughness	slightly rough, some slickensides	slightly rough and planar, some slickensides	slightly rough and planar with occional clay infilling	rough, irregular	rough and planar to slightly irregular	smooth and planar, slickensides	rough and slightly irregular
UCS [MPa]*	106-196 (151)	90-166 (128)	12,1-66 (42)	60-10 (89)	45-141 (101)	12-24 (18)	117-141 (129)
GSI*	60-70 (65)	60-70 (65)	60-70 (65)	60-70 (65)	60-70 (65)	45-55 (50)	60-70 (65)

	Rock Mass Types (RT)					
	RT-8	RT-9	RT-10	RT-11	RT-12	RT-13
Formation	Grimsby	Power Glen	Whirlpool	Queenston Q10 to Q8	Queenston Q7 to Q4	Queenston below St. D. G.
Thickness [m]	12,5-15	10-13	4,5-8,5	>300		
Lithology	fine to medium grained sandstone with interbedded shale, thin to thick bedded, often calcareous, a weathered zone frequently occurs at the top of the formation, moderately fractured, gas producing	shale with siltstone beds and stringers, limestone and dolomite beds, slightly fractured	fine to medium grained sandstone, medium bedded and cross bedded, occasional shale inclusions and chloritic shale partings occur throughout, slightly fractured, gas producing	shale, thin to medium bedded, moderately fractured, gas encountered along primary bedding planes	shale, thin to medium bedded, scattered gypsum nodules occur throughout lower section, slightly fractured, gas encountered along primary bedding planes	shale, thin to medium bedded, scattered gypsum nodules occur throughout lower section,intensely fractured, gas encountered along primary bedding planes
Weathering	fresh	fresh	fresh	fresh to slightly weathered	slightly weathered	slightly weathered
Spacing of Discontinuities [m]*	0,3	0,4	0,5	0,3	0,5	0,1
Roughness	slightly rough and irregular, some slickensides	slight rough and irregular	rough and irregular	rough and slightly irregular, numerous slickensides	rough and slightly irregular, some slickensides	rough and slightly irregular, slickensides
UCS [MPa]**	74-242 (146)	12-34 (24)	108-235 (180)	8-118 (33)	8-118 (46)	8-118 (33)
GSI**	55-65 (60)	55-65 (60)	70-80 (75)	55-65 (60)	60-70 (65)	40-50 (45)

* av. spacing

** min-max (av.)

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The relevant information concerning average joint spacing and discontinuity surface conditions were derived from [3.10] and [3.19]. These values enable the parameters *s* and *a*, to be defined as follows:

$$m_b = m_i \cdot \exp\left(\frac{GSI - 100}{28\text{-}14D}\right)$$

$$s = \exp\left(\frac{GSI - 100}{9 - 3D}\right)$$

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$$

D (Disturbance Factor) is a factor which depends upon the degree of disturbance to which the rock mass has been subjected by blast damage and stress relaxation. It varies from 0 for undisturbed in situ rock masses to 1 for very disturbed rock masses. Due to the planed excavation method the *D*-Factor was generally assumed to be 0.

The Hoek-Brown criterion serves to derive the Mohr-Coulomb parameters ϕ' and c'. Furthermore, the modulus of elasticity using the parameters σ_{ci} and *GSI* can also be determined.

$$\phi' = \sin^{-1}\left[\frac{6am_b(s + m_b\sigma'_{3n})^{a-1}}{2(1+a)(2+a) + 6am_b(s + m_b\sigma'_{3n})^{a-1}}\right]$$

$$c' = \frac{\sigma_{ci}\left[(1+2a)s + (1-a)m_b\sigma'_{3n}\right](s + m_b\sigma'_{3n})^{a-1}}{(1+a)(2+a)\sqrt{1 + (6am_b(s + mb\sigma'_{3n})^{a-1})/((1+a)(2+a)}}$$

where $\sigma_{3n} = \sigma'_{3\max} / \sigma_{ci}$

The value of $\sigma'_{3\max}$ is the upper limit of confining stress over which the relationship between the Hoek-Brown and the Mohr-Coulomb criteria is considered.

$$Em(GPa) = \left(1 - \frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}}\,10^{((GSI-10)/40)} \quad \text{for } \sigma_{ci} \le 100$$

$$Em(GPa) = \left(1 - \frac{D}{2}\right)10^{((GSI-10)/40)} \quad \text{for } \sigma_{ci} > 100$$

The results of the calculations for the proposal design are listed in table 3.2 and will be updated in detail design.

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Table 3.2: Determination of rock mass parameters according to Hoek-Brown

Formation	Lithology	Joint Spacing		Parameter of intact rock				Rock Mass Parameters							
		Mean		UCS		mi		GSI		φ		C		Def. Modulus	
		J/m	Spac.	[MPa]		[-]		[-]		[°]		[MPa]		[GPa]	
			[m]	mean[1]	range[1]	mean	range	mean	range	mean	range	mean	range	mean	range
Lockport	Limestone	2,1	0,5	151	106-196	9	1	65	5	34	2	9,5	4,0	24	6
	Dolostone	2,1	0,5	125	87-163	9	2	65	5	34	3	7,9	3,0	24	7
DeCew	Dolostone	2,1	0,5	128	90-166	9	2	65	5	34	3	8,0	3,0	24	7
Rochester	Shale	2,3	0,4	42	12,1-65,5	7	1	65	5	32	2	2,5	2,0	15	9
Irondequoit	Dolostone/ Limestone	1,4	0,7	89	60,3-105,2	10	1	65	5	35	2	5,7	2,0	22	8
Reynales	Dolostone	2,1	0,5	101	45-140,8	9	2	65	5	34	3	6,3	4,0	24	8
Neahga	Shale	5,5	0,2	18	12,0-24,0	6	1	50	5	26	3	0,8	0,4	4	2
Thorold	Sandstone	3,7	0,3	129	117,4-141,3	18	2	65	5	40	2	9,5	2,0	24	6
Grimsby	Sandstone	3,9	0,3	146	73,5-242,2	17	2	60	5	38	2	9,9	5,0	18	6
	Shale	3,9	0,3	35	12,8-64,4	7	1	60	5	30	2	1,2	0,6	11	6
Power Glen	Shale	2,5	0,4	24	11,9-33,9	7	1	60	5	30	2	1,3	0,6	9	4
	Sandstone	2,5	0,4	152	71,7-223,8	17	2	60	5	38	2	10,3	6,0	18	6
Whirlpool	Sandstone	1,9	0,5	180	108-234,5	19	2	75	5	43	2	16,0	7,0	42	10
Queenston	Q8-Q10 (app. 30m thick)	3,6	0,3	33	7,5-117,5	7	1	60	5	30	2	1,8	1,0	10	6
	Q1-Q7	1,9	0,5	46	7,5-117,5	8	1	65	5	33	2	2,8	2,0	16	11
	25m below St. David's Gorge	8,2	0,1	33	7,5-117,5	6	1	45	5	24	2	1,3	1,0	4	3

[1]) It is assumed that that the values for UCS of intact rock,obtained from GBR A, table 6.3, were determined according to chapter 1, point 8 and 9 of GBR A

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3.4 Rock Mass

Rock mass behaviour is decisive for the design of the required initial support and final lining of a tunnel. Various methods have been applied in order to determine rock mass behaviour along the proposed tunnel alignment including block stability analyses and FE-modelling. Details of the applied methodology are summarized in [3.17].

3.4.1 Boundary Conditions

The boundary conditions influencing the rock mass behaviour can be listed as follows:

- Rock mass properties
- In situ stress conditions
- Groundwater conditions
- Orientation of the opening
- Dimension and shape of the opening

3.4.1.1 Rock Mass Properties

Rock mass properties to be encountered along the tunnel are presented in chapters 3.3.4 and 3.3.5.

3.4.1.2 In Situ Stress Conditions

Extensive in situ testing was carried out in order to determine stress conditions along the tunnel alignment. The results to be considered for the tunnel design are presented in table 6.14 of the [3.19]. These results cover the Concept Alignment which is basically situated within the Queenston Formation.

In situ horizontal stress conditions included in GBR will be adopted for design. Vertical stress is assumed to be governed by the overburden only with the exception of the outlet section. There 3D in situ stress measurements indicate, that vertical stresses are 30% higher than stresses induced by overburden only.

The following table 3.3 summarizes the in situ stress conditions considered for the design of the proposal and will be updated in the detail design.

Table 3.3: Stress Regimes for Design Purposes

In Situ Stress Conditions along the Proposed Tunnel Alignment					
Tunnel section	Horizontal Stress (respect to tunnel)		Vertical Stress		
	[MPa]	[MPa]	[MPa]		
	Radial	Axial	min	max	mean
0+000-2+840	17	11	0,5	2,3	1,4
2+840-7+070	19	17	2,3	3,9	3,1
7+070-8+900	22	16	3,3	3,4	3,3
8+900-10+421,380	15	23	0,6	4,5	2,6

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Several attempts have been made in the past in order to predict the effect of in situ stress on rock mass behaviour and support requirements for underground structures. Hoek and Brown introduced the Hoek-Brown stability classification based on their experiences from deep lying mines in South Africa. This classification system is based on the evaluation of the relation between σ_1 and σ_c for a K_o = 0,5. To overcome this limitation the Damage Index was introduced, which can be correlated to the Hoek-Brown stability classification (see Figure 3.2).

$$Di = \frac{\sigma_{\max}}{\sigma_c}$$

where:

$\sigma_{\max} = 3\sigma_1 - \sigma_3$ is the maximum tangential boundary stress, and

σ_c is the uniaxial compressive strength of the intact rock.

The below figure shows the correlation between *Di* and the Hoek-Brown stability classification. According to this classification:

$\frac{\sigma_1}{\sigma_c} \leq$ 0,1: stable rock mass, no support required

$\frac{\sigma_1}{\sigma_c} =$0,2: minor spalling, light support

$\frac{\sigma_1}{\sigma_c} =$0,3: severe spalling, moderate support

$\frac{\sigma_1}{\sigma_c} =$0,4: heavy support required

$\frac{\sigma_1}{\sigma_c} \geq$ 0,5: extremely difficult to support

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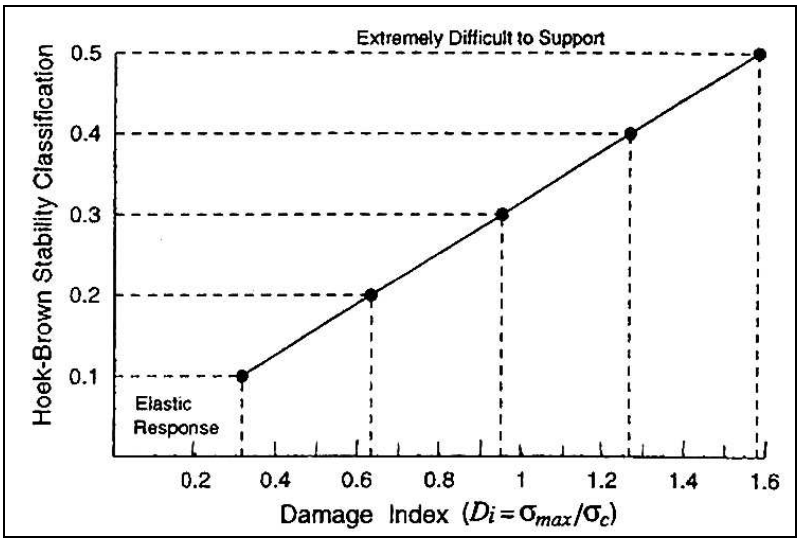

Figure 3.2: Correlation between Damage Index (*Di*) and the Hoek-Brown Stability Classification

The depth of stress induced failure was estimated using the below formula.

$$\frac{Rf}{a} = 0{,}49(\pm 0{,}1) + 1{,}25 * Di$$

Rf is the depth of failure measured from the tunnel center

a is the tunnel radius.

Both procedures are derived from [3.8]. The results of the calculations are summarised in Appendix 3.3 for the four tunnel sections shown in Table 3.3. They were used for choosing the necessary model for evaluating rock mass behaviour (see Chapter 3.4.2).

3.4.1.3 Groundwater Conditions

Groundwater can have a major impact on rock mass behaviour during tunnel construction. Groundwater conditions along the proposed tunnel alignment are expected to vary significantly due to the encountered rock mass properties. Significant groundwater inflow is to be expected within the Lockport and the De Cew Formations. It is assumed that groundwater has no influence on rock mass behaviour of those formations, due to their rock mass properties.

Groundwater inflow in the below situated formations is very limited.

Within shale formations, groundwater can trigger rock mass swelling if appropriate clay minerals are available.

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Groundwater inflow to the tunnel was estimated following the procedure described in [3.11]. This procedure follows Heuer's experience [3.3], which shows that tunnel inflow is 1/8 of that predicted by Goodman's equation [3.2].

$$Q = \frac{2 * \pi * kf * H}{\ln(\frac{2 * H}{r})} * \frac{1}{8}$$

where:

Q is tunnel inflow in m^3 per second

kf is the permeability

H is the groundwater table above tunnel center

r is the tunnel radius (the calculations were carried out for a tunnel radius of app. 7,2m).

The following table 3.4 summarizes the results of these calculations for the proposal design and will be updated in the detail design (excluding interconnections).

Table 3.4: Estimated Groundwater Inflow for the Niagara Facility Tunnel

Section	Length	Formation	Q [l/s*100m]		
			min	max	av
1	230	Rochester (Outlet)	0,00	1,0	0,1
2	130	Reynals	0,00	0,1	0,1
3	190	Grimsby	0,00	0,6	0,1
4	210	Power Glen	0,00	1,2	0,4
5	460	Upper Queenston	0,00	4,5	0,7
6	305	Lower Queenston	0,00	0,5	0,1
7	530	St. Davids Gorge	0,00	1,4	0,2
8	4445	Lower Queenston	0,00	0,5	0,1
9	2835	Upper Queenston	0,00	5,1	0,9
10	230	Whirlpool	0,00	2,2	0,4
11	320	Grimsby	0,00	1,1	0,1
12	305	Rochester	0,00	1,6	0,2
13	235	Lockport (Inlet)	0,00	92,3	12,3

Note that the above shown sections are listed in direction of the tunnel advance.

The results of the calculations were compared to the water inflow encountered in the test adit which was in total 0,74l/s during and 0,14l/s after tunnel construction for the 612m long tunnel. The test adit is situated in the Queenston Formation, therefore only calculation results for the Queenston Formation can be directly correlated to these findings.

In addition the hydrochemical properties of the encountered groundwater were evaluated in order to predict the influence on steel and concrete. Testing results showed that the groundwater encountered in the formations below the Eramosa member of the Lockport formation contain in general significant contents of chloride and sulphate and thus is to be

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classified as highly corrosive and concrete aggressive. Excluded from this general assumption has to be a tunnel section around borehole NF4 where chloride and sulphate contents are significantly lower. It is assumed that surface water inflow from the existing channel is causing dilution of the groundwater.

The Lockport formation shows highly variable chloride and sulphate contents due to the changing influence of surface water all along the tunnel alignment.

The results of the evaluation of the hydrochemical testing with respect to the tunnel alignment are summarized in Appendix 3.1. The assumed distribution of the hydrochemical properties along the tunnel alignment is shown in [3.14].

3.4.1.4 Orientation of Opening

The orientation of the opening relative to the major discontinuity sets governs the stress relevant for the tunnel design. It also has a major impact on size, shape and stability of rock wedges formed by the intersection of discontinuities and the tunnel opening. Therefore the orientation of the opening is considered in the block stability analysis as well as the FE-analysis.

3.4.1.5 Dimension and Shape of Opening

The distribution of stress around the tunnel opening is governed to a large extent by the size and shape of the opening. They also affect size and shape of potentially unstable blocks during tunnel excavation. Therefore the size and shape of the opening are considered in the block stability analysis as well as in the FE-analysis.

The bored part of the Diversion Tunnel has a circular excavation cross section of 14.44 m diameter. The circular cross section is favourable for redistribution of stresses, which develop in the rock mass around the excavation opening. Rock mass loosening will such be minimized.

A short section of tunnel, adjacent to the Intake and Outlet structures, is excavated by mining methods. The tunnel cross section has to be changed from circular to square on a length, which corresponds to approximately one tunnel diameter. The square end of excavation is up to 19 m wide. The excavation cross section at the interface to the bored tunnel is horse-shaped and 16 m wide and 17 m high at its top.

The cross sections for channels at the Intake and the Outlet area is generally rectangular.

3.4.2 Rock Mass Behaviour Types

[The rock mass behaviour types in this section were developed during the proposal and are for information only]

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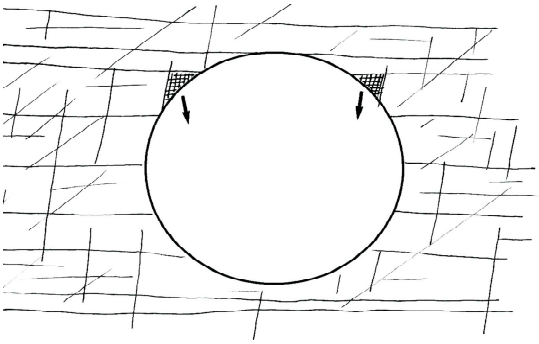
In total 8 basic rock mass behaviour types have been identified along the tunnel alignment. It has to be mentioned that some rock mass behaviour types can coexist along a tunnel section since some types represent short term rock mass behaviour (e.g. wedge failure) and some types represent long term rock mass behaviour (e.g. swelling or squeezing rock). During future design phases it may be found reasonable to refine this rock mass classification by partitioning the identified rock mass behaviour types into more subtypes.

Note that rock mass behaviour types are defined considering an endless long tunnel without any construction stages and support measures.

3.4.2.1 Behaviour Type 1: Stable Rock

Rock mass behaviour was analysed using block theory. The block modelling was carried out applying the software UNWEDGE [3.13].

<table>
<tr><th colspan="3">Rock Mass Behaviour: Stable Rock Mass</th></tr>
<tr><td colspan="3"> 
Sketch of assumed rock mass failure; wedges not in scale</td></tr>
<tr><td>Formations</td><td colspan="2">Lockport, De Cew, Irondequoit, Reynales, Whirlpool</td></tr>
<tr><td>Characteristics of Discontinuities</td><td><u>Bedding:</u>
Persistence: >20m
Spacing: dm - m
Roughness: rough to slightly rough, fresh to slightly weathered</td><td><u>Joints:</u>
Persistence: <10m
Spacing: dm - m
Roughness: rough to slightly rough, fresh to slightly weathered</td></tr>
<tr><td>In Situ Stress Conditions</td><td colspan="2">in situ stresses do not exceed rock mass strength</td></tr>
<tr><td>Groundwater Conditions</td><td colspan="2">groundwater conditions are varying from wet to flowing, significant inflow will occur close to ground surface (Lockport and De Cew Formation)</td></tr>
<tr><td>Rock Mass Behaviour</td><td colspan="2">local, gravity controlled failure of rock wedges induced by discontinuities; max. wedge size up to several dm³; groundwater has no influence on rock mass behaviour</td></tr>
<tr><td>Deformations</td><td colspan="2">minor deformation < 5mm, which stabilize quickly</td></tr>
</table>

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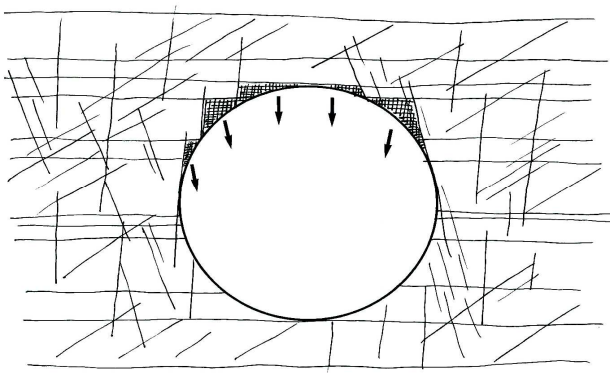
3.4.2.2 Behaviour Type 2A: Failure of Rock Blocks Induced by Discontinuities

Rock mass behaviour was analysed using block theory. The block modelling was carried out applying the software UNWEDGE [3.13].

Rock Mass Behaviour: Failure of Rock Blocks Induced by Discontinuities		
 Sketch of assumed rock mass failure; wedges not in scale		
Formations	Irondequoit, Reynales, Thorold, Grimsby, Whirlpool, Queenston	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered, clayey infilling possible (fault gauge)	Joints: Persistence: <10m Spacing: dm - m Roughness: rough to slightly rough, fresh to slightly weathered
In Situ Stress Conditions	in situ stresses do not exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from dry to wet	
Rock Mass Behaviour	systematic, gravity controlled failure of rock wedges induced by discontinuities; max. wedge size up to several m³; the assumed groundwater quantities have no influence on rock mass behaviour; changes of the moisture content of the rock mass of shale formations can contribute to rock mass degradation; it is assumed that it takes several month till cracks of sufficient extent develop to delaminate rock blocks	
Deformations	minor deformation < 20mm, which stabilize quickly	

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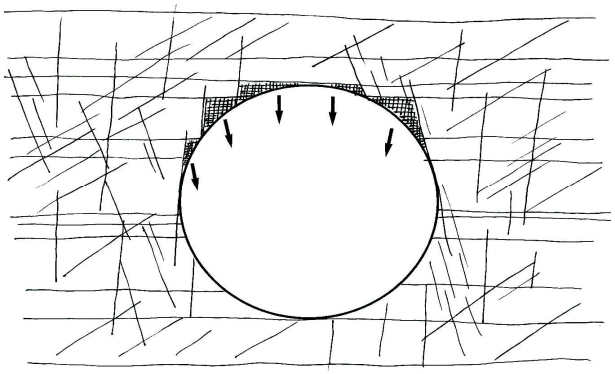
3.4.2.3 Behaviour Type 2B: Failure of Rock Blocks Induced by Discontinuities

Rock mass behaviour was analysed using block theory. The block modelling was carried out applying the software UNWEDGE [3.13].

Rock Mass Behaviour: Failure of Rock Blocks Induced by Discontinuities



Sketch of assumed rock mass failure; wedges not in scale

Formations	Lockport, De Cew	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered	Joints: Persistence: <10m Spacing: dm - m Roughness: slightly rough, slightly weathered
In Situ Stress Conditions	in situ stresses do not exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from wet to flowing	
Rock Mass Behaviour	systematic, gravity controlled failure of rock wedges induced by discontinuities; max. wedge size up to several m³; groundwater can reduce shear strength of discontinuities	
Deformations	minor deformation < 5mm, which stabilize quickly	

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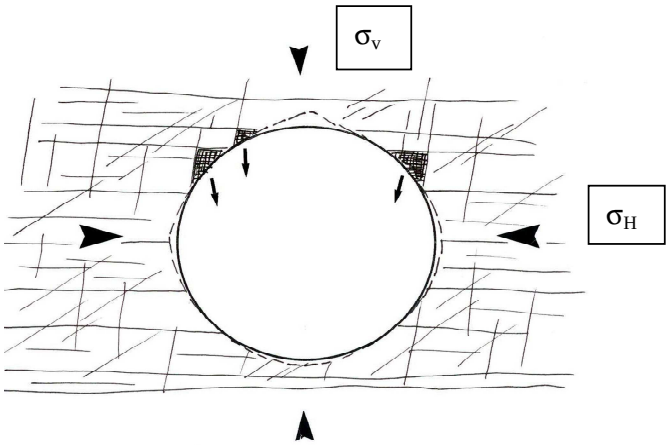
3.4.2.4 Behaviour Type 3A: Failure of Rock Blocks Induced by Stress and/or Discontinuities

Rock mass behaviour was analysed using block theory and the FE-method. The block modelling was carried out applying the software UNWEDGE [3.13].

Rock Mass Behaviour: Failure of Rock Blocks Induced by Stress and/or Discontinuities		
 Sketch of assumed rock mass failure; wedges and stress induced failure depth not in scale		
Formations	Rochester, Irondequoit, Reynales, Neahga, Thorold, Grimsby, Power Glen, Whirlpool, Queenston	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered, clayey infilling possible (fault gauge)	Joints: Persistence: <10m Spacing: dm - m Roughness: rough to smooth, fresh to slightly weathered
In Situ Stress Conditions	in situ stresses slightly exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from dry to wet	
Rock Mass Behaviour	systematic failure of rock wedges induced by in situ stresses and discontinuities resulting in wedge failure and minor rock mass slabbing and spalling; max. depth of stress induced failure few dm; spalling and slabbing will primarily occur in the roof and sidewalls; max. wedge size up to several m^3; the assumed quantities of groundwater inflow have no influence on rock mass behaviour; changes of the moisture content of the rock mass of shale formations can contribute to rock mass degradation; it is assumed that it takes several month till cracks of sufficient extent develop to delaminate rock blocks	
Deformations	minor deformation <20mm, which stabilize quickly	

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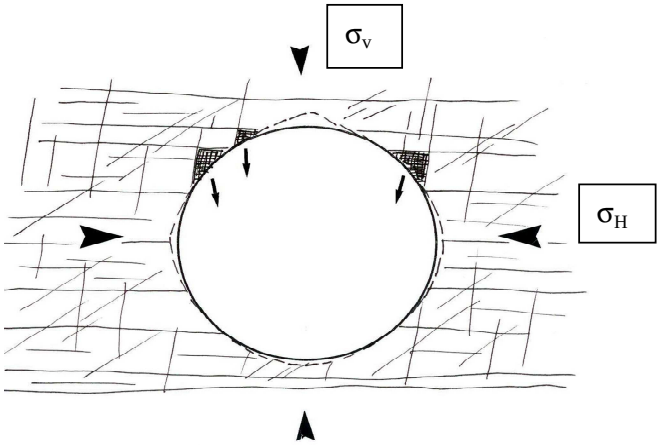
3.4.2.5 Behaviour Type 3B: Failure of Rock Blocks Induced by Stress and/or Discontinuities

Rock mass behaviour was analysed using block theory and the FE-method. The block modelling was carried out applying the software UNWEDGE [3.13].

Rock Mass Behaviour: Failure of Rock Blocks Induced by Stress and/or Discontinuities		
 Sketch of assumed rock mass failure; wedges and stress induced failure depth not in scale		
Formations	Lockport, De Cew	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered	Joints: Persistence: <10m Spacing: dm - m Roughness: slightly rough, slightly weathered
In Situ Stress Conditions	in situ stresses slightly exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from wet to flowing	
Rock Mass Behaviour	systematic failure of rock wedges induced by in situ stresses and discontinuities resulting in wedge failure and minor rock mass slabbing and spalling; max. depth of stress induced failure few dm; spalling and slabbing will primarily occur in the roof and sidewalls; max. wedge size up to several m^3; groundwater can reduce shear strength of discontinuities	
Deformations	minor deformation <20mm, which stabilize quickly	

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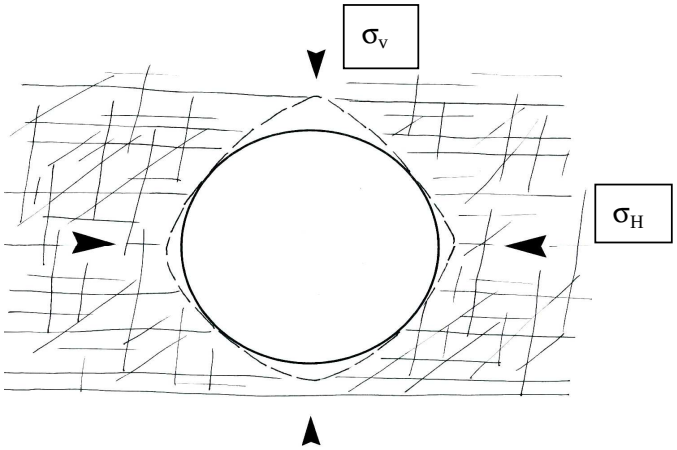
3.4.2.6 Behaviour Type 4A: Brittle Failure Induced by Stresses

Rock mass behaviour was analyses using the FE-method.

Rock Mass Behaviour: Brittle Failure Induced by Stresses		
 Sketch of assumed rock mass failure; stress induced failure depth not in scale		
Formations	Queenston	
Characteristics of Discontinuities	<u>Bedding:</u> Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered, clayey infilling possible (fault gauge)	<u>Joints:</u> Persistence: <10m Spacing: dm - m Roughness: slightly rough, slightly weathered
In Situ Stress Conditions	in situ stresses significantly exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from dry to flowing	
Rock Mass Behaviour	in competent rock mass high in situ stress conditions will result in brittle failure of the rock mass in terms of rock mass spalling and slabbing; according to [18] a slab with a max. thickness of 3m has to be considered, accordingly it is assumed that 3m also forms the max. depth of stress induced failure; in very strong, brittle rock, rock failure can be violent resulting in rock burst, according to [16] the app. lower limit of UCS for violent rock burst is 125-165 MPa; groundwater has no significant influence on rock mass behaviour	
Deformations	minor deformations <20mm, which stabilize quickly	

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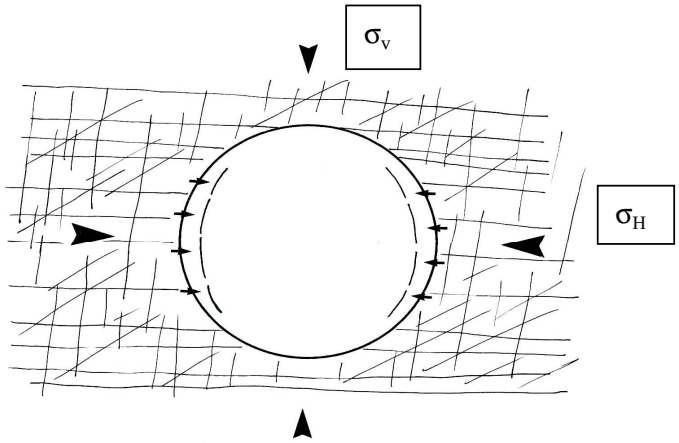
3.4.2.7 Behaviour Type 4B: Squeezing Rock

Rock mass behaviour was analysed using the FE-method.

Rock Mass Behaviour: Squeezing Rock		
 Sketch of assumed rock mass failure; tunnel wall deformation not in scale		
Formations	Lockport, De Cew, Rochester, Irondequoit, Reynales, Neahga, Thorold, Grimsby, Power Glen, Whirlpool, Queenston	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered, clayey infilling possible (fault gauge)	Joints: Persistence: <10m Spacing: dm - m Roughness: rough to smooth, fresh to slightly weathered
In Situ Stress Conditions	in situ stresses significantly exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from dry to wet	
Rock Mass Behaviour	in incompetent rock mass high in situ stress conditions will result in ductile deformations; the assumed groundwater quantities have no influence on rock mass behaviour; rock squeezing can occur around the whole opening or can be confined to distinct areas e.g. interbedding of incompetent and competent strata (sequence Reynales, Neahga, Thorold) or along weak bedding planes (bedding plane Q8/Q9); long term rock squeeze and swelling are interrelated processes which can be difficult to distinguish	
Deformations	long lasting deformations >20mm	

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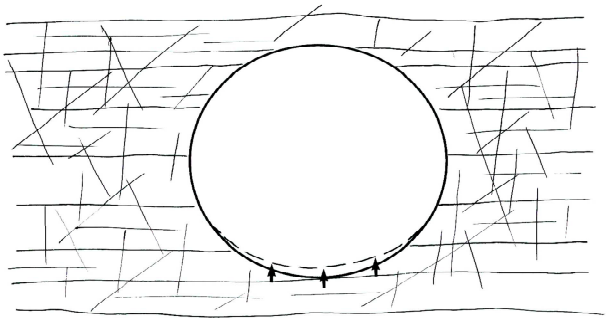
3.4.2.8 Behaviour Type 4C: Swelling Rock

Rock mass behaviour was analysed using the FE-method.

Rock Mass Behaviour: Swelling Rock



Sketch of assumed rock mass failure; invert heave not in scale

Formations	Rochester, Neahga, Power Glen, Queenston	
Characteristics of Discontinuities	Bedding: Persistence: >20m Spacing: dm - several m Roughness: rough to slightly rough, fresh to slightly weathered, clayey infilling possible (fault gauge)	Joints: Persistence: <10m Spacing: dm - m Roughness: slightly rough, slightly weathered
In Situ Stress Conditions	in situ stresses significantly exceed rock mass strength	
Groundwater Conditions	groundwater conditions are varying from damp to wet	
Rock Mass Behaviour	shale formations with a considerable content of swelling clay minerals are prone to rock mass swelling resulting primarily in invert heave; stress relief and the presence of fresh water are substantial for the swelling process; shale interbeds in the sandstone and carbonate formations may also be subject to swelling, however the presence of sandstone and carbonate interbeds tend to inhibit the overall deformation; the swelling process predominatingly occurs in the invert due to gravity related water accumulation, however it can occur at any place around the opening where groundwater is present; long term rock squeeze and swelling are interrelated processes which can be difficult to distinguish	
Deformations	long lasting deformations >20mm	

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3.5 Excavation and Support

3.5.1 Requirements

The requirements for excavation and support are based on the following conditions:

- Safety for working personnel
- Structural stability of excavation and support
- Safety against wedge and block failure
- Stability of the excavation face
- Avoidance of rock mass loosening
- Initial lining capacity
- Allowable deformations

The Diversion Tunnel is aligned through built-up area. However ground conditions are considered to be favourable for tunnelling, that only with a very shallow rock cover surface effects will be registered.

3.5.2 Excavation Methods

The bored tunnel is excavated by means of a hard rock Tunnel Boring Machine (TBM). The TBM consists of main body, cutter head and grippers. Disks on the rotating cutter head break the rock mass, which is conveyed in form of loose chips to the back of the TBM. The forces which develop as a result of forward movement of the TBM are transferred back to the ground by grippers. The TBM as such is only approx. 20 m long, however a 100 to 200 m long backup system is required to manage all the logistics for tunnel excavation and support installation.

The short sections of tunnel at the Intake and Outlet, which require a cross section, which deviates from circular are excavated by drill and blast. Smooth-blasting methods have to be employed to avoid undesired vibrations and subsequent rock mass loosening. A horizontal drilling pattern is to be employed with a borehole length not longer than 4 m.

3.5.3 Support Measures

The following support measures are used and represent in total the initial lining:

- rock dowels
- steel wire mesh
- steel ribs
- shotcrete

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A dimple membrane is placed on to the intrados of the initial lining, where water seepage has to be channelled into the temporary construction drainage system to facilitate tunnel construction.

3.5.3.1 Rock dowels

Fast acting standard Swellex or equivalent rock dowels with a length L = 2,4 m and L = 3,6 m are used to be installed just behind the cutterhead of the TBM.

For the installation of rock dowels further back from excavation, cement/resin grouted rock dowels with a length of L = 2.5 m to 4.0 m are used.

The rock dowels are installed through the steel ribs (UPN-profiles) or with an anchor plate (L x W x T = 100 x 100 x 8 mm) at its base.

They serve as rock reinforcement through bedding – and shear planes and improve block stability. The steel wire mesh installed in the tunnel crown for protection is also attached with rock dowels and short anchors.

3.5.3.2 Steel Wire Mesh

Steel wire mesh with bar size of 6 mm and bar-spacing of 100 mm by 100 mm is installed to

- reinforce the shotcrete and
- to protect personnel from falling rock particles until shotcrete is installed.

In addition the welded steel wire mesh facilitates the application of shotcrete to the tunnel crown and to the sidewalls in the bored tunnel.

3.5.3.3 Steel Ribs

Two types of steel ribs are used for the construction of the bored tunnel.

The light UNP-Profile is used as a crown support element in geological conditions, which require roof protection mainly. It is applied in form of

- UNP 100: H x W = 50 x 100 mm (10,6 kg/m)
- UNP 140: H x W = 60 x 140 mm (16,0 kg/m)

Where heavy steel support is required full round, steel sets are to be used in form of

- IPB 160: H x W = 160 x 160 mm (42,6 kg/m)
- IPB 260: H x W = 260 x 260 mm (93,0 kg/m)

Steel ribs are installed just behind the TBM cutter head with mechanical erectors.

3.5.3.4 Shotcrete

Shotcrete is considered the main supporting element of the initial lining.

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The thickness of shotcrete lining depends on the type of rock support to be applied and is ranging from 50 mm to 300 mm. A shotcrete thickness larger than 200 mm is installed in 2 layers at least. Shotcrete thinner than 70 mm is not considered as a structural element. However it serves as a sealing layer to protect the ground from drying out or abrasive water.

3.5.4 Tunnel Support Application

The arrangement of mechanical and electrical parts on a TBM allows for two locations, where support of excavation may be regularly installed.

The location L1 is situated just behind the cutter head between 4 m and 7 m back from the excavation face. Steel ribs may be installed full round or as a light profile on the crown of the tunnel cross section. Steel wire mesh and rock dowels can also be installed at distinctive locations above springline, where support is not harmed by the gripper loads exerted to the side walls of the tunnel. Shotcrete application is possible in L1 but limited to the absolute minimum requirement. Sensible electronic and mechanical parts of the TBM, which are situated in L1 may be affected by dust and rebound material. Protection measures and cleaning of the TBM as a result of shotcrete application in L1 reduces the rate of tunnel advance considerably.

All support installation in L1 adversely affects the rate of tunnel advance, therefore the intention is to install the majority of the required ground support, from a working platform at location L2 situated 20 m to 40 m back from the excavation face.

Depending on the ground conditions, which prevail in the tunnel at certain locations it is important to gradually increase the amount of support in a way, that the reduction of tunnel advance rate is minimized, but the required level of safety for people working in the tunnel is always maintained.

It has to be acknowledged, that full support of the bored tunnel is only in operation some 40 m back from the excavation. However, the ground support required early is, depending on the prevailing ground conditions, installed already behind the cutter head of the TBM.

In order to allow for gradually increasing support installation in an organized manner, support types are defined.

3.5.5 Support Types

6 Types of support are differentiated for the bored Diversion Tunnel. The support types ranging from support, if required to heavy steel sets and reinforced shotcrete full round to cover a wide range in rock mass behaviour, which is anticipated for the project.

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3.5.5.1 Support Type 1:

Support Type 1 consisting of a sealing layer of 50 mm thick shotcrete, which is reinforcement by steel wire mesh. The support type is to be applied in stable rock conditions with a uniaxial compressive strength comparable to lean concrete. Only if rocks are sensitive to water or will degrade if exposed to air the shotcrete and mesh is to be applied.

3.5.5.2 Support Type 2

In case blocks of ground are differentiable in otherwise stable rock conditions, Support Type 2 is to be applied. It consists of steel ribs in form of UNP-100 profiles, which are bolted with a limited number of rock dowels to fix steel wire mesh to the tunnel crown and sides.

This arrangement shall provide safety for personnel working at the front of the TBM. Further back the steel support is covered with a layer of shotcrete (70 mm thickness) in the top section of the tunnel and additional rock dowels are installed. In case of seepage water dimple membrane panels are fixed to the tunnel crown and wall to drain the water into the invert area. If necessary in ground sensitive to water sealing shotcrete is applied to the invert section of the tunnel equal to Support Type 1.

3.5.5.3 Support Type 3

Support Type 3 is used in friable ground, where small blocks of ground tend to fall from the tunnel crown if left unsupported. It consists of steel rips UNP 140, rock dowels 3,6 m – 4,0 m long and steel wire mesh, which is installed close to the front of the TBM. Further back (i.e. working platform) reinforced shotcrete (t = 100 mm) and more rock dowels are installed to support the full circumference of the tunnel.

3.5.5.4 Support Type 4

Close to the intersection of the tunnel crown and major bedding planes, an increasing number and size of blocks of ground is to be expected. Support Type 4 consisting of steel profiles UNP 140 at close spacing, rock dowels 3,6 m to 4,0 m long and steel wire mesh is to be applied close to the front of the TBM. Reinforced shotcrete (t = 150 mm) and additional rock dowels are installed from the working platform of the TBM that support around the full circumference of the tunnel is realised.

3.5.5.5 Support Type 5

In squeezing ground, where slabbing and spalling is experienced soon after excavation Support Type 5 is to be installed. Support Type 5 consists of steel ribs in form of mid weight IPB 160 steel sets, which are installed close to the front of the TBM around the full circumference of the cross section. As for support types 2 to 4, steel wire mesh is installed in the tunnel crown to provide safety of the personal working at the TBM front. 200 mm of

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reinforced shotcrete applied from the working platform of the TBM full round is completing Support Type 5.

3.5.5.6 Support Type 6

Support Type 6 is to be installed in heavily squeezing rock, where spalling and slabbing is experienced even in front of the excavation face. Heavy IPB 260 steel sets and reinforced shotcrete (t = 100 mm) are to be installed at the front of the TBM. Additional shotcrete (t = 200 mm) and mesh reinforcement is installed at the working platform to support the full circumference of the excavation cross section.

3.5.6 Geotechnical Sections along the Tunnel Alignment

3.5.6.1 General

In order to allocate the support types, rock mass behaviour along the tunnel alignment has been evaluated. Five tunnel sections have been identified, which suggest consistent rock mass behaviour being encountered. The following chapters summarize the geological, geotechnical and hydrogeological conditions for each of these sections and the prevailing rock mass behaviour. More detailed information of the geological and geotechnical properties of the encountered rock mass types is provided in chapters 3.3.4 and 3.3.5. The description of the tunnel sections starts at the outlet structure and proceeds to the intake structure.

The following issues apply more or less to all defined tunnel sections:

- The length of each section is based on the tunnel axis. Prolonged interfaces in tunnel crown or invert are not considered when estimating the section length. The length of tunnel sections was rounded to 5m.
- Significant overbreak has to be expected in all tunnel sections where weak bedding planes or flat lying shears occur above the crown. This may result in crown instability. During upslope tunnel advance overbreak is possible when approaching such a feature, during downslope tunnel advance overbreak may occur when leaving such a feature. The depth of the overbreak is controlled by the distance to the overlying plane. During previous tunnel construction works, crown slabs of up to 0,5m were recorded. Relevant discontinuities are reported from all formations encountered in the project area.
- Where rock mass spalling and slabbing occurs, it is expected soon after excavation took place.
- Shale units are prone to change in moisture content, which will result in the development of cracks and degradation of rock mass when surfaces are left unprotected. Due to previous construction experiences it is assumed, that it will take

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months before relevant cracks develop. Application of sealing shotcrete stops the process.

- Long term rock mass behaviour in terms of rock swelling has to be expected for all shale formations. Laboratory testing proofed that even shale interbeds within the sandstone and carbonate units show swelling potential. However it is assumed that the nonswelling sandstone/carbonate interbeds inhibit overall deformation. Extent and range of the actual swelling will depend to a large extent on the presence of groundwater and the prevailing in situ stress conditions.

- Long term rock mass behaviour in terms of rock squeezing has to be expected within all sections. Previous construction experience reveals that even competent rock mass types like the Lockport formation show long lasting squeezing behaviour.

The prevailing Support Types applicable to each section of tunnel for the Proposal are shown on drawing PD-01-1002 "Diversion Tunnel, Geotechnical Longitudinal Section". To cover a range of support, which may be used in a particular tunnel section, a distribution of applicable Support Types is defined by:

- Very applicable = 60% probability
- Applicable = 30% probability
- Less applicable = 10% probability

Based on this assumptions, the support measures (i.e. rock dowels, wire mesh, steel ribs and shotcrete) for the Diversion Tunnel are estimated.

3.5.6.2 Tunnel Section 1

Section Length: Starting at the outlet structure, the tunnel section has a length of app. 740m.

Geology/Geotechnics: The tunnel is descending from the outlet structure at a gradient of 7,62% towards the low point. Within this section the tunnel will intersect the total sequence of all formations relevant for the Niagara Tunnel Facility Project including Lockport, De Cew Rochester, Irondequoit, Reynales, Neahga, Thorold, Grimsby, Power Glen, Whirlpool and Queenston Q10 and Q9 formation. Thus the tunnel section is also characterised by frequent changes of lithology and rock mass properties. The spectrum of lithologies to be encountered includes limestone, dolostone, shale and sandstone. The rock mass is in general slightly to moderately fractured and fresh to slightly weathered. In situ stress conditions are expected to be homogeneous throughout the section but their effect on rock mass is changing due to the variability of rock mass properties. In some parts the in situ stresses are expected to exceed rock mass strength in some parts they don't.

Groundwater Conditions: Groundwater conditions are expected to vary between dry and wet. The later can be expected to prevail in Irondequoit, Reynales, Thorold, Grimsby, Whirlpool and Queenston Q10 and Q9 formations. In the tunnel section intersecting the

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Lockport and De Cew formation no significant groundwater inflow is expected due to grouting in the outlet section.

Expected Rock Mass Behaviour: Rock mass behaviour is expected to be stable to friable and varying within short distance due to frequent changes of rock mass and rock mass properties. In case failure occurs in the rock mass, the prevailing failure mode will change between failure induced by stress and/or along discontinuities, resulting in rock mass slabbing and spalling and/or wedge failure.

3.5.6.3 Tunnel Section 2

Section Length: app. 765m

Geology/Geotechnics: This tunnel section is situated entirely within the Queenston formation, members Q10 to Q6. The prevailing lithology is shale. The rock mass is slightly to moderately fractured and fresh to slightly weathered. In general in situ stress conditions exceed rock mass strength throughout the tunnel section. The low point of the tunnel is falling within this section. Thus there is both descending and ascending tunnel advance.

Groundwater Conditions: Groundwater conditions are expected to vary between dry and wet. The later can be expected to prevail in formation member Q10 and Q9 due to the higher degree of fracturing.

Expected Rock Mass Behaviour: Rock mass behaviour is expected to be friable to squeezing. More frequent than in Section 1, failure induced by stress and along discontinuities is expected. This is the prevailing short term failure mode in the rock mass, resulting in wedge failure and rock mass slabbing and spalling.

3.5.6.4 Tunnel Section 3

Section Length: app. 530m

Geology/Geotechnics: This tunnel section is situated entirely within the Queenston formation, member Q7 and Q6. The prevailing lithology is shale. Within Q6 a gypsum nodule horizon occurs. The rock mass is intensely fractured and slightly weathered. In situ stress conditions exceed rock mass strength throughout the tunnel section, in some parts significantly. The tunnel is passing under the buried St. David's Gorge with shallow rock cover. Tunnel advance is ascending at a gradient of 0,10% for the proposed alignment.

Groundwater Conditions: Groundwater conditions are expected to vary between dry and wet. Wet conditions are expected to prevail due to intense fracturing.

Expected Rock Mass Behaviour: Rock mass behaviour is expected to be squeezing with sections of tunnel classified friable. Failure induced by stress is expected to be the prevailing short term failure mode in the rock mass, resulting in rock mass spalling and slabbing. Block failure may also occur due to intense fracturing.

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3.5.6.5 Tunnel Section 4

Section Length: app. 7280m

Geology/Geotechnics: This tunnel section is situated entirely within the Queenston formation, member Q10 to Q6. The prevailing lithology is shale. Within formation member Q6 a gypsum nodule horizon occurs. The rock mass is slightly to moderately fractured and fresh to slightly weathered. In general in situ stress conditions exceed rock mass strength throughout the tunnel section. The geological conditions are comparable to Section 2. Tunnel advance is ascending at a gradient of 0,10%.

Groundwater Conditions: Groundwater conditions are expected to vary between dry and wet. The later can be expected to prevail in formation member Q10 and Q9 due to their higher degree of fracturing.

Expected Rock Mass Behaviour: Rock mass behaviour is expected to be friable to squeezing. Failure induced by stress and along discontinuities is expected to be the prevailing short term failure mode in the rock mass, resulting in wedge failure and rock mass slabbing and spalling.

3.5.6.6 Tunnel Section 5

Section Length: app. 1090m

Geology/Geotechnics: Within this section the tunnel will intersect the total sequence of all formations relevant for the Niagara Tunnel Facility Project including Lockport, De Cew Rochester, Irondequoit, Reynales, Neahga, Thorold, Grimsby, Power Glen, Whirlpool and Queenston Q10 and Q9 formations. Thus the tunnel section is also characterised by frequent changes in lithology and rock mass properties. The spectrum of lithologies to be encountered includes limestone, dolostone, shale and sandstone. The rock mass is in general slightly to moderately fractured and fresh to slightly weathered. In situ stress conditions are expected to be homogeneous throughout the section but their effect on rock mass is changing due to the high variability of rock mass properties. In some parts the in situ stresses are expected to exceed rock mass strength in some parts they don't. In general the geological conditions are comparable to section 1. Tunnel advance is ascending at a gradient of 7,23%.

Groundwater Conditions: Groundwater conditions are expected to vary between dry and wet. The later can be expected to prevail in Irondequoit, Reynales, Thorold, Grimsby, Whirlpool and Queenston Q10 and Q9 formations. Tunnel sections intersecting the Lockport and De Cew formations can expect groundwater conditions which vary between wet and flowing. Significant groundwater inflow can occur within this part of the section.

Expected Rock Mass Behaviour: Rock mass behaviour is expected to be stable to friable. Due to lithological changes of the rock mass a frequent variation of rock mass properties is expected. The prevailing failure mode will change between failure induced by stress and

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failure along discontinuities, resulting in rock mass slabbing and spalling and/or wedge failure.

3.6 Invert Segments

Invert segments made of precast concrete are placed to support rails of the construction trains for material supply and the backup system of the TBM. Any seepage water entering the tunnel during excavation shall also be diverted to the deep point of the alignment via the invert segments.

The concrete may be reinforced with standard bar reinforcement or steel fibres. There is no connection planned between invert segments and the initial lining, which is installed for rock support during excavation of the tunnel. However invert segments are connected to the final lining and participate in carrying all permanent design loads. Two types of standard segments are envisaged for use Type A is 600 mm thick and installed in the upper levels of the tunnel alignment. Type B is 700 mm thick and installed in the deep sections. Purpose built segments are placed at locations where the lining thickness changes to avoid abrupt steps at interfaces. Up to 100 mm difference in lining thickness can be compensated without causing significant effects on the flow rate of water transfer.

Measures to avoid load concentrations on the waterproofing membrane with regard to effects of shimming and unevenness in shotcrete see appendix 3.5.

3.7 Cavity Grouting

Injections will be made to reduce the water ingress in permeable sections and to improve the ground where necessary. Since no long-term use is expected from cavity grouting, Ordinary Portland Cement is used for binder. If mortar or cement grout is to be applied, will be determined on site and confirmed by grouting trials.

3.7.1 Ground improvement

In case rock slabs are becoming loose between TBM and backup and prior to complete the initial support with shotcrete, grout holes are drilled through the blocks. This will be done preceding the interface grouting operation from the secondary rock drills installed at the back of the TBM. Grouting will be performed by a low pressure grout pump type MAI 400 or similar.

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3.7.2 Reduction of water ingress

3.7.2.1 Diversion Tunnel

Tunnel inflow will be covered by standard pumping measures. Grouting will only be applied in case higher rates of water ingress will be encountered. In case of higher than anticipated inflows or significant washout from the tunnel face, the TBM will be stopped for cavity grouting or for formation grouting.

Grout holes are bored in a radial pattern of 1.5 m and 2.5 m longitudinally at a depth of 4 m. These grout holes are subsequently grouted with a cement based grout mixture in order to reduce the water inflow to a manageable level.

All commencing mixes will be at a water cement ratio of 3: 1 by volume unless a thinner mix is indicated by pre-mature refusal. Increasing or static flow conditions will determine the mix adjustment. In order to prevent washouts, sodium silicate based admixtures and filter pipes are used

Any grout hole that accepts significant grout will have two additional adjacent holes drilled and grouted A recorder will take records of the whole grout operation The recorder will take readings of the volume of grout injected and the number of sacks of cement with corresponding water cement ratios batched. The recorder will also keep in contact with the header operator to verify injection pressures and conditions at the face; i.e grout leakage, interconnection with other holes, etc. He will produce a daily time sheet. On a regular basis, an as built record of the grout operation and wilt be produced. Together with the tunnel water inflow record, this will be the basis for the decision to advance with the TBM.

Typically, a series of grout holes are drilled at a minimum angle of about 60° over the whole tunnel circumference and at a distance of about 50 cm. Standpipes of a length of 3 m approx. are drilled and grouted prior to the start of the grouting operations. The grouting operation is performed in accordance to standard grouting procedures developed and applied in similar cases

For cavity grouting in the permeable section of the Lockport and Decew Formations an approx. 250 m long, 5 m diameter horseshoe shaped exploratory tunnel will be driven by drill and blast from the intake. Depending on the water inflow, formation grouting will be performed.

3.7.2.2 Intake area

Grouting of the intake area and the intake Channel will be carried out to reduce the amount of seepage water, which has to be pumped out of the construction pit. Up to four stages of cement based grouting will be envisaged For each phase grout holes spacing max. 12 m shall be drilled. Accelerator may be added to the grout mix to prevent washout.

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3.7.2.3 Outlet area

Grouting of the outlet area and Canal will be carried out to reduce the amount of seepage water, which has to be pumped out of the construction pit. Up to four stages of cement based grouting will be envisaged in the outlet area. For each phase grout holes spacing max. 12 m and reaching into the Rochester Formation shall be drilled. Accelerator may be added to the grout mix to prevent washout

30 m deep holes spacing 3 m are drilled for grouting purposes around the periphery of the Outlet Structure and Canal.

3.8 Waterproofing Membrane System

To prevent seepage of aggressive ground water into the Diversion Tunnel, a waterproofing membrane system is placed between the initial lining and the final lining. The waterproofing membrane system consists of

- regulating shotcrete
- Membrane-backed geotextile
- waterproofing membrane

A dual layer waterproofing system shall be installed in tunnel sections, where the swelling potential of the rock mass may affect the stability of the tunnel, In all other tunnel sections, a single layer waterproofing system is envisaged.

Regulating shotcrete is to provide the smooth surface, which enables membrane installation and counteracts any potential damage on sharp corners and edges of the waterproofing membrane during placement, concreting and during the specified design life.

The geotextile also protects the waterproofing membrane and enables subject to the thin membrane-backing the flow of interface grout.

The waterproofing membrane is designed to act as an impermeable layer between initial and final lining and to sustain all pressures and strains throughout the specified design life of 90 years.

3.9 Final Lining

The final lining consists of cast in place concrete without steel reinforcement. The final lining is min. 600 – 700 mm thick and compressed by interface grouting at high pressures to sustain internal water pressures, which develop during standard operation, without cracking. It is erected with using approx. 12 m long steel shutters, that run on the invert segments installed before hand. The steel skin used for formwork is designed to fullfill tight smoothness criteria set for flow of water in the Diversion Tunnel. Abrasivity is also

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counteracted by the smoothness of the concrete surface such maintained. Ordinary Portland Cement is used for the manufacture of final lining concrete, since particular resistance to aggressive water is not required due to the presence of the waterproofing membrane. When interface grouting is executed at pressures higher than the external water pressure, the presence of groundwater around the outside of the tunnel can be excluded.

3.10 Contact Grouting

Contact grouting is to be carried out after concreting of the final lining is finished. The aim is to close all voids, cracks joints and inconsistencies in the final lining concrete resulting from the concreting operation and to provide a tight interface between rock mass / initial lining and final lining.

The tunnel final lining sits on the sidewalls of the precast invert segment while exerting the gravitational load of selfweight to the lower parts of the excavated cavity. A gap remains in the top half of the circumference of the tunnel between the initial and the final lining. The tunnel final lining is bedded smoothly to the surface of the initial lining in the tunnel invert.

Contact grouting is applied through the grouting pipe installed at the intrados of the waterproofing system. Grout is flowing along the outer surface of the final lining thus filling the gap in the top half of the tunnel. Once the gap is filled and voids are closed, the contact grouting pressure of approx. 2 bar is uniformly loading the final lining in all areas, where this pressure is exceeding the bedding reaction in the invert resulting from self weight of the final lining.

The injection lines are spot-welded to the waterproofing membrane and have openings at regular intervals to release the grout. Cement grout consisting of Ordinary Portland Cement compatible to the final lining concrete is used.

For the determination of quantities a 10 mm gap is assumed around one quarter of the tunnel circumference in the roof area.

3.11 Interface Grouting

The interface grouting at pressure high enough to sustain internal water pressures has been originally developed for pressure tunnels and shafts at hydropower schemes. Grout is injected between initial lining and waterproofing system at pressures up to 30 bar to open the interface and prestress the final lining at one hand and the rock mass surrounding the tunnel on the other hand. The final lining is compressed and the rock mass around the tunnel is brought close to its original stress state before excavation of the tunnel took place.

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The interface grouting operation is carried out after final lining installation in stages through a system consisting of grout-hose-rings installed at the surface of the initial lining.

Circular grout hose lines with valves at regular intervals are placed between initial lining and the waterproofing membrane system. This shall ensure an evenly distributed flow of grout along the membrane-backed extrados of the waterproofing system and facilitate filling of joints and cracks in the initial lining and rock mass with grout.

The ends of grout hoses are guided through the waterproofing membrane system and through the cast in place final lining into the tunnel. By pumping grout to the interface between membrane and initial lining a circumferential joint is opened and filled with cement grout. The final lining is prestressed against the rock by the grout pressure acting in the circumferential joint. The deformations of initial lining, final lining and the rock mass are locked after the cement grout has hardened.

Since grout escapes into the cracks and fissures of the rock mass, the ground is consolidated and sealed against ingress of water at the same time.

Grout blocking rings are installed every 12 m approx. to control the flow of grout.

The grouting procedure follows a defined pattern of pressure application with aid of two or more pumps, hence creating a consistent flow of grout along the tunnel. For estimating purposes 100 m advance rate per day is assumed for the interface grouting process. The average gap to be filled with cement is assumed to be 3 mm thick.

Grouting is carried out in a first phase at every other interface grouting ring from both ends of the grout hose. If necessary the remaining rings are grouted in a second phase of interface grouting. The success of grouting is carefully monitored by precise deformation measurements of the final lining around the full circumference of the tunnel. Pumping pressures defined by structural analysis, are such controlled within allowable limits.

All operational pressures and loads are carried by the compressed final lining concrete ring after successful grouting. Shrinkage of concrete and the shrinkage due to the drop in temperature when filling the tunnel with water are carefully considered in calculations for the required grouting pressure.

When interface grouting is starting, the final tunnel lining can be considered under at least 1 bar pressure round the circumference increasing from top to bottom of the tunnel according to the distribution of bedding reaction resulting from self weight of the lining. Interface grout is pumped into the grouting hoses in two to three grouting rings simultaneously spaced approx. 3 m at centres (in tunnel axis direction). Once the local existing pressure (contact grouting and bedding reaction) is exceeded at the valve (situated at 3 m circumferential centres), grout starts to travel along the outside of the grout hose at pressures, just above the existing pressure affecting small areas around the circumference of the tunnel until the grouting ring is fully closed. This fully closed grouting "coat" around the

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tunnel circumference travels at pressures defined by the grouting procedure along the tunnel with the progress of interface grouting works.

Regrouting is required in case the anticipated initial (short term) grouting pressure is not achieved or if the pressure loss falls below the calculated minimum prestressing pressure determined to sustain the internal water pressure.

Outline of the procedure:

1. Calculation of the required long term prestressing pressure and associated tunnel convergence.

2. Calculation of the anticipated short term prestressing pressure and associated tunnel convergence including deformation allowance for shrinkage of concrete and temperature contraction after watering up.

3. Calculation of acceptable differential deformations including the shrinkage of concrete before watering up.

4. Online measurement of tunnel convergence during interface grouting.

5. Measurement of differential convergence after interface grouting is completed.

6. Regrouting is required if the differential deformations (divergence of tunnel lining) rise beyond the values anticipated before watering up (i.e. differential deformation associated with the conservation of the minimum long term prestressing pressure including the temperature contraction after watering up is exceeded).

The tolerable differential deformations associated with the loss of lining prestress differ with relation to the location in the tunnel. They have to be determined individually for each section of tunnel and are based on the success of grouting (=actual prestress measured for a particular section of tunnel). Tolerable differential deformations are at least 30% of the convergence measured for the interface grouting operation in case only the minimum interface grouting pressure is applied. If more than the minimum grouting pressure is applied (standard case), the tolerable differential deformation associated with relaxation is much larger.

3.12 Dewatering System Shafts

5 dewatering shafts will be located on the centreline of the tunnel at approx. km 8.9 of the Diversion Tunnel so that the Owner's pumping equipment can be positioned over the tunnel invert. Each shaft is circular and drilled with a minimum diameter of 1.05 m in overburden and 0.915 m in rock to accommodate a min. 750 mm steel pipe as shown on the Proposal

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Drawings. The pipe is coated with 3 HDPE and lined with fusion bonded epoxy to resist the corrosion-aggressive environment. The annulus around the pipe is grouted to prevent water seepage between different geological formations along the outside of the pipe. One 2.0 m x 2.0 m wide sump is provided at the invert below one of the dewatering shaft locations such that a submersible pump can be positioned below the tunnel invert to achieve the required operating submergence in the final stage of dewatering.

The water pumped from the tunnel during dewatering will be discharged into a Water Collection Sump and conveyed via a buried 227 m long 1.0 m dia. HDPE Pipe and a 3.45 m wide chute into the SAB2 Canal.

The shafts are capped for normal operation of the tunnel and the cap is protected from pressure surges with air vents.

3.13 Intake Structure, Outlet Structure and Channels

3.13.1 Intake Structure, Intake Channel

The location and dimensional geometry of the intake channel and intake approach wall are fixed as defined on the Concept Drawings. The adjustments for final tunnel slope and diameter are shown in the Proposal Drawings. The alignment and dimensional geometry of the ice accelerating wall is generally shown on the Concept Drawings. The design of surfaces of structures and excavations as shown on the Proposal Drawings is intended to convey water smoothly into the intake structure and shall provide satisfactory performance for both open water and ice conditions.

The intake structure location, internal dimensional geometry, and transition from the shape at the entrance to the circular shape of the tunnel are fixed as defined on the Concept Drawings. Adjustment to the geometry for tunnel diameter and tunnel slope is shown on the Proposal Drawings.

100-mm of compressible material (Polystyrol or similar) is provided between the rock surface of excavated walls and the intake and outlet structures to accommodate movement due to time-dependent deformations of the rock.

Suitable venting will be provided at the intake behind the Sectional gate to permit aeration of the tunnel during filling and dewatering. Vent sizing is 1,0 m diameter, but will be adjusted such as to limit noise levels during filling and dewatering to the relevant noise restrictions in future design stages.

A cover will be provided over the top of the Sectional service gate openings in the intake structure to avoid the possibility of ice being drawn into the structure. The cover is of ample mass to prevent dislodgement and will be detailed alt future design stages to prevent seizing of the cover after prolonged submergence. Appropriate lifting devices will be

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provided on the covers to enable the Sectional service gate follower to engage and lift the gate slot cover.

3.13.2 Excavations for Channels and Structures

Smooth plasting techniques will be employed to excavate the sides of the intake channel and outlet canal. Care is taken to ensure, that the rock beyond the excavation limits is not damaged or destabilized by the blasting operation. Any damaged rock will be removed and backfilled with concrete adequately tied back to sound rock to produce the required excavation lines.

The need for preset rock reinforcement prior to blasting for the intake excavation to secure the integrity of the foundation of the INCW control structure will be examined upon detailed inspection of the structure and surrounding ground conditions.

During excavation, methods will be employed to prevent damage to existing structures and buildings and affect operation of existing equipment. Blasting velocities will be carefully controlled and the affected structures will be monitored to ensure adequate control.

Any exposed shaly rocks (e.g. the Rochester Formation) or shale layers which are susceptible to deterioration upon exposure to wetting and drying cycles and large temperature differences will be immediately protected by sealing shotcrete.

Overburden slopes are designed subject to analysis results at 1:1.5 (temporary slopes for excavations of trenches, sumps, etc.) and 1:2 (permanent slopes) grades. Vertical excavations for trenches are only allowed to a depth of 1.2 m.

3.13.3 Outlet Canal Rock Plug Removal

The rock plug between the Outlet canal and the existing PGS canal will be removed by excavation under water. The outlet gate will be closed to provide balanced water conditions during rock plug removal.

The excavated material will be removed from the PGS canal and taken to the muck depot prior to the PGS canal being brought back into operation.

A sounding survey of the PGS canal will be performed before and after removal of the rock plug to verify that no excavated material remains within the PGS canal and the results submitted to the Owner.

Protection measures will be installed to ensure that no material is carried down the PGS canal during and after removal of the rock plug.

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3.14 Additional Ground Investigations proposed

The rock surface in the area of the Diversion Tunnel crossing under the buried St' David's Gorge is steep and highly uneven that predictions of rock elevation are uncertain. Seismic investigations and several boreholes suggest, that the difference in rock surface elevation vary within meters by an order of magnitude (i.e. $\pm$ 10 m). Since the vertical alignment of the tunnel is aiming to be optimized during detail design stage in vicinity of the buried St' David's Gorge, several boreholes are proposed exactly on the tunnel axis to confirm the elevation of rock at the base of the gorge.

The geotechnical drilling operation will be concentrated between km 8+550 and km 8+850 of the Diversion Tunnel.

The borehole location are planned, where the seismic investigations predict the deepest elevations along the tunnel alignment.

3.15 Instrumentation

3.15.1 Purpose

Instrumentation will be installed and monitored until Final Completion by the Contractor.

Movements of existing structures and buildings affected by the Work are monitored to ensure their protection, structural integrity and safety.
In particular the existing Toronto Power Station and the Niagara GS Power Station will be closely monitored by precise levelling. Also the existing tunnels, as far as accessible, will be closely monitored. Where the Diversion Tunnel is bored at shallow depth with less than two diameter cover under existing roads, services and buildings, the surface will be monitored and any settlement and tilting documented.

It is proposed to monitor the response of rock adjacent to the tunnel at regular intervals of 200 m with convergence monitoring sections throughout the advance of tunnel excavation. In addition a long-term measuring section consisting of piezometers and extensometers is planned close to the dewatering shafts or tunnel piezometer holes, since the wiring for instruments could be integrated into the backfill of borehole casings. However it is intended, that such suitable monitoring section, where rock's response to the tunnel during construction, filling and commissioning is maintained, is selected by the Owner.

3.15.2 Instrument Types

Surface movement monitoring (SM) is carried out with survey equipment and surface movement monitoring points (SMMP). The SMMP is a marker fixed to a surface, and used for the measurement of the vertical and horizontal movements of that surface. For SMMP permanent pins on structures or grouted rods in rock are used. Survey equipment

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(theodolite, level, electronic distance measuring device, tape extensometer), is capable of measuring vertical and horizontal movements of the SMMPs to ±1 mm.

Borehole Extensometers (EX)— is a device installed in boreholes for monitoring the changing distance between two or more than two points along the axis of the borehole. The EX to be used is of the vibrating wire type and capable of determining the relative position of each anchor to the surface installation with a repeatability of ±0.1 mm. Multiple Point Borehole Extensometers or several Single Rod Extensometers will be used to measure differential movements at each location to be monitored.

Piezometer (PI)—A groundwater piezometer is a device that is sealed within the ground so that it responds only to groundwater pressures around itself. Tunnel Piezometers are used to measure the water pressure within the tunnel. Piezometers to be provided are of the vibrating wire type and shall be capable of measuring the head of water at the piezometer tip to a repeatability of ±0.1 m.

Plumbline—A plumbline is a device to measure the relative tilt of a structure between two or more locations and is used for predominantly vertical structural elements, such as walls of pits and shafts.

3.15.3 Surface Movement Monitoring

SM will be carried out on masonry, buildings and road structures like bridges from prior to commencing any excavation until completion of final structures or linings in the area affected by the excavation. Buildings include, but are not limited to, INCW structure Bays 1 to 5 and the INCW control and maintenance buildings, existing Toronto Power Station and the Niagara GS Power Station.

A series of SMMPs will be installed and monitored on the INCW structure on Bays 1 to 3 above the intake excavation with a spacing of no more than 5 m.

A series of SMMPs will be installed and monitored at the pier nose of Piers 1 and 2.

A plumbline will be installed at the pier nose of Piers 1 and 2 extending to rock level. The plumbline shall have measuring tables at min. three locations.

3.15.4 Excavation Monitoring

On 2 vertical or near vertical rock cuts at the intake and outlet excavations at approximately the midpoint horizontal extensometers will be installed, that have monitoring positions (anchors) at 20, 10, 5 and 2 m from the wall of the excavation. Electrical leads are in watertight conduits leading to a lockable watertight box located at the deck level, which allows long-term monitoring of wall movement

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3.15.5 Instrumented Tunnel Sections

The following instrumentation for long-term monitoring is provided for the section of the tunnel as selected by the Owner (see. Drawings PD-01-1008 and PD-01-1009: Diversion Tunnel, Geotechnical Measurements and Diversion Tunnel, Geotechnical Measurements, Surface and Subsurface)

- A permanent array of eight extensometers that have monitoring positions (anchors) at 25, 10, 5, 2 and 1 m radially from the surface of the tunnel excavation. Installation is completed and the initial readings taken, subject to installation of the initial lining, before the tunnel face advances more than 25 m beyond the array. This array of extensometers is capable of being monitored remotely from the surface during the initial filling and operation of the tunnel.
- A permanent array of six piezometers around the exterior of one section of the tunnel final lining and one on the interior of the lining at the tunnel invert. The array of piezometers is capable of being remotely monitored from the surface during the initial filling and operation of the tunnel.
- Electrical leads for extensometers and piezometers are routed in watertight conduits, adequately fixed to the tunnel crown and extending up one of the boreholes used for dewatering shafts or tunnel piezometers leading to a lockable watertight box located at approx. ground level.

3.15.6 Tunnel Piezometers

(see. Drawing PD-01-1021: Diversion Tunnel, Tunnel Piezometers, Sections and Details)

Tunnel piezometric levels are measured at two locations along the alignment of the tunnel at approximate km 1.4 and km 7.3. Each location consists of two piezometers, 2 m to 20 m apart. The borehole for one piezometer is extending through the tunnel lining at the tunnel crown to the ground surface. The cable for the other piezometer is routed in watertight conduits embedded in the final lining to the same borehole. The final locations will be agreed with the Owner prior to installation.

Piezometer holes are cased with HDPE casings with a minimum 95 mm inside diameter. The annular gap between the rock and the casing will be grouted to prevent groundwater migration between the different rock formations.

Detailing of the piezometer fitting at the tunnel crown, shown on the Proposal Drawings, ensures that the velocity head is not measured and that degradation of the adjacent tunnel lining or fitting does not occur. The fitting is made of stainless steel and designed to facilitate maintenance or replacement of the instrument, in case damage does occur.

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The piezometer pit at the ground surface is made of concrete and set out to a depth that problems of ground movement due to frost heave are prevented. A watertight, lockable cap is also provided.

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4 STRUCTURAL DESIGN

4.1 Diversion Tunnel

The design basis and design criteria for the structural design of the diversion tunnel are included in the structural design analysis for the Diversion Tunnel, document PR-00-4001. Also any reference to standards and codes is given in this document.

4.2 Intake and Outlet Structures

The design basis and design criteria for the structural design of the intake and outlet structures are included in the Draft Design Basis for Concrete Structures. Further details are given in structural design analysis for Intake and Outlet Structures, document PR-00-4004. Also reference to standards and codes is given in these documents.

4.3 Intake and Outlet Canal

The design basis and design criteria for the slope design of the channels are included in the slope stability analysis for excavations, document PR-00-4003. Also reference to standards and codes is given in this document.

4.4 Dewatering Shafts, Pipes, Culverts and Minor Items

The design basis and design criteria for the design of dewatering shafts, pipes buried in the ground, culverts for transport of water and minor items like foundations and shallow shaft pits are included in the stability analysis documents PR-00-4002 and PR-00-4005. Also reference to standards and codes is given in these documents.

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5 APPENDICES

5.1 Hydraulic Design

APPENDIX 2.1: Steady Flow Analysis for the Proposal

5.2 Geotechnical Design

APPENDIX 3.1: Summary of the hydrochemical properties of groundwater

APPENDIX 3.2: GSI-Chart

APPENDIX 3.3: Damage Index and Depth of Stress Induced Failure

5.3 Civil Design

APPENDIX 3.4: Interface Grouting References

APPENDIX 3.5: Installation of Invert Segment

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APPENDIX 2.1: Steady Flow Analysis for the Proposal

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Niagara Tunnel Facility Project
Hydraulic calculation and longitudinal profile

ILF Project I 921 Date: 26.04.05

Input: **Discharge:** 502 m3/s

1) **Intake Channel** Roughness 25 Kst

2) **Intake Structure** Rouhgness 80 Kst

3) **Tunnel** Rouhgness 85 Kst
Tunnel outer diameter 14,44 m

>>> strg+a Calculation of the tunnel outer diameter
>>> strg+y Calculation of the discharge

Tunnel	INPUT		Result
Section	Length	lining thickn.	Inner Diameter
No.	(m)	(m)	(m)
1	1.119	0,83	12,78
2	3.295	0,93	12,58
3	4.877	0,98	12,48
4	1.107	1,08	12,28
5	32	0,83	12,78
Sum:	10.429	(m)	

4) **Outlet Structure** Roughness 80 Kst

5) **Outlet channel** Rouhgness 30 Kst
Length 306,96 m
in section 28 (after dilatation and up to the gauge, originally 292m)

Assumptions for calculation:
- Calculation acc. to the formula of Strickler
- Kst coefficients acc. to the Strickler formula
- Circular inner profile in the tunnel
- Tunnel profile filled, no free surface flow
- lower Kst-coeff. in the intake tunnel to consider 3D-flows and its losses

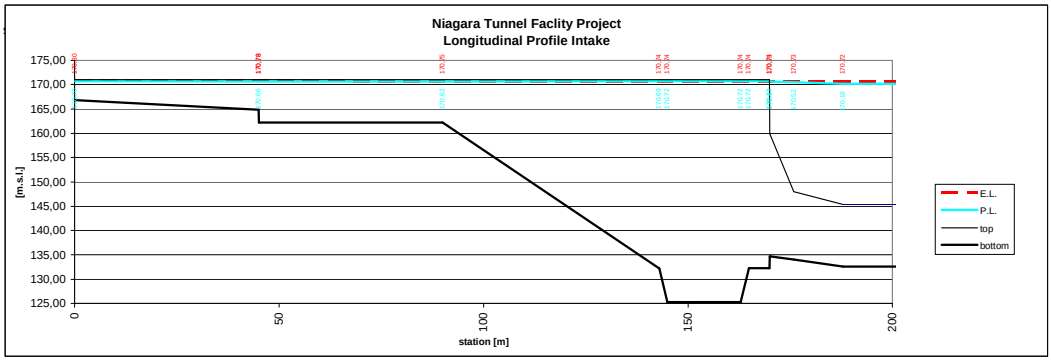
2.) Hydraulic Losses in the system

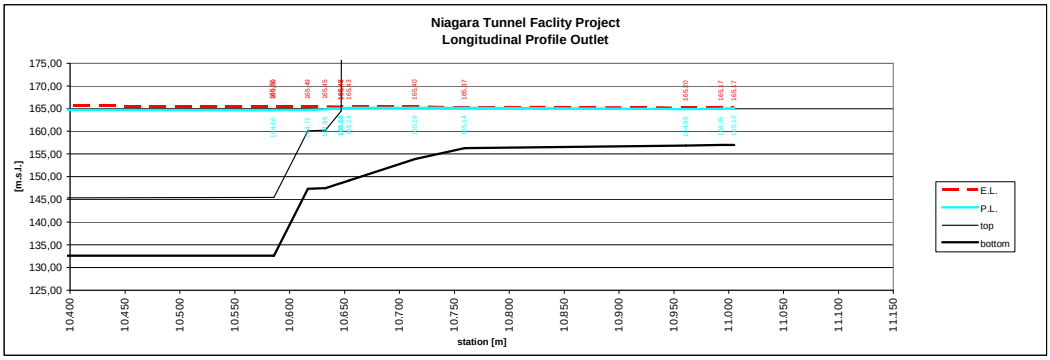
inlet gauge = E.L.

section	section	stat. beg.	stat. end	L	v	kST	hv,r	zeta 1	hv,zeta	hv, tot.	E.L. beg.	E.L. end	P.L. beg.	P.L. end
		[m]	[m]	[m]	[m/s]	[-]	[m]	[-]	[m]	[m]	[m.s.l.]	[m.s.l.]	[m.s.l.]	[m.s.l.]
intake channel	1	0,00	0,10	0,10	1,42	25	0,00	0,00	0,00	0,00	**170,80**	170,80	170,70	170,70
	2	0,10	45,00	44,90	1,51	25	0,02	0,00	0,00	0,02	170,80	170,78	170,69	170,66
	3	45,00	45,10	0,10	1,57	25	0,00	0,00	0,00	0,00	170,78	170,78	170,65	170,65
	4	45,10	90,00	44,90	1,60	25	0,02	0,00	0,00	0,02	170,78	170,75	170,65	170,62
	5	90,00	143,00	53,00	1,05	25	0,01	0,00	0,00	0,01	170,75	170,74	170,70	170,69
	6	143,00	145,00	2,00	0,69	25	0,00	0,00	0,00	0,00	170,74	170,74	170,72	170,72
	7	145,00	162,90	17,90	0,65	25	0,00	0,00	0,00	0,00	170,74	170,74	170,72	170,72
	8	162,90	164,90	2,00	0,70	25	0,00	0,15	0,00	0,00	170,74	**170,74**	170,72	170,72
intake structure	9	164,90	169,90	5,00	0,78	80	0,00	0,00	0,00	0,00	**170,74**	170,74	170,71	170,71
	10	169,90	170,00	0,10	1,06	80	0,00	0,25	0,01	0,01	170,74	170,73	170,68	170,67
	11	170,00	175,90	5,90	2,00	80	0,00	0,00	0,00	0,00	170,73	170,73	170,52	170,52
	12	175,90	187,90	12,00	3,27	80	0,00	0,00	0,00	0,00	170,73	**170,72**	170,18	170,18
tunnel	13	187,90	1.306,53	1.118,63	3,91	85	0,50	0,00	0,00	0,50	**170,72**	170,22	169,94	169,44
	14	1.306,53	1.307,53	1,00	3,97	85	0,00	0,00	0,00	0,00	170,22	170,22	169,41	169,41
	15	1.307,53	4.601,15	3.293,62	4,03	85	1,61	0,00	0,00	1,61	170,22	168,61	169,39	167,78
	16	4.601,15	4.602,15	1,00	4,07	85	0,00	0,00	0,00	0,00	168,61	168,61	167,76	167,76
	17	4.602,15	9.478,00	4.875,85	4,10	85	2,49	0,00	0,00	2,49	168,61	166,12	167,75	165,26
	18	9.478,00	9.479,00	1,00	4,17	85	0,00	0,00	0,00	0,00	166,12	166,12	165,24	165,24
	19	9.479,00	10.584,58	1.105,58	4,23	85	0,61	0,00	0,00	0,61	166,12	165,51	165,21	164,59
	20	10.584,58	10.585,58	1,00	4,07	85	0,00	0,00	0,00	0,00	165,51	165,50	164,66	164,66
	21	10.585,58	10.616,58	31,00	3,91	85	0,01	0,00	0,00	0,01	165,50	**165,49**	164,73	164,71
outlet structure	22	10.616,58	10.632,58	16,00	3,44	80	0,01	0,05	0,03	0,04	**165,49**	165,45	164,89	164,85
	23	10.632,58	10.647,01	14,43	2,74	80	0,00	0,01	0,00	0,01	165,45	165,45	165,07	165,06
	24	10.647,01	10.647,11	0,10	2,42	80	0,00	0,05	0,01	0,01	165,45	165,43	165,15	165,13
	25	10.647,11	10.654,11	7,00	2,41	80	0,00	0,00	0,00	0,00	165,43	**165,43**	165,14	165,14
outlet channel	26	10.654,11	10.714,11	60,00	2,15	30	0,03	0,00	0,00	0,03	**165,43**	165,40	165,19	165,16
	27	10.714,11	10.759,38	45,27	2,15	30	0,02	0,00	0,00	0,02	165,40	165,37	165,16	165,14
	28	10.759,38	10.961,07	201,69	2,52	30	0,17	0,00	0,00	0,17	165,37	**165,20**	165,05	164,88
	29	10.961,07	10.993,07	32,00	2,09	30	0,02	0,05	0,01	0,03	165,20	165,17	164,98	164,95
	30	10.993,07	11.005,07	12,00	1,04	30	0,00	0,05	0,00	0,00	165,17	**165,17**	165,12	165,12
	total			**11005,07**			**5,55**	**0,61**	**0,08**	**5,63**		**165,17**		165,17

outlet gauge = E.L.

total friction losses [m] in the intake channel	0,062	m
total friction losses [m] in the intake strukture	0,019	m
total friction losses [m] in the tunnel	5,230	m
total friction losses [m] in the outlet structure	0,059	m
total friction losses [m] in the outlet channel up to outlet gauge	0,229	m
total friction losses [m] between position of intake gauge and outlet gauge	**5,60**	**m = Sum of losses**





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APPENDIX 3.1: Summary of the hydrochemical properties of groundwater

Borehole	Elevation [m]	Formation	Lithology	pH	Conductivity [µS/cm]	Cloride [mg/l]	Sulphate [mg/l]	Water Inflow [l/s]
Inlet Section: 0+000 to 3+490 (3.490m)								
NF28	146,10	Rochester	Shale	7,0	45.240	26.000	1.480	
NF3	134,10	Lockport Goat Isl.	Dolostone	7,6	2.800	450	1.370	0+000 to 2+485
NF2	130,02	Lockport Goat Isl.	Dolostone	7,1	9.800	29.000	1.463	Max: 1830
NF3	129,60	Lockport Gasport	Dolostone	7,3	10.000	55.000	1.550	Av: 259
NF2	122,52	Lockport Gasport	Dolostone	7,6	32.000	17.000	1.281	2+485 to 3+490
NF3	119,10	De Cew	Dolostone	7,7	56.000	55.000	1.349	
			Mean	7,4	25.973,3	30.408,3	1.415,5	Max: 14
			Standarddev.	0,3	21.738,7	21.485,8	99,1	Av: 2,0
			Min	7,0	2.800,0	450,0	1.281,0	
			Max	7,7	56.000,0	55.000,0	1.550,0	
Central Section I: 3+490 to 5+605 (2.115m)								
NF28	72,60	Queenston, upper	Shale	6,7	56.840	45.000	1.050	
NF28	128,10	Irondequoit	Limestone	6,4	99.760	91.000	1.060	
NF28	105,60	Grimsby	Sandstone	6,2	90.480	83.000	1.080	
NF28	-11,40	Queenston, lower	Shale	6,9	56.840	46.000	1.430	Max: 16
			Mean	6,6	75980,0	66250,0	1155,0	Av: 3,5
			Standarddev.	0,3	22423,3	24185,1	183,8	
			Min	6,2	56840,0	45000,0	1050,0	
			Max	6,9	99760,0	91000,0	1430,0	
Central Section II: 5+605 to 7+725 (2.120m)								
NF4	87,50	Queenston, upper	Shale	7,7	5.600	1.120	6	Max: 75 Av: 12
Central Section III: 7+725 to 10+030 (2.305m)								
NF30	-18,50	Queenston, lower	Shale	6,4	95.120	81.000	820	
NF30	79,00	Queenston, upper	Shale	6,1	104.400	108.000	980	
NF30	112,00	Power Glen	Shale	5,7	90.480	85.000	1.100	
NF30	98,50	Whirlpool	Sandstone	5,8	78.880	66.250	1.200	
NF30	133,00	Reynales	Dolostone	7,1	8.820	2.500	1.570	Max: 35 Av: 5,5
			Mean	6,2	75540,0	68550,0	1134,0	
			Standarddev.	0,6	38412,9	39842,8	281,9	
			Min	5,7	8820,0	2500,0	820,0	
			Max	7,1	104400,0	108000,0	1570,0	
Outlet Section: 10+030 to 10+277,780 (247,78m)								
NF35	159,60	Rochester	Shale	7,2	2.150	630	110	
NF6	150,79	Rochester	Shale	6,6	76.000	60.000	14	
NF6	155,29	Rochester	Shale	6,7	70.000	60.000	11	
NF6	144,79	Rochester	Shale	6,4	67.000	48.000	11	
NF6	175,79	Lockport Gasport	Dolostone	8,0	8.000	24.000	12	Max: 5,0 Av: 1,0
			Mean	7,0	44.630,0	38.526,0	31,6	
			Standarddev.	0,6	36.312,7	25.783,4	43,8	
			Min	6,4	2.150,0	630,0	11,0	
			Max	8,0	76.000,0	60.000,0	110,0	

Niagara River Water (Trailrace SAB No.1)	8,5	285	19	23
Adit Water Supply (Whirlpool)	8,1	592	71	62

Water inflow was calculated using the procedure proposed by John H. Raymer (RETC Proceedings, 2001)

Classification of the pH-Value according to DIN 4030, Part 1

		Degree of aggressiveness	Measures: Cement according to DIN 1164	Measures: Concret permeability Acording to DIN 1045
	> 6,5	no		
	≤ 6,5 and ≥ 5,5	Low		
	< 5,5 and ≥ 4,5	High		
	< 4,5	Very High		

Classification of the Sulphate Content according to DIN 4030, Part 1

	< 200 mg/l	No	-	-
	≥ 200 and ≤ 600 mg/l	Low	-	≤ 50 mm
	> 600 and ≤ 3000 mg/l	High	HS-Cement	≤ 30 mm
	< 3000 mg/l	Very High	HS-Cement	≤ 30 mm

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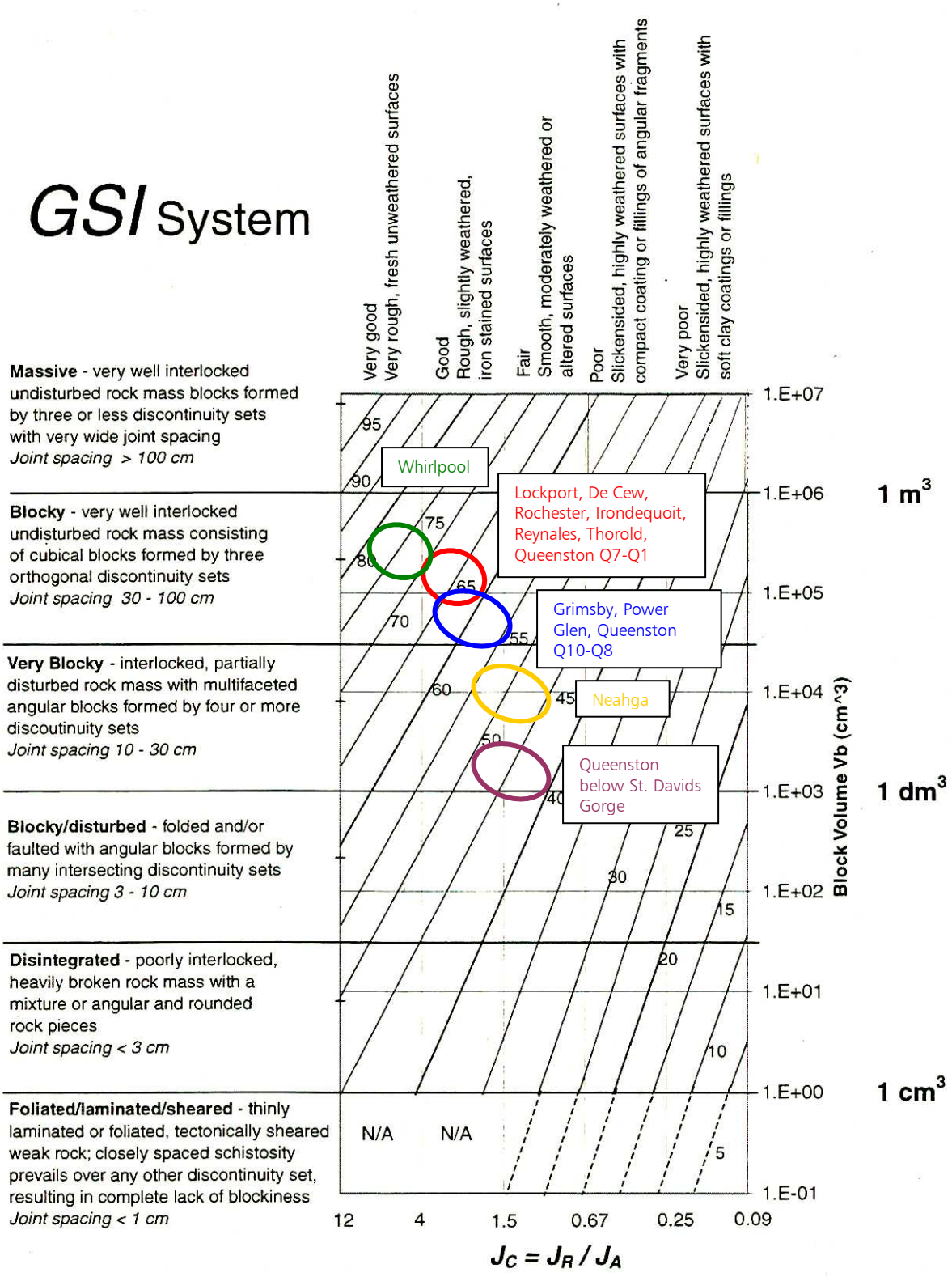
APPENDIX 3.2: GSI-Chart



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APPENDIX 3.3: Damage Index and Depth of Stress Induced Failure

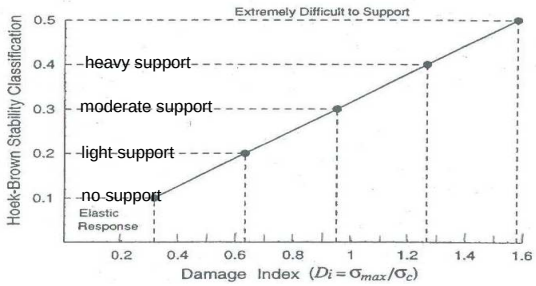
BERATENDE INGENIEURE				
Project:	I921: Niagara Tunnel Facility Project		Bearb.:	L.S.
Object:	In Situ Stress		Gepr.:	
Titel:	**Damage Index and Depth of Stress Induced Failure**		Datum:	March 05

Tunnel Section 0+000 to 2+840

$$\sigma_{max} = 3 * \sigma 1 - \sigma 3$$

$$Di = \frac{\sigma_{max}}{\sigma_c}$$

$$\frac{Rf}{a} = 0{,}49(+/-0{,}1) + 1{,}25 * Di$$



σ1	σ3	σmax
17	2,3	48,7

Formation	Lithology	σc_{av}	σc_{min}	σc_{max}	Di_{av}	Di_{max}	Di_{min}	Rf/a_{av}	Rf/a_{max}	Rf/a_{min}
Lockport	Limestone	151	106,0	196,0	0,3	0,5	0,2	0,9	1,1	0,8
	Dolostone	125	87,0	163,0	0,4	0,6	0,3	1,0	1,2	0,9
DeCew	Dolostone	128	90,0	166,0	0,4	0,5	0,3	1,0	1,2	0,9
Rochester	Shale	42	12,1	65,5	1,2	4,0	0,7	1,9	5,5	1,4
Irondeque	Dolostone/ Limestone	89	60,3	105,2	0,5	0,8	0,5	1,2	1,5	1,1
Reynales	Dolostone	101	45,0	140,8	0,5	1,1	0,3	1,1	1,8	0,9
Neahga	Shale	18	12,0	24,0	2,7	4,1	2,0	3,9	5,6	3,0
Thorold	Sandstone	129	117,4	141,3	0,4	0,4	0,3	1,0	1,0	0,9
Grimsby	Sandstone	146	73,5	242,2	0,3	0,7	0,2	0,9	1,3	0,7
	Shale	35	12,8	64,4	1,4	3,8	0,8	2,2	5,2	1,4
Power Glen	Shale	24	11,9	33,9	2,0	4,1	1,4	3,0	5,6	2,3
	Sandstone	152	71,7	223,8	0,3	0,7	0,2	0,9	1,3	0,8
Whirlpool	Sandstone	180	108,0	234,5	0,3	0,5	0,2	0,8	1,1	0,7
Queenston	Q8-Q10 (app. 30m thick)	33	7,5	117,5	1,5	6,5	0,4	2,3	8,6	1,0

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BERATENDE INGENIEURE	Project:	I921: Niagara Tunnel Facility Project	Bearb.:	L.S.
	Object:	In Situ Stress	Gepr.:	
	Titel:	**Damage Index and Depth of Stress Induced Failure**	Datum:	March 05

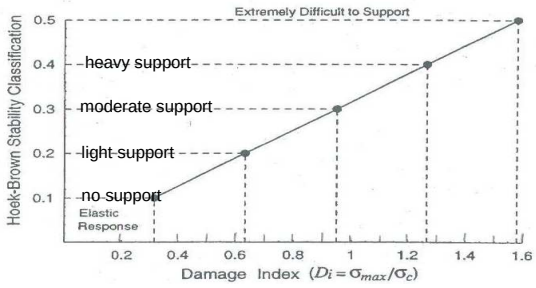
Tunnel Section 2+840 to 7+070

$$\sigma_{max} = 3 * \sigma 1 - \sigma 3$$

$$Di = \frac{\sigma_{max}}{\sigma_c}$$

$$\frac{Rf}{a} = 0{,}49(+/-0{,}1) + 1{,}25 * Di$$

σ1	σ3	σmax
19	3,9	53,1



Formation	Lithology	σc_{av}	σc_{min}	σc_{max}	Di_{av}	Di_{max}	Di_{min}	Rf/a_{av}	Rf/a_{max}	Rf/a_{min}
Queenston	Q8-Q10 (app. 30m thick)	33	7,5	117,5	1,6	7,1	0,5	2,5	9,3	1,1
	Q1-Q7	46	7,5	117,5	1,2	7,1	0,5	1,9	9,3	1,1

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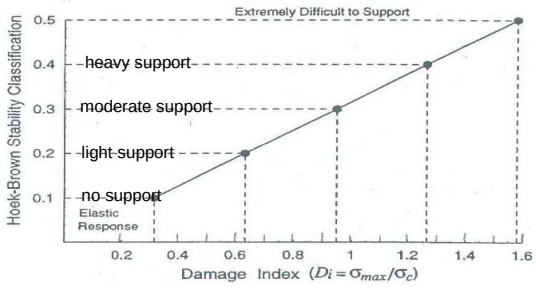
BERATENDE INGENIEURE	Project:	I921: Niagara Tunnel Facility Project	Bearb.:	L.S.
	Object:	In Situ Stress	Gepr.:	
	Titel:	**Damage Index and Depth of Stress Induced Failure**	Datum:	March 05

Tunnel Section 7+070 to 8+900

$$\sigma_{max} = 3 * \sigma 1 - \sigma 3$$

$$Di = \frac{\sigma_{max}}{\sigma_c}$$

$$\frac{Rf}{a} = 0{,}49(+/-0{,}1) + 1{,}25 * Di$$



σ1	σ3	σmax
22	3,4	62,6

Formation	Lithology	σc_{av}	σc_{min}	σc_{max}	Di_{av}	Di_{max}	Di_{min}	Rf/a_{av}	Rf/a_{max}	Rf/a_{min}
Queenston	Q1-Q7	46	7,5	117,5	1,4	8,3	0,5	2,2	10,9	1,2
	25m below St. David's Gorge	33	7,5	117,5	1,9	8,3	0,5	2,9	10,9	1,2

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BERATENDE INGENIEURE				
	Project:	I921: Niagara Tunnel Facility Project	Bearb.:	L.S.
	Object:	In Situ Stress	Gepr.:	
	Titel:	**Damage Index and Depth of Stress Induced Failure**	Datum:	March 05

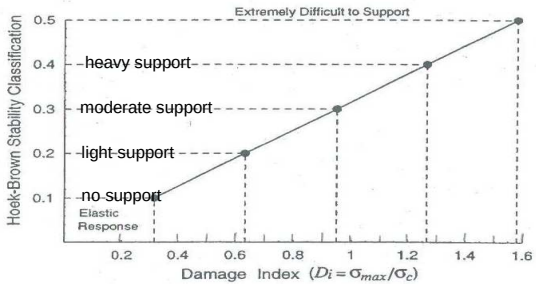
Tunnel Section 8+900 to 10+421,380

$$\sigma_{max} = 3 * \sigma 1 - \sigma 3$$

$$Di = \frac{\sigma_{max}}{\sigma_c}$$

$$\frac{Rf}{a} = 0{,}49(+/-0{,}1) + 1{,}25 * Di$$

σ1	σ3	σmax
23	4,5	64,5



Formation	Lithology	σc_{av}	σc_{min}	σc_{max}	Di_{av}	Di_{max}	Di_{min}	Rf/a_{av}	Rf/a_{max}	Rf/a_{min}
Lockport	Limestone	151	106,0	196,0	0,4	0,6	0,3	1,0	1,3	0,9
	Dolostone	125	87,0	163,0	0,5	0,7	0,4	1,1	1,4	1,0
DeCew	Dolostone	128	90,0	166,0	0,5	0,7	0,4	1,1	1,4	1,0
Rochester	Shale	42	12,1	65,5	1,5	5,3	1,0	2,4	7,2	1,7
Irondeque	Dolostone/ Limestone	89	60,3	105,2	0,7	1,1	0,6	1,4	1,8	1,3
Reynales	Dolostone	101	45,0	140,8	0,6	1,4	0,5	1,3	2,3	1,1
Neahga	Shale	18	12,0	24,0	3,6	5,4	2,7	5,0	7,2	3,8
Thorold	Sandstone	129	117,4	141,3	0,5	0,5	0,5	1,1	1,2	1,1
Grimsby	Sandstone	146	73,5	242,2	0,4	0,9	0,3	1,0	1,6	0,8
	Shale	35	12,8	64,4	1,8	5,0	1,0	2,8	6,8	1,7
Power Glen	Shale	24	11,9	33,9	2,7	5,4	1,9	3,8	7,3	2,9
	Sandstone	152	71,7	223,8	0,4	0,9	0,3	1,0	1,6	0,9
Whirlpool	Sandstone	180	108,0	234,5	0,4	0,6	0,3	0,9	1,2	0,8
Queenston	Q8-Q10 (app. 30m thick)	33	7,5	117,5	2,0	8,6	0,5	2,9	11,2	1,2
	Q1-Q7	46	7,5	117,5	1,4	8,6	0,5	2,2	11,2	1,2

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Appendix 3.4: Interface Grouting References

PRESSURE TUNNELS LINED WITH CONCRETE PRESTRESS BY INTERFACE GROUTING APPLIED						
Project	**Year**	**Maximum Internal Water Pressure**	**Lining Geometry**		**Rock Mass Type**	**Interface Grouting Pressure**
			ID	thickness		
		MPa	mm	mm		MPa
KW Kaunertal Section 1	1963	1,40	4000	450	Firm Gneiss	2,50
KW Kaunertal Section 3	1964	1,60	4000	400	Mylonite Gneiss	4,00
KW Enzinger-boden	1967	0,64	3100	375	Firm Granite-Gneiss	3,50
KW Fragant	1968	2,60	2250	230	Firm Granite-Gneiss	4,00
KW Hongrin-Leman	1968	1,35	4000	300	Limestone Schist	4,00
KW Gordon	1977	3,00	8200	600	Firm Quarzite	3,50
PSW Kühtai	1979	5,50	4000	300 - 700	Hornblend Gneiss	4,00
PSW Drakensberg	1981	6,30	5500	750	Sandstone Siltstone	8,00
KW Amlach	1988*	1,10	3400	250	Dolomite Schist	3,00
Niagara		1,40	12600	700	Sandstone Siltstone	2,20

* The development of Hydropower Schemes came to a standstill in Europe since 1988

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Appendix 3.5: Installation of Invert Segment

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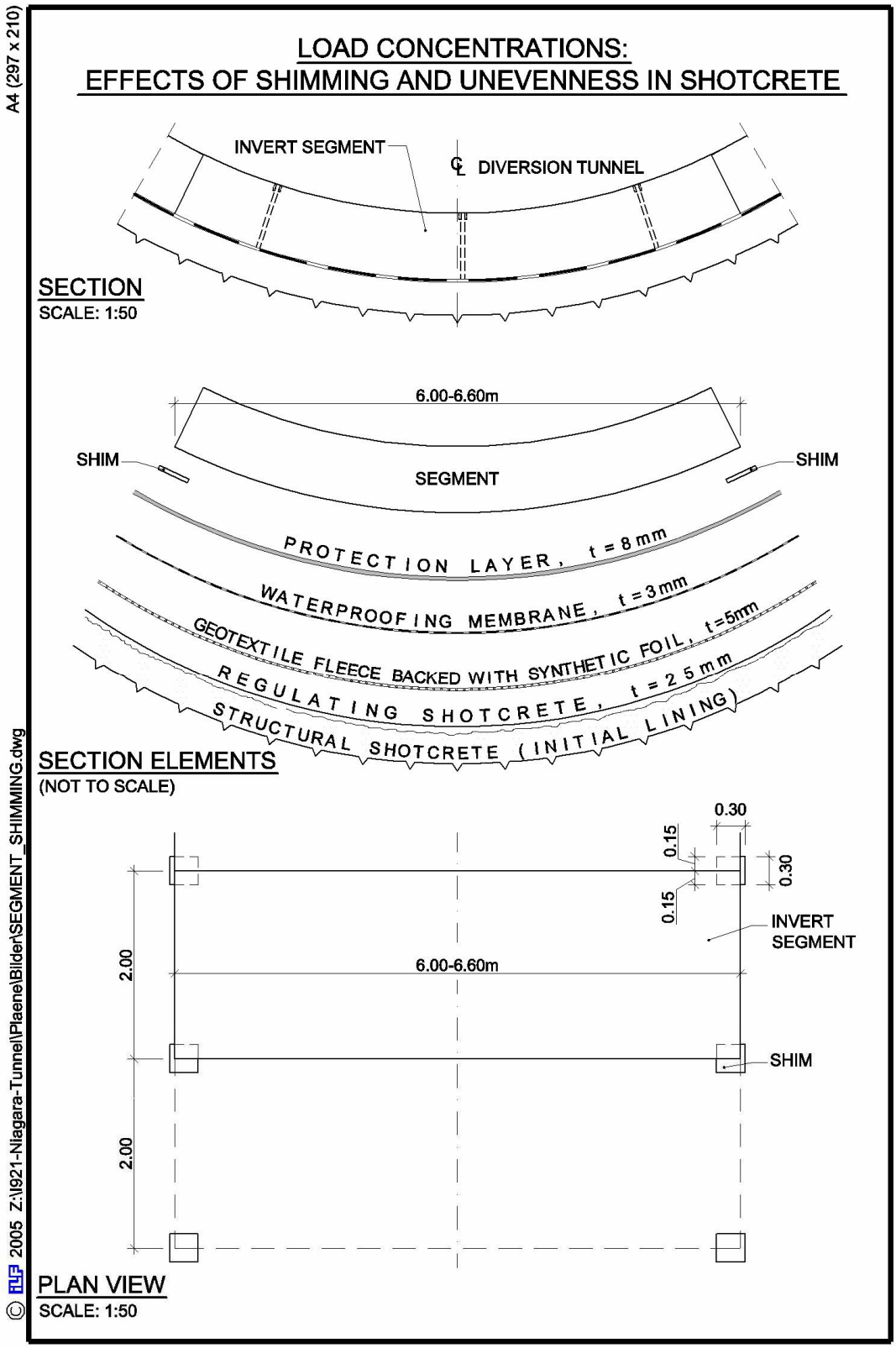
A4 (297 x 210)
LOAD CONCENTRATIONS:
EFFECTS OF SHIMMING AND UNEVENNESS IN SHOTCRETE
INVERT SEGMENT
℄ DIVERSION TUNNEL
SECTION
SCALE: 1:50
6.00-6.60m
SHIM
SHIM
SEGMENT
PROTECTION LAYER, t = 8 mm
WATERPROOFING MEMBRANE, t = 3 mm
GEOTEXTILE FLEECE BACKED WITH SYNTHETIC FOIL, t=5mm
REGULATING SHOTCRETE, t = 25 mm
STRUCTURAL SHOTCRETE (INITIAL LINING)
SECTION ELEMENTS
(NOT TO SCALE)
0.30
0.15
0.15
0.30
INVERT SEGMENT
2.00
6.00-6.60m
SHIM
2.00
PLAN VIEW
SCALE: 1:50
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PR-00-4001, Rev 1
Structural Design Analysis for the Diversion Tunnel

ONTARIO POWER GENERATION
OPG

NIAGARA TUNNEL FACILITY PROJECT

STRUCTURAL DESIGN ANALYSIS FOR THE DIVERSION TUNNEL

August 2005

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REVISION

0					
Rev.	Date	Issue, Modification	Prepared	Checked	Approved

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1 INTRODUCTION

1.1 General

This report provides a comprehensive stability analysis for the structural tunnel design for the proposed Diversion Tunnel. Induced stresses in the initial support due to excavation as well as short- and long-term stress analysis on the final lining are considered in detail. The type of analysis depends on the potential failure mode during excavation and installation of tunnel support. In order to determine the required tunnel support, the following calculation models are applied:

- 3 dimensional and 2 dimensional Finite Element Methods
- Elastic Beam-Spring-Model Methods
- Key-Block Theory Methods
- Convergence-Confinement Methods

The sequenced and combined application of these methods makes it possible to get a level of detail, which enables to evaluate a safe and economic tunnel design.

1.2 Diversion Tunnel Alignment

The proposal design follows the concept alignment in principle. Only below the buried St' David's Gorge, the alignment is slightly relocated to the north-west to gain maximum rock cover. In addition the alignment close to the existing outlet structure is moved away from underneath the existing Delivery Tunnel No. 1, to facilitate the drilling of the borehole for tunnel piezometers. The overall depth of the tunnel has been slightly reduced as compared to the Concept Design.

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3 SUMMARY OF RESULTS

In the following an abridgement of the subsequent comprehensive documentation of all calculation results is presented:

3.1 Initial Support Design

a) Wedge Analysis:
The wedge analysis is carried for support types 2 to 4, which are applicable for support of blocks which may fail. The results show that in general support types 2 to 4 are sufficient to support all rock loads produced by block failure. Restrictively it has to be mentioned that few blocks will require additional spot bolting.

b) "3 m slab":
The calculations proof that a rock load due to a "3m slab" can be supported by one of the initial support elements:

i. HEB 160 spacing 1.8 m, or

ii. >20 cm shotcrete full round or

iii. rock bolting , raster 0.9mx2.0m, l=6m, F=240kN

c) Stress Induced Calculations:
On the basis of preliminary calculations (using a Convergence-Confinement Method and 3D-FE Calculations) the relevant stress release factors and load-transfer factors (time-dependent load transfer to the individual support elements behind the face) have been derived for a subsequent use within detailed 2D-FE calculations. The results show that the individual support classes along the Diversion Tunnel are capable to support all short-term load effects.

3.2 Final Lining Design – Grouting Pressure – Internal Water Pressure

Based on the FE-method the interaction between primary lining and subsequently installed and pre-stressed final lining has been investigated. Hereby the initial support was simulated in such a way, that it does not contribute to any load-bearing capacity during operating time. In addition to rock loads the final lining is designed for:

a) Long-Term Grouting Pressure:
The high pressure interface grouting has been designed to pre-stress the final lining and the surrounding rock such that internal water pressure does not mobilize any tensile stresses in the lining. Due to the internal water pressure (maximum 1.4 MPa) a long-term grouting pressure in the range of 0.15 to 0.77 MPa is to be expected.

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b) Short-Term Grouting Pressure:
The expected constrains of the final lining concrete due to shrinkage, creep and temperature has been analyzed in order to evaluate the short-term grouting pressure, which has to be applied to the individual sections. It results a relevant final lining shortening of maximum 0.5 ‰ in radial direction. These constrains require a short-term grouting pressure in order of 1.45 to 2.15 MPa.

3.3 Short-Term Ground Behaviour

Generally in-situ stresses are characterized by high horizontal stresses, exceeding vertical stresses in parts significantly. Within this high-stress level environment stress changes and stress redistribution around excavation leads often to full mobilization of strength capacity of the rock. The failure zone that forms around the opening is then a function of the tunnel geometry, the excavation procedure, the in-situ stress regime and the strength of the rock mass.

Within the more competent rock formations of Lockport, DeCew, Irondeque, Reynales, Thorold, Power Glen and Whirlpool only small failure zones above the tunnel crown and below the invert can be observed. The calculations show that the weaker rock formations, such as Grimsby, Rochester and especially Neahga and Queenston tend to widespread areas of failure zones at the shoulders as well as underneath the invert. During interface grouting, the failure zones reach further into the rockmass at the shoulders as well as underneath the invert.

Within the rock mass the development of shear strains is small, thus softening behavior of the rock mass has not been observed. Sheared, weak bedding planes exist between many of the rock formations and within the Queenston Formation. Especially the primary bedding planes present between the subunits of the Queenston Formation will affect the stresses and strains around the tunnel during and after excavation. Using a discontinuum approach different bedding plane levels were considered: (a) 2 m above tunnel heading, (b) within tunnel - 3 m below heading, (c) in the centre of the tunnel opening. A sensitivity analysis indicated that the bedding plane above the tunnel crown is most severe for tunnel design. Calculation results in widespread failure zones below the invert and on top of the tunnel crown; shear displacement within bedding plane exceeds peak strength – therefore strain softening was introduced as soon as 10 mm shear displacement was reached in any point.

The failure zones do not affect the stability of the opening because the numerical calculations results in balanced forces.

3.4 Influence on Existing Structures

Along the proposed tunnel alignment the existing Diversion Tunnels 1 and 2 will be above the new excavation

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The FE-calculations show that the influences due to the excavation and lining installation, as well as operating with respect to stress and strain state are marginal. No significant increase of stresses around existing structures has been observed. Within the less competent rock strata marginal additional deformations will be mobilized, but mobilization of failure zones is restricted to a small area. This will be reviewed in detail design.

3.5 External Water Pressure

The high pressure interface grouting is designed to prestress the final concrete lining and the surrounding rock. Thus water seepage along the outside surface of the tunnel is prevented. However the water pressure from water seepage has been considered as a "worst case" scenarios..

3.6 Dewatering of the Tunnel

Dewatering of the proposed Diversion Tunnel has been considered as a temporary load case in the proposal design and will be considered as a normal load case in detail design

3.7 Long-Term Analysis

a) Swelling:
It is expected that swelling has not to be taken into account for the present tunnel lining system as the tunnel lining incorporates an impermeable water proofing membrane so that long-term rock swelling does not develop (no accessibility to fresh water). In addition the high pressure interface grouting, which is designed to pre-stress the final concrete lining and the surrounding rock, will additionally suppress potential swelling pressures.

b) Rock-Squeeze
Squeeze is usually associated with the long-term creep behavior of rock, initiated by the relief of high in-situ horizontal stresses. The long-term behavior has been taken into account by using a reduced stiffness modulus $E_{rock}(t)$ for the time t. The potential stress increase around the excavated tunnel has been analyzed using the Convergence-Confinement Method. The long-term stress increase has then been applied to the FE-calculations. Those calculations proof that the final lining is able to support the long-term stress increase in the vicinity of the tunnel.

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4 DESIGN CRITERIA

4.1 General

The purpose of the Design Criteria is to locate general criteria, technical background information, guidelines, requirements and procedures. This information will be used for the subsequent analysis and design of the initial support for excavation and of the final lining of the proposed Diversion Tunnel.

4.2 Lining System

Lining system design criteria assume tunnel construction will utilize a double shell lining consisting of an initial support and a final lining separated by a waterproofing membrane. The waterproofing membrane system prevents seepage between inside and outside of the Diversion Tunnel and acts as a suitable corrosion protection for the final lining. The final lining will be installed once tunnel excavation is completed. The initial support is designed to carry the rock loads, which develop during stress redistribution upon excavation.

High pressure interface grouting, which is designed to prestress the final concrete lining and the surrounding rock is applied, such that internal water pressure does not cause cracking of the final lining concrete and that water seepage along the outside surface of the tunnel is prevented.

4.3 Codes and Standards

[a] Canadian Standard Association, S16-01: Limit States Design of Steel Structures, December 2001.

[b] Canadian Standard Association, A23.3-94: Design of Concrete Structures, December 1994 (reaffirmed December 2000).

[c] National Building Code of Canada (1995)

[d] The Building Code of Ontario (1997)

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4.4 Structural Materials

4.4.1 Shotcrete

In order to model time-depended behaviour of the shotcrete (creep and hardening), short term and longterm stiffness (modulus of elasticity) of the shotcrete are taken into account. For a short time after the tunnel lining installation, the so-called "young" shotcrete (i.e. the characteristics of shotcrete before it has reached final design strength) is used in calculations. A reduced modulus of elasticity (HME) is applied; This HME reflects the behaviour of ground, shotcrete material and reinforcement. The values for HME are derived from the literature {1}.

	Modulus of Elasticity for green (young) shotcrete (HME) in MPa	
Rock Mass Behavior / Shotcrete Material and Reinforcement	Slow Stress Redistribution Ductile Behavior	Fast Stress Redistribution Brittle Behavior
1-day-strength <10 MPa slightly reinforced	1,000 – 3,000	1,500 – 3,000
1-day-strength <10 MPa moderately reinforced	3,000 – 5,000	3,500 – 6,000
1-day-strength <10 MPa heavily reinforced or steel-fiber reinforced	4,000 – 6,000	4,500 – 7,000

Table 1: Modulus of Elasticity for Young Shotcrete

For hardened shotcrete a value for Young's Modulus of 15,000 MPa is used.

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4.4.2 Reinforcement

The reinforcement of the shotcrete has not been explicitly modelled in the calculations.

4.4.3 Rock Dowels

The load bearing capacity of a rock dowel in tension is determined by the ultimate tensile strength.

The shear strength of steel bars, according to the Mises's hypothesis, is given by:

$$\tau = \frac{\sigma_t}{3^{1/2}} = 0.58\ \sigma_t$$

Where: σ_t = tensile strength,
τ = shear strength.

4.4.4 Steel Ribs

The following material properties apply in accordance with CSA S16-01 [a]:

Minimum yield stress f_y - 410 MPa,

Modulus of elasticity E_s - 200,000 MPa.

4.4.5 Final Lining Concrete

Normal density concrete has been applied to subsequent calculations and has at least the properties shown below (in accordance with CSA A23.3.94 [b]):

Specified compressive strength f_c' = 35 MPa at 28 days
Poisson´s ratio ν = 0.2
E-modulus $E_C = 4500\sqrt{f_c'}$

The actual compressive strength used in the calculation will be based on the 90 days strength as determined by testing.

4.5 Design Loads

4.5.1 Structural and Dead Loads

Dead load of structural and non-structural elements is based on unit weight and computed volume of the materials. The following unit weights is used:

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Unreinforced Concrete	24.0 kN/m³
Structural Steel	78.5 kN/m³
Rock / Soil	see GBR for details [4]
Water	10.0 kN/m³

4.5.2 Live Loads

Live Load consists of any non-permanent load placed on or in the tunnel.

4.5.3 Ground Pressure

Ground loads on the tunnel lining are not predetermined in FE-calculations, since full overburden is modelled.

Geostatic loads have to be defined in accordance with the load case considered for structural calculations with Beam Spring Models.

4.5.4 Hydrostatic Pressure

It has to be distinguished between the internal hydrostatic pressure and the external ground water pressure. Relevant water pressures to be applied to the subsequent calculations are summarized in chapter 5.2.6.

4.5.5 Seismic Loads

Underground structures are generally less sensitive to seismic effects than surface structures, therefore no seismic loads are considered for preliminary design. At detail design stage a seismic analysis based on actual data will be carried out.

4.5.6 Thermal Forces

Temperature changes cause thermal strains and internal forces in the final lining. Temperature variations during and after concreting are related to heat of hydration. The temperature is assumed to cool down to approx. 10 °C on the shotcrete/rock interface (extrados) and to 10 to 20 °C (seasonal variations before filling the tunnel) on the intrados of the final lining concrete. When filling the tunnel with water, the concrete temperature is assumed to drop from max. 20 °C to a minimum of approx. 4 °C on the intrados. The extrados of the final lining remains at a temperature of 10 °C as a conservative assumption.

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This drop in temperature will cause a design-relevant contraction of the lining. It results in a loss of prestress of the final lining as a consequence.

Concrete Lining Thickness d	Max. temp. gradient before filling the tunnel with water °C	Max. temp. gradient after the tunnel is filled with water °C
extrados (rock)	+10	+10
centre line	+15	+7
intrados	+20	+4
ΔT (d)	10	6

Table 2: Temperature Gradient in Final Lining Concrete

4.5.7 Concrete Shrinkage

Concrete shrinkage is caused by the migration of the excessive water from the interior of the concrete mass and leads to shortening of the concrete per unit length. Since the final lining is restraint the shortening of the concrete leads to stresses in the lining. Shrinkage strains are assumed to be constant over the entire lining thickness.

The shrinkage strain mainly depends on the ratio of volume to surface of the structure, on the drying time of the concrete and on the humidity of the environment.

A concrete shrinkage strain of ε_s = -15.7 x 10-5 is applied based on experience with comparable tunnel linings.

4.5.8 Concrete Creep

Creep will be taken into account by reducing Young's Modulus for concrete. From experience a stiffness-reduction-factor between μ = 1.5 and μ = 2.3, dependent on the concrete age, may be assumed. In the calculations an average reduction factor of μ = 2.0 is applied. This leads to a reduction of Young's Modulus for concrete to 50%.

4.5.9 Long-term Rock Squeeze

4.5.9.1 General

The tunnel lining system for the Diversion tunnel is designed to be *capable of adequately supporting all loads including those imparted on the lining from long-term rock swelling [2]*.

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It is recognized, that high horizontal stresses are prevealing in the rock formations in Southern Ontario. Rock excavation at surface and underground relieves the initial state of stresses, providing an initiating mechanism for time-dependent deformation to occur.

4.5.9.2 Time Dependent Deformation Behaviour

It has to be emphasized that the time dependent deformation phenomenon is described in terms of **"rock squeeze"** and **"swelling"**. It is well recognized that these processes are interrelated, and the individual effects of each are difficult to distinguish. Both effects can continue for many years [4].

Squeeze is usually associated with the long-term creep behaviour of rock, initiated by the relief of high in situ horizontal stresses. There is a well documented history of rock 'squeeze' affecting surface excavations in the upper dolostones and dolomitic limestones. This squeeze, however, may include the effects of swelling of the shale interbeds in these rock units [4].

4.5.9.3 Swelling Behaviour

Swelling to be assumed for design purposes in the Queenston Formation is given in the Owner's Mandatory Requirements [2]. There is no available data regarding suppression of swell potential for the other formations.

Generally swelling involves a volume increase and is initiated by the relief of the high in situ stresses. However, swelling also requires the presence of fresh water. The process is associated with ionic diffusion of salts from the connate pore water in the rock. The swelling phenomenon can be suppressed under applied stresses.

For swelling to occur, the necessary conditions are:

- the relief of initial stresses, which serves as an initiating mechanism,
- the accessibility to fresh water,
- an outward salt concentration gradient from the pore fluid of the rock to the ambient fluid.

The proposed tunnel lining system includes the following features:

- The tunnel lining incorporates an impermeable liner in form of a waterproofing membrane system. No accessibility for fresh water is allowed and long-term rock swelling does not develop.
- The state of effective stress in the rock mass after excavation affects the rate of swelling. The high pressure interface grouting, which is designed to prestress the final concrete lining and the surrounding rock will additionally suppress potential swelling pressures because effective stresses in the rock mass.

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The processes "swelling" and "rock squeeze" are interrelated. Model assumptions for rock swelling are presented in chapter 5.2.4.3.

4.5.9.4 Rock Squeeze Behaviour

The rock expansion upon unloading observed in previous constructions [4] is not necessarily associated with the swelling of clay minerals, although in the presence of swelling clay minerals the time dependent deformation is generally greater.

Rock squeeze is defined as substantial time-dependent deformation in the vicinity of the tunnel as a result of load introduced by redistribution of stresses adjacent to the excavated tunnel. Model assumptions for rock squeeze behaviour are presented in chapter 5.2.4.4.

4.5.10 Load Combinations

For load combinations not including earthquake, factored loads are determined in accordance with CSA A 23.3. Herein the effect due to specified loads multiplied by a load factor α, a load combination factor ψ and an importance factor γ is considered:

$$\alpha_D D + \gamma\psi(\alpha_L L + \alpha_T T)$$

where:

- Load factors α for:
  - Dead loads D: $\alpha_D = 1.25$
  - Live loads L: $\alpha_L = 1.5$
  - Temperature loads T: $\alpha_T = 1.25$
- Load combination factor ψ:
  - $\psi = 1.00$ when L or T is considered
  - $\psi = 0.7$ when a combination of L and T is considered.
- The importance factor is equal to 1.0 for all load combinations.

4.6 Analysis Assumption

4.6.1 Analysis Methods

The type of analysis depends on the potential failure mode during excavation and installation of tunnel support. The failure mechanism is generally differentiated into the following failure modes:

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- failure of rock blocks,
- fracturing induced by stresses and/or discontinuities,
- progressive failure induced by stresses,
- failure induced ahead of tunnel face,
- failure of tunnel face.

The following calculation methods are used (also shown in the flowchart of Figure 1):

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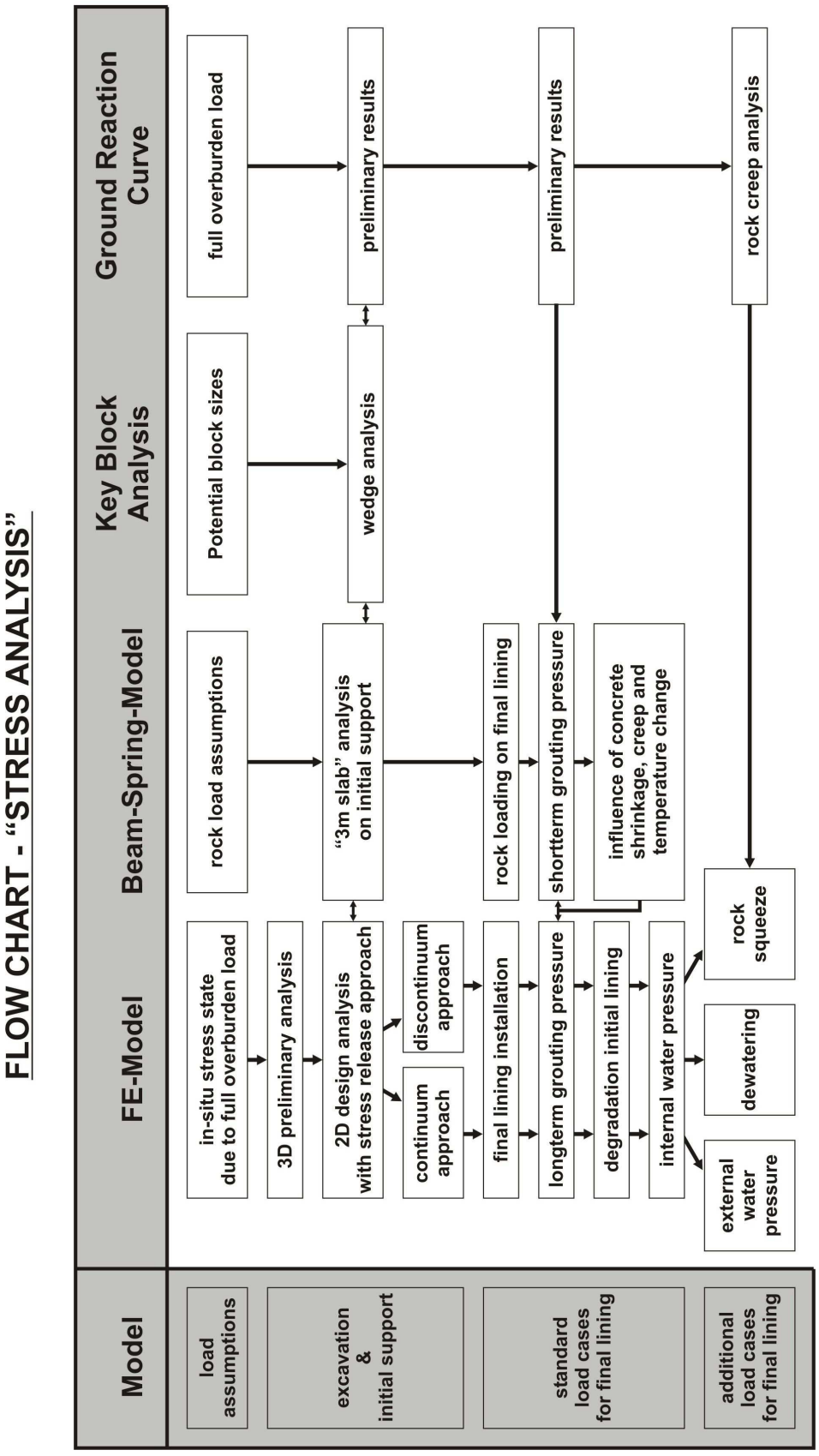

Figure 1: Flow Chart "Stress Analysis"

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4.6.2 Initial Support

The initial lining is subject to variations in stresses and strains during its intended use. Rock load, water load, chemical/physical influence of aggressive water, swelling phenomena of the surrounding rock, swelling and shrinking processes in the concrete, etc.. The resulting changes in stiffness and in strength determine the load-bearing behaviour of the support system.

The full contribution of load bearing capacity of the initial lining over the operation time of the Diversion Tunnel cannot be considered due to the above mentioned influence and the combination of adverse effects. It is assumed that the initial lining may gradually loose its load-bearing capacity. It deforms and thus exerts stresses and strains on to the final lining.

This aging process of the initial lining is simulated by modelling a transition from a purely elastic to an elasto-plastic material behaviour. The analysis model takes into account a potential change of stiffness and strength of the initial lining over time due to

- corrosion/failure of the reinforcement,
- degradation, weathering of shotcrete,

A conservative approach according to the "Gray Rock Philosophy" {7} is selected: The initial lining is modelled elasto-plastic as part of the rock with adequate strength parameters. Tensile stresses are to be avoided. The modulus of elasticity is reduced.

4.6.3 Final Lining

The final lining is analysed for all permanent and temporary loads. The analysis is carried out under the assumption that the initial lining does not contribute to resist the superimposed loads and displacements.

4.7 Tunnel Lining Design

4.7.1 Concrete Design

The initial lining consisting of rock dowels, steel ribs, steel wire mesh and shotcrete is checked against the design strength of concerte. In the calculation, the contribution of steel elements (reinforcement, dowels, ribs) to the bearing capacity of the initial lining is ignored. The degree of safety of the lining (α degree of mobilization of the strength of the unreinforced concrete) is expressed by checking the safety factor f_{NM}, which is the ratio of the design normal force N_{sd} and the resisting normal force N_{rd}, considering the calculated eccentricity $e = M_{sd} / N_{sd}$ of the unreinforced shotcrete only.

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The final lining consisting of cast in place concrete is checked against the factor f_{NM} in the same way as the initial lining.

The minimum safety factors f_{NM} are listed as calculation results in chapter 6.

The following formula is used for the design of unreinforced concrete:

$$N_{rd} = \phi_c \cdot f_c' \, d\left(1 - 2\frac{e}{d}\right)$$

N_{rd} is the resisting normal force with
b = 1 m
d …thickness of the tunnel lining
e …eccentricity (e = M/N)

The resistance factor of concrete Φ_c is assumed to be 0.60 according to CSA A23.3-94 [b]. The required design factor $f_{NM} = N_{sd} / N_{rd}$ for design check of the lining is:

$f_{NM} \geq 1.$

Herein the computed structural forces N will be multiplied by a factor $\alpha_L = 1.5$ according to CSA A23.3 in order to get the design structural forces N_{sd}.

In addition the maximum eccentricity is controlled by

$e / h_w \leq 0.33.$

h_w represents the structural height of the element.

4.7.2 Steel Design

Steel– if required – is designed according to CSA S16-01 [a].

4.7.3 Safety factors

The following factors of material resistance are selected:

- concrete $\Phi_c = 0.6$
- steel $\Phi_s = 0.9$

The load factors are generally selected in accordance with the Design Criteria, chapter 4.5.10. Reduced factors are applied solely for following extraordinary load cases:

a) short-term prestressing pressure for interface grouting with a load factor $\alpha_L = 1.0$ is in accordance with CSA A23.3-94 [b], since the grouting operations is carefully monitored and the pressure can be instantly controlled.

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b) worst-case scenarios of a groundwater pressure on the lining (worst credible assumption as outlined in chapter 5.2.6) in combination with an unfrequent temporary operation state "Dewatering of Tunnel".
Factors for such a load-combination "worst case – temporary state" have been assumed to be:

load factor	$\alpha_L = 1.0$
resistance factor of concrete	$\Phi_c = 0.6$

In the detail design the load factor of 1.25 (instead of 1.0) will be used for external hydrostatic water pressure. (A design check proved the application of the load factor of 1.25 for external hydrostatic water pressure to be o.k.)

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5 DESIGN BASIS

5.1 General

It has to be appreciated that, prior to tunnelling, tunnel design represents a prediction which is either verified on site to ensure, that all design assumptions are confirmed, or which has to be adjusted in-situ to suit actual conditions.

The initial steps of the tunnel design procedure are to collect geological data, then to establish geotechnical parameters in those sections along the tunnel profile with consistent characteristics and finally to summarize the geological series with similar mechanical properties.

Further, the boundary conditions such as virgin stresses, size, shape and orientation of the opening are taken into account in order to establish a possible failure mechanisms, thereby establishing the potential behaviour of the rock mass while the opening is excavated. Different failure mechanisms require different support measures and different models of analysis to design the support measures. In order to simplify procedures at the site, support types are established which apply to the various types of behaviour of rock mass as a result of excavation.

5.1.1 Geology

Twelve stratigraphic formations are identified in the project area. They consist of sequences of sedimentary rock of Ordovician to Devonian age. These are namely the Guelph, Lockport, De Cew, Rochester, Irondequoit, Reynales, Neahga, Grimsby, Power Glen, Whirlpool and Queenston formations. Some of these are only a few meters thick. Eleven of the mentioned formations are expected to occur along the tunnel structure. The uppermost Guelph formation will not intersect with the proposed tunnel alignment. The lithological spectrum of the encountered formation covers limestone, dolostone, sandstone and shale (see Design Basis and Method Statements [5] for details).

5.1.2 Calculation Sections

3 preliminary Finite Element Calculations were defined:

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Calculation	approx. Station [m]	Location	Rock Mass Type	Analysis Method
1	1+213.5	Turbine Pit	Lockport / DeCew / Rochester	FE back analysis
2	general	not specific	Rochester	3D-FEM 2D-FEM
3	general	not specific	Queenston	3D-FEM 2D-FEM

Table 3: Preliminary Calculation Sections

Five calculation sections were defined along the tunnel. The details of each section are included in the subsequent table 4:

Calculation Section	approx. Station [m]	Location	Rock Mass Type	Analysis Method
B/0	0+080	Close to Intake	Lockport	2D-FEM BSM CCM
C/0	1+800	below existing Tunnels No. 1/2	Upper Queenston	2D-FEM BSM CCM
D/0	not specific	Tunnel Section including Bedding Plane Q8/Q9 of Queenston Formation	Queenston Q8/Q9	2D-FEM Discontinuum Analysis
E/0	8+660	Section under Gorge	Queenston	2D-FEM BSM CCM
F/0	8+920	Deepest Section	Queenston	2D-FEM BSM CCM

Table 4: Analysed Calculation Sections – Proposed Tunnel Alignment

legend: 3D-FEM: 3-dimensional FE-Calculations
2D-FEM: 2-dimensional FE-Calculations
BSM: Beam-Spring Model
CCM: Convergence Confinement Method

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Calculations with Key Block Theory depend on the varying trend and plunge of the tunnel axis. The tunnel sections to be analysed by KeyBlockTheory are summarized in Chapter 5.2.8.

5.1.3 Groundwater

Three major groundwater flow regimes are encountered in the rock formations of the project area. The uppermost occurs in the Guelph, Lockport and De Cew formations. This aquifer is connected to the surface water and shows the highest permeability of the entire sequence. A second flow regime is associated with the low permeability strata of the Rochester, Neahga, Power Glen and Queenston formations, forming a system of aquitards. A third flow regime is associated with the deeper permeable strata of the Irondequoit, Reynales, Thorold, Grimsby, Whirlpool and upper Queenston formations. These strata form deep lying aquifers. Groundwater elevations are reported to vary significantly from strata to strata and from location to location. Some groundwater heads encountered showed artesic behaviour with pressure heads above ground elevation.

The following maximum groundwater levels (measured groundwater levels within the Queenston Formations as indicated in the GBR in determination of the external hydrostatic water pressure) are applied to the calculations with respect to the ranges of the groundwater level (see Design Basis and Method Statements [5] and Geotechnical Longitudinal Section (2) for details):

Calculation Section	approx. Station [m]	max. el. [m] groundwater level
B/0	0+080	168.0
A/1	1+213.5	160.0
B/1	1+400	160.0
C	4+380	165.0
D	6+665	130.0
E	8+660	150.0
F	8+920	150.0

Table 5: Maximum Groundwater Levels for Calculations

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5.2 Input Parameters

Generally best estimate values for ground and lining properties are applied to the analysis. The effect of variation of the selected design values for these properties has been continuously checked by means of sensitivity analysis.

The range of parameters that is used to appreciate parameter variability in the design is defined in the GBR-A, "Required Response 3" [4].

5.2.1 In-Situ Stresses

In-situ stress conditions in southern Ontario are characterised by high horizontal stress, exceeding vertical stresses in parts significantly. The stress field is reported to be relatively consistent trending in a north-eastern direction. However the magnitudes of stress and the direction of the maximum stress can vary significantly depending on lithology, depth and topographical features (see Design Basis and Method Statements [5] for details).

The in-situ stresses applied to the calculations are based on the Geotechnical Data Report [1] and are summarized in GBR-B [4] and in Design Basis and Method Statements [5]:

Calculation Section	B/0	B/1 and C	A/1 and D	F	E and G
Lockport	6.1	11.3			
DeCew					
Rochester	3.7		13.2		
Irondeque	6.5				
Reynales	4.1				
Neahga					
Thorold	1.8		12.0		
Grimsby	1.5		10.2	10.3	
Power Glen	4.0		5.0		
Whirlpool	2.3		5.6	2.0	4.4
Queenston	4.3		4.5	2.0	4.5

Table 6: In-Situ Stress Conditions (Stress Ratio: Horizontal Stresses / Vertical Stresses)

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The vertical stresses are generally based on the full overburden gravity load of the rock mass. Insitu testing showed, that the vertical stresses are 30% above the calculated vertical stresses.

The above mentioned stress ratios are used to initialize the primary stress field within the FE-calculations. In case widespread plastic zones develop during initial state, either increase of vertical stress or decrease of horizontal stress has to be applied to the analysis in order to ensure stable initial conditions of the analysis model.

5.2.2 Rock Mass Strength & Stiffness Parameters

The rock mass parameters used in the analysis are based on table 6.16 of the Geotechnical Baseline Report [4].

The strength and deformation properties to be considered with the calculations are summarized for the proposal design in Table 7 below and will be updated in detail design.

Formation		ϕ [°]	c [MPa]	E [GPa]
Lockport		34	7.9	24
DeCew		34	8.0	24
Rochester		32	2.5	15
Irondeque		35	5.7	22
Reynales		34	6.3	24
Neahga		26	0.8	4
Thorold		40	9.5	24
Grimsby		30	1.2	11
Power Glen		38	10.3	18
Whirlpool		43	16.0	42
Queenston	Upper QF (30m)	30	1.8	10
	Lower QF	33	2.8	16
	St. David's Gorge	24	1.3	4

Table 7: Rock Mass Strength & Stiffness Parameters

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The following soil parameters have been determined in addition to the parameters listed in Table 7 (see Geotechnical Data Report [1] and the Geotechnical Baseline Report [4]):

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Formation		ϕ [°]	c [MPa]	E [GPa]
overburden layer		15	0.02	0.01
sedimentary layers within St' Davids Gorge	layer A above 120 m el.	27.5	0.03	0.10
	layer B below 120 m el.	37.5	0.02	0.55

Table 8: Additional Soil Strength & Stiffness Parameters

The strength parameters summarized in Tables 7 and 8 are considered as "peak-strength" data. According to the Owner's Mandatory Requirements [2] especially the Queenston shale exhibits a predominant "post-peak" behavior. The reduction from peak strength to post-peak strength is considered according to the Owner's Mandatory Requirements, chapter 8.3.4 [2]:

The following parameters shall be used in the analysis:

(iii) Hoek.Brown residual rock mass strength parameters: mr = 1.0, sr=0.001 (or equivalent)

(iv) plastic shear strain in rock for peak to post-peak: ranging from 0.5% to 2.0 %

Consequently the following "peak-" and "post-peak" strength parameters are applied to the Queenston formation (Table 9).

	Peak-Strength		Post-Peak-Stength	
Formation	ϕ_{peak} [°]	c_{peak} [MPa]	$\phi_{res.}$ [°]	$c_{res.}$ [MPa]
Upper Queenston (30m)	30	1.8	26	0.5
Lower Queenston	33	2.8	26	0.4

Table 9: Strain Softening Strength Parameters for Queenston Shale

The decrease in strength due to strain softening is considered in the analysis with the mobilization of plastic shear strains during all calculation phases. As soon as a critical plastic shear strain will be reached in any zone, a post peak strength decrease to the residual strength will be executed. According to the Owner's Mandatory Requirements [2] the relevant plastic shear strain to reach a decrease to a residual strength is in the range of 0.5%

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to 2.0 %. Within the subsequent analysis, a best estimate value of 1.25 % is selected for the critical plastic shear strain. An elasto-brittle material model is used, i.e. a sudden decrease in post-peak strength is modeled as soon as the critical plastic shear strain is reached.

5.2.3 Bedding Plane Parameters

Sheared, weak bedding planes exist between many of the rock formations and within the Queenston Formation. Primary bedding planes are defined as major bedding planes between lithological units above the Queenston Formation and between subunits within the Queenston Formation. According to the geotechnical data available [1,4] six major stratigraphic divisions have been identified in the Queenston Formation, which are separated by fairly distinctive primary bedding planes.

It is expected that especially the primary bedding planes, which are present between the subunits of the Queenston Formation, affect the stresses and strains around the tunnel during and after excavation. In order to account for such discontinuous behaviour the following parameters based on test data given in the GDR [1] (Volume 2, Figure 12.1) are used for modelling the bedding planes (Table 10):

	Peak-Strength		Post-Peak-Stength	
Formation	ϕ_{peak} [°]	c_{peak} [MPa]	$\phi_{res.}$ [°]	$c_{res.}$ [MPa]
bedding planes between subunits of Queenston Shale	24	0.45	15	0.0

Table 10: Strength Parameters for bedding planes between subunits of Queenston Shale

Since no particular information is available so far, the relevant displacement within the bedding plane to trigger the decrease to residual strength is selected on the basis of engineering judgement. Within the subsequent analysis a best estimate value of 10 mm is selected for this critical displacement. The elasto-brittle material model is used (see chapter 5.2.2).

5.2.4 Long-term Behaviour

As already outlined in chapter 4.5.9 time dependent deformation phenomenon is described in terms of processes, which are interrelated: “rock squeeze” and “swelling”.

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5.2.4.1 Time-dependent deformations observed during previous constructions

Vertical Shaft Wheel Pit:

During the construction of the vertical shaft Wheel Pit of the Canadian Niagara and Toronto Power Plants the 5.5 m wide and 50 m deep slots an inward movement of both walls was recognized (total maximum inward movement of both walls over a 68-yr period was approx. 7 cm) [4]. The data shows a general trend of decreasing rate of rock movement with time. According to an additional study evaluated by Yolles {14} in 1991 the rock squeeze is expected to continue at the presently established rate of approximately 0.15 – 0.48 mm per year.

12-m diameter Trial Enlargement

According to the GBR [4] within a 12-m diameter Trial Enlargement in the Queenston Formation a pattern of on-going, very small creep movements were measured in the first few months after excavation (maximum 5 mm measured from 7 to 70 days following excavation).

Diversion Tunnel No. 1 and 2

Measurements during and after excavation recorded horizontal inward movements of up to 60 mm over a 6-month period in Tunnel 1 (vertical movement of the crown was significantly smaller). Most of the movement occurred immediately after installation of the instrument. According to [4] the creep movement appears to be a logarithmic function of time.

Construction of the Queenston-Chippawa Canal 2

The canal was constructed in the early 1950s. The excavations extend about 18 m into the Lockport/DeCew Formations. According to [4] elastic deformation at the top of the rock cut amounted to about 1 to 1.3 cm on the first lift, with an additional 1.3 to 1.8 cm closure immediately following final excavation. Small creep movements of up to 0.33 cm/yr were noted for the 2 years that measurements were taken [4].

5.2.4.2 Back-Analyses of the Toronto Power Turbine Pit Excavation

Appendix 01 provides computer plots of a FE-back-analysis of the vertical shaft of the Toronto Power Plant. The measurements of this excavation have been used to estimate deformations with respect to the excavation work itself and to distinguish between additional swelling deformations and long-term rock squeeze deformations.

This calculation indicates:

- Sequenced excavation and installation of the shaft:
  maximum horizontal displacements ~ 6 mm

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- Due to stress release and water ingress a swelling strain in the order of 0.5 % is expected in a limited area around the Shaft Wheel Pit:
  maximum additional horizontal displacements ~ 10 mm
- Rock Creep has been modeled in agreement with the model assumption given in the chapter hereafter. The maximum creep-value of 1.5 has been applied to the calculation resulting in:
  maximum additional horizontal displacements ~ 18 mm

The total horizontal displacements of 35 mm (each side-wall) are in good agreement with the observations as reported in the previous chapter.

5.2.4.3 Swelling Behaviour

The swelling behaviour initiated due to the tunnel excavation is correlated to the decrease of the first invariant of the stress state (mean effective normal stress) I_1 {15}.

The primary stress state σ_p will change to the secondary stress state σ_s. Due to the excavation the tunnel lining will deform and a relaxation of the surrounding rock may appear. According to {15} swelling behaviour may occur as soon as the first invariant of the secondary stress state stress $I_{1,\sigma s,}$ will be smaller then the first invariant of the primary stress state $I_{1,\sigma p}$:

$$I_{1,\sigma s} < I_{1,\sigma p}$$

with:

$$I_{1,\sigma s} = \sigma_{x,s} + \sigma_{y,s} + \sigma_{z,s} \quad \text{and} \quad I_{1,\sigma p} = \sigma_{x,p} + \sigma_{y,p} + \sigma_{z,p}$$

Due to such a stress release ($I_{1,\sigma s} < I_{1,\sigma p}$) swelling strains δ_{sw} will develop. Under the assumption that the swelling potential during primary stress state has been already vanished, it can be stated that the swelling potential equals the difference of the strain invariant of the primary and secondary state $\Delta I_{1,\varepsilon,sw}$

$$\Delta I_{1,\varepsilon,sw} = I_{1,\varepsilon p} - I_{1,\varepsilon s}$$

with

$$I_{1,\varepsilon,sw} = K_{sw} \frac{I_{1,\sigma}(1-\upsilon)}{\sigma_0(1-\upsilon)}$$

The subsequent FE-calculations indicate that the area with swelling potential according to the above mentioned criteria ($I_{1,\sigma s} < I_{1,\sigma p}$) is small. The reason in this regard is based on the advantages of the proposed lining system.

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In addition a suppression pressure of > 5 MPa exists due to the high in-situ stresses – especially in horizontal direction. The sedimentary rock has anisotropic stress and strain behaviour. It has to be mentioned, that according to test results reported in [4] application of stress in one direction not only suppresses the swelling in that direction but also reduces the swelling in the orthogonal direction.

It can be concluded that the swelling potential is negligible on the one hand due to the expected secondary stress state and on the other hand due to the proposed excavation method and double shell lining system.

5.2.4.4 Rock Squeeze Behaviour

A time related approach to estimate "rock squeeze" or "rock creep" phenomena as described in Chapter 4.5.9 is used to estimate potential long-term stress-increase on the tunnel lining:

$$E_{rock}(t) = \frac{E_{rock}(t=0)}{1+\varphi(t)}$$

The long-term rockmass behaviour is taken into account by calculating a reduced stiffness modulus $E_{rock}(t)$ for the time t, $\varphi(t)$ represents the so-called creep-value. The long-term rock squeeze behaviour is simulated using a creep-value in the range of 0.5 to 1.5 for the time t = 90 years. The range for φ (t = 90 years) is selected on the basis of conservative engineering judgement. The maximum creep rate $\varphi_{max} = 1.5$ has been evaluated on the basis of measurements of an existing structure (Wheel Pit back-analysis).

5.2.5 Interface Grouting Properties

The objective of the interface grouting is to lock into the lining a compressive strain greater than the tensile strain expected after filling the tunnel with water. This will prevent the development of tensile stresses in the lining and therefore avoid cracking during operation.

Prior to filling the tunnel and after grouting, the lining is highly compressed. These short-term grouting pressure will consequently decrease due to creep and shrinkage before filling the tunnel. Together with temperature decrease (cooling of concrete) these effects add up to the long-term grouting pressures to be applied.

Calculations are carried out:

- to estimate required long-term grouting pressures in order to avoid final tensile stresses in the tunnel final lining,
- to estimate compressive strain losses due to creep, shrinkage and temperature changes,

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- to finally define the required short-term grouting pressures (without exceeding the allowable compressive strength of concrete).

The grouting pressure is assumed to be uniformly distributed within the grouting interface. Local deviations from this are largely unpredictable, but can be controlled during the carefully monitored Interface Grouting Operation.

5.2.6 Water Pressure

The applicable "Internal water pressure" is shown in the geotechnical longitudinal section (2) and will be treated as basis for subsequent analysis.

The high pressure interface grouting is designed to prestress the final concrete lining and the surrounding rock in such a way, that

- internal water pressure does not cause cracking of the lining concrete and
- water seepage along the outside surface of the tunnel is prevented.

Therefore an "external water pressure" will be taken as the measured groundwater levels indicated in section 5.1.3 a regular load case.

5.2.7 Lining Properties and Lining Dimensions

Initial Lining:

Immediately after excavation "young" shotcrete properties (E = 7500 MN/m^2) are applied in the analysis. For subsequent design stages properties for "old" shotcrete (E = 15000 MN/m^2) are taken into account after the shotcrete has hardened sufficiently.

The lining shotcrete is initially subjected to radial and tangential stresses as a result of the interlocking mechanism with the ground. The transfer of tangential stresses is limited in case shear failure occurs. Either the failure of rock or the failure of shotcrete is theoretically possible, therefore the strength parameter associated with the weaker material is used as failure criterion for the interface.

The lining thickness and geometrical parameters are presented in the drawings (5), (6) and (7) for each Rock Support Type.

Final Lining:

The Concrete properties used for analysis are presented in chapter 4.4.5. The geometry of the typical cross section is presented in (3). Different thicknesses of final lining (600 mm and 700 mm) are proposed in (3), which depend on the stress level, the lining has to resist.

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5.2.8 Discontinuity Orientation and Additional Parameters for Wedge Analysis

Discontinuity Orientation

Five major discontinuity sets are identified along the tunnel alignment including bedding planes and 4 joint sets. The table 11 lists the major discontinuity sets provided in the GBR A [3].

Major Discontinuity Sets			
No.	Type	Strikedirection	Dip
		[°]	[°]
1	bedding	E-W	0,3
2	J1	5	80-90
3	J2	45	80-90
4	J3	85	80-90
5	J4	135	80-90

Table 11: Major Discontinuity sets for the Niagara Tunnel Facility Project

The software used for Key Block Analysis enables to compute all possible discontinuity combinations and the resulting wedges. A total of 10 combinations are obtained from the combination of the 5 major discontinuity sets.

Discontinuity Set Combinations			
Combination	Joint_A	Joint_B	Joint_C
1	2	4	5
2	1	4	5
3	1	3	5
4	1	2	5
5	1	2	4
6	3	4	5
7	2	3	4
8	2	3	5
9	1	2	3
10	1	3	4

Table 12: Discontinuity combinations resulting from the major discontinuity sets

Size, Shape and Orientation of the Tunnel

The shape of the bored Diversion Tunnel is circular with a diameter of 14.44 m. Along the proposed tunnel alignment, the tunnel changes its orientation several times significantly. The trend of the tunnel axis represents the orientation with respect to North: The plunge of the tunnel axis represents the grade with respect to a horizontal plane. Both parameters are evaluated resulting in 6 tunnel sections with varying trend and plunge. The relevant tunnel sections are summarised in table 13.

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Alignment Trend/Plunge			
Section		Plunge	Trend
from	to	[°]	[°]
0+000	2+168	0	100
2+168	2+868	0	178
2+868	6+944	1	178
6+944	8+415	1	195
8+415	8+865	1	235
8+865	10+364	-4	235

Table 13: Variation of trend and plunge of the tunnel axis along the alignment

The 10 possible discontinuity combinations are analysed for the six above listed tunnel sections separately, resulting in 60 individual computations.

Discontinuity Properties

The discontinuity properties are defined applying the Mohr-Coulomb parameters (friction angle ϕ and cohesion c). The following discontinuity properties are applied in the analysis (see GBR [4]):

Discontinuity Type	ϕ [°]	c [MPa]
Bedding Plane	24	0,45
Joint	30	0,0

Table 14: Discontinuity properties

5.3 Analysis Models

5.3.1 FE-Model

General:

The Finite Element (FE) Method is applied to consider the surrounding ground as a load carrying element and to take nonlinear ground parameters into account. The dimensions of the Finite Element mesh are selected in a way that effects of the excavation on the boundaries of the system can be excluded. The boundary conditions of the FE mesh are as follows: The ground surface is free to displace, the side surfaces have roller boundaries and the base is fixed.

The Finite Element Code PLAXIS is used for the computations. Verification of the selected elements, materials and methods are given in {3,4}.

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In general, the ground is modelled using the isotropic constitutive model of Mohr Coulomb with linear elasticity and perfect plasticity. The Mohr-Coulomb model requires a total of five parameters:

E	-	Young's modulus
ν	-	Poisson's ratio
ϕ	-	friction angle
c	-	cohesion
ψ	-	dilatancy angle

Details of the constitutive model used are presented in {3}.

Stress Release ahead of face:

The excavation of a tunnel is a three dimensional problem. As a result of excavation, deformations occur in the ground ahead the tunnel face. After excavation and initial lining application further deformations occur causing stresses in the shotcrete.

The stress release ahead of tunnel face is evaluated using preliminary 3D-FE analysis. The portion of forces acting on the ground ahead of excavation and the portion acting on the combined system of ground and lining depend on:

- Size of excavation
- Stiffness of ground
- Stiffness of the lining
- Unsupported length of excavation.

The stress analyses for the selected analysis sections are performed with 2D-FE models (i.e. plane strain analysis). In the 2D-analysis it is necessary to consider deformations of the ground, ahead of excavation (i.e. to approximate the load sharing effect). To evaluate the stress release of the ground in front of the tunnel face, the so-called β-method is used in the numerical analysis. The initial stress p_i acting around the tunnel excavation is divided into a part $\beta_1 \, p_i$, that is applied to the unsupported tunnel ahead of the face and a part $(1-\beta_1) \, p_i$, that is applied to the supported tunnel (see Figure 3). The factor β_1 represents the stress release factor.

When simulating the excavation sequence of a tunnel, the finite elements within the excavation area are deactivated and equivalent lining forces (nodal forces) are analyzed to find a comparable initial stress state p_i. Equivalent nodal forces (F_i) act on the boundaries of the excavation and equilibrium conditions are not disturbed. In the first calculation phase, the equivalent pressure is reduced stepwise to the stress release value $\beta_1 \, F_i$ (see Figure 2,

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Section B-B). In a second calculation phase, the remaining out-of-balance stress $(1-\beta_1)\ F_i$ is applied (lining installation) to the tunnel support (see Figure 2, Section A-A).

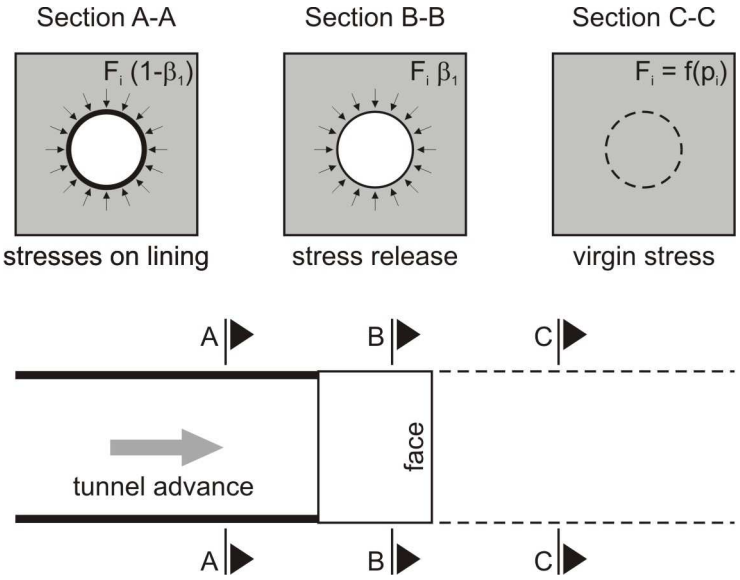

Figure 2: Calculation phases simulating stress release

The stress release in front of the tunnel face is determined on the basis of comparison with preliminary 3D-FE calculations. In addition information of literature {2} is used.

5.3.2 Beam-Spring Model

An elastic beam-spring model is used for certain aspects of the design of the final lining. As indicated in the analysis assumptions for the Diversion Tunnel (see flow-chart, Fig. 1), the influence of:

- maximum short-term grouting pressure,
- shrinkage and creep,
- temperature change on the final lining concrete,

is analysed. Ultimate limit state and serviceability limit state analysis is carried out.

Linear elastic beam elements are used to model the lining. The subgrade reaction is represented by radial springs are following the tension cut-off criterion. Due to a waterproofing membrane between the initial lining and the final lining, tangential springs can be ignored.

Also the analysis of a "loosened slab of a thickness not less than 3 m" as rock load for the initial lining is analysed using a Beam Spring Model.

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5.3.3 Key Block Theory

The potential influence of discontinuities on the excavation of the Diversion Tunnel is analysed by the program code "Unwedge".

Unwedge {6} is a 3D stability analysis and visualization program for underground excavation in rock containing intersecting structural discontinuities using block theory {5}. Safety factors are calculated for potentially unstable wedges and support requirements can be modeled using pattern bolting or spot bolting and shotcrete. *Unwedge* determines all possible wedges that can be formed by the intersection of 3 joint planes and the excavation. A maximum of 8 wedges is formed around the opening, but less than 8 wedges may be formed depending on the joint orientation and the shape and orientation of the excavation. *Unwedge* also determines the wedges that can be formed at both "ends" of the excavation.

The following failure modes can occur:

1. Falling or lifting
2. Sliding on a single plane
3. Sliding on two planes, along the line of intersection

The analysis is based on the assumption, that the wedges, defined by three intersecting discontinuities, are subjected to gravitational loading only. Stresses in the rock mass result in a confinement of rock blocks for which reason the chosen assumption is conservative. This means that the stresses on the joint planes are a result of self-weight of each wedge (as well as support forces, water pressure, seismic forces etc). While this assumption leads to some inaccuracy in the analysis, the error is generally conservative, leading to a reduced factor of safety. However, the 3.005 version of the software enables to include the effect of in-situ stress on the wedges. But the inclusion of the Field Stress can only increase the factor of safety, it cannot reduced the factor of safety. Field stress is therefore not considered for the analysis.

Water pressure is not considered for the analysis too.

The following important limitations and assumptions have to be kept in mind for interpretation of the analysis results:

- Unwedge is used to analyze wedge failure around excavations constructed in hard rock, where discontinuities are persistent, and where stress induced failure does not occur. It is assumed that displacements take place at the discontinuities, and that the wedges move as rigid bodies with no internal deformation or cracking.
- All of the discontinuity surfaces are assumed to be perfectly plane.
- Discontinuity surfaces are assumed to be persistent and extend through the volume of interest, therefore the discontinuities defining the wedge do not terminate in the

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region where the wedges are formed. The implication is, that no new cracks are formed in the analysis to allow wedge movement.

- The discontinuities are considered to be ubiquitous: in other words, they can occur at any location in the rock mass.
- The underground excavation is assumed to have a constant cross section along its axis.
- A maximum of three structural planes can be analyzed at one time. If more than three major planes are identified for the analysis of the structural data, then all combinations of these planes should be considered.

5.3.4 Convergence-Confinement Method

The convergence-confinement method is based on a concept that involves analysis of the ground structure interaction by an independent study of the behaviour of the ground and of the tunnel support. The ground behaviour is represented by a ground-reaction curve and the tunnel support is represented by a support reaction curve. The support pressure is evaluated from canputations of the initial lining characteristics including shotcrete, steel ribs and anchors.

This method allows to estimate the load imposed on the support installed in the tunnel. When a section of support is installed in the immediate vicinity of the tunnel face, it does not carry the full load as a part of the load that is redistributed around the excavation is carried by the rock forming tunnel face. With great distance to the tunnel face, this so-called face-effect decreases and the support carries a greater proportion of the ground load. When the excavation face has moved well away from the section considered, the initial support carries the full design load.

The method applied in the convergence confinement calculations is based on literature {8,9} and is particularly used for:

1) preliminary tunnel support design
2) time-dependent load distribution of ground load to the initial support (short-term)
3) time-dependent load distribution of ground load to the final lining (long-term)

(1) is used before starting decisive stress analysis, (2) is applied to analyse load assumptions for FE-calculations as indicated in table 15 and (3) is applied to estimate the long-term stress increase due to rock-squeeze on the final lining.

Time-dependent behaviour is incorporated into the convergence-confinement method based on the literature {10, 11}.

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5.4 Load Assumptions

Ground loads are defined depending on the following structural models:

5.4.1 Finite Element Model:

The initial lining is stressed as a result of tunnel excavation and it is deformed depending on the primary stress state, the strength and the stiffness of the rock mass. The continuum finite element model is used for the design of the tunnel initial support and the design of the final support. The following load cases are considered within the 2D calculations (Table 15):

Load Case	Description		Detail of Load Case	Remarks
Standard Load Cases (see Figure 3)				
1	In-situ Stress State			
2	Stress Release		Stress release factor β_1 in front of excavation face	β_1 based on preliminary 3D calculations
3	Excavation and Installation Temporary Support	a	Excavation and installation of steel ribs close to excavation face	load transfer factor β_2
		b	Young shotcrete at working platform	load transfer factor β_3
		c	Hardened shotcrete	remaining load β_4 (ground load)
4	Final Lining Installation		self weight	
5	Grouting Pressure		Long-term grouting pressure	
6	Internal Water Pressure			
Additional Load Cases (see Figure 4)				
7	External Water Pressure		Groundwater and internal water pressure	Worst case scenario

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8	Dewatering of Tunnel		Groundwater pressure	Temporary service state
9	Long-term Rock Squeeze	a	assumption 1: long-term stress increase	
		b	assumption 2: horizontal stress increase	
10	Discontinuity Analysis		Shear Zone within tunnel section	Worst case scenario

Table 15: Relevant Load Cases for the FE-Calculations

The loads presented in the individual load cases are subsequently added up

Only the loads "a" and "b" of load case 9 are calculated separately.

Load case 10 covers in fact the loads of load case 1 to 6, which are applied on a system model including a shear zone within the tunnel section and added up. In this calculation the loads of load cases 7 to 9 are not applied, since those loads are not decisive as shown by the load combinations of the standard case.

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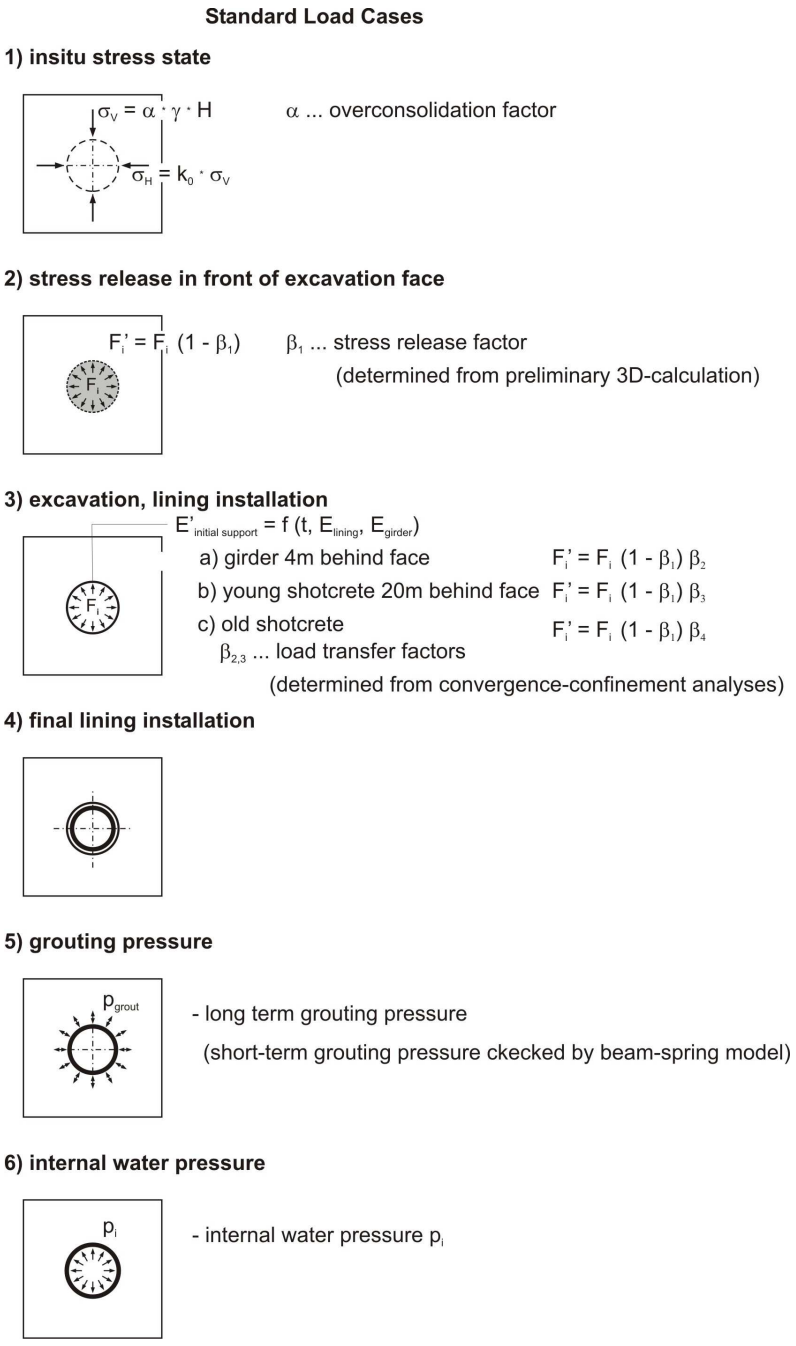

Figure 3: Calculation Phases "Standard Load Cases"

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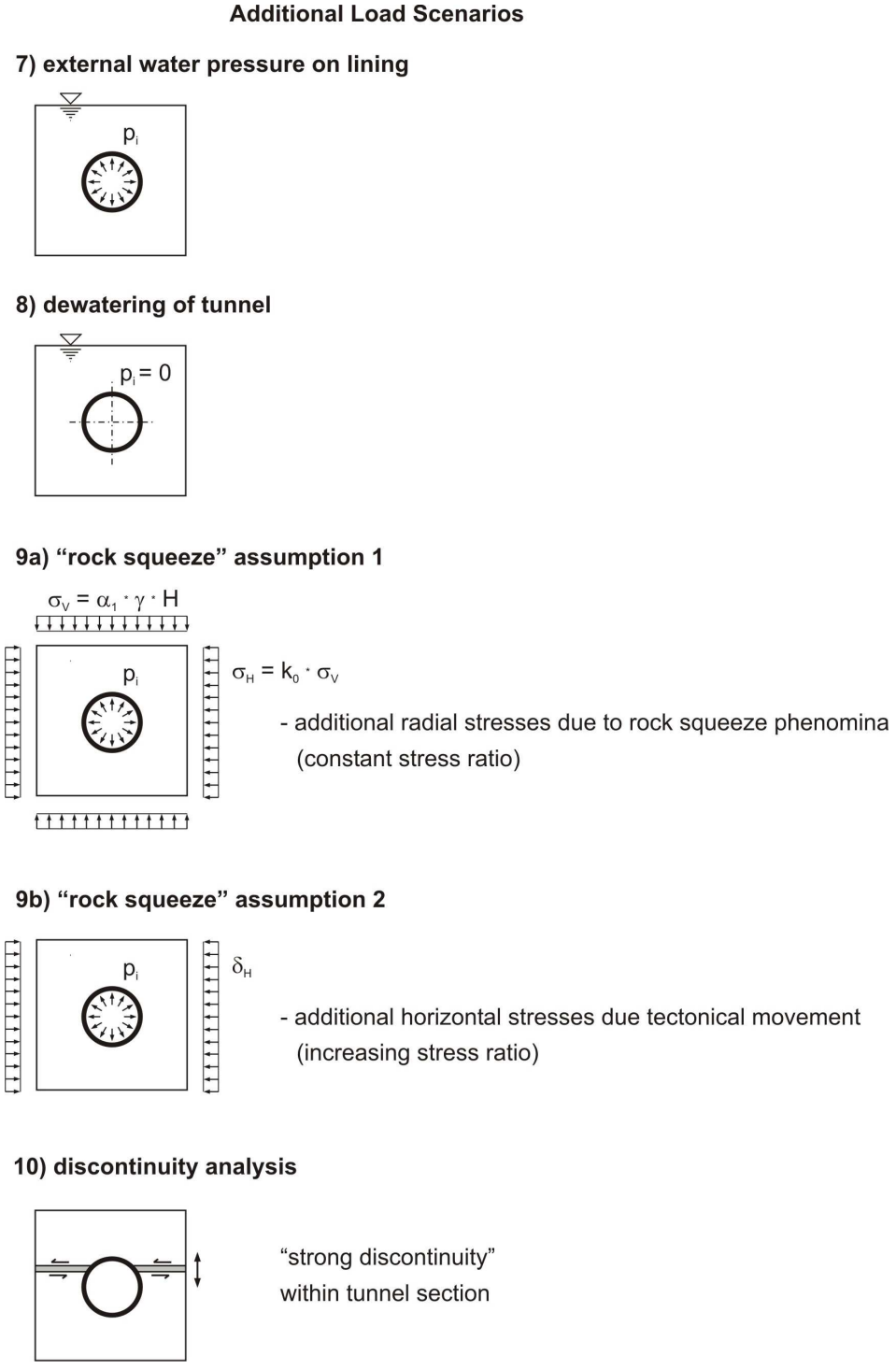

Figure 4: Calculation Phases "Additional Load Cases"

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5.4.2 Beam-Spring Model

The following loads have been determined for the subsequent calculations:

Rock loads:

A loosened rock slab of 3 m thickness up to the full width of the tunnel and shear deformations along bedding plane is analysed.

Grouting Pressure:

Short-term grouting pressures according to the assumptions indicated in Chapter 5.2.5 are analysed.

Temperature

With respect to temperature changes during and after filling of the tunnel with water, thermal strains are activated in the final lining. The applied maximum temperature gradients within the final lining are summarized in Table 2. To facilitate analysis the temperature changes are split in two parts:

- constant temperature change T_{const}
- temperature gradient ΔT

	before watering up °C	after watering up °C
constant temperature change T_{const}	+5	-3
temperature gradient ΔT	+10	-6

Table 16: Thermal Forces

In the analysis it is assumed that an initial constant temperature of 10°C.

Concrete Shrinkage

A concrete shrinkage strain of ε_s = -15.7 x 10-5 is applied to the analysis (see Chapter 4.5.7).

Concrete Creep

A reduction of young's Modulus for concrete of 50% is assumed for the analysis (see Chapter 4.5.8).

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5.4.3 Wedge Analysis:

The rock loads are determined by the geometry of rock blocks, which are formed by sets of discontinuities.

5.4.4 Convergence-Confinement Method

In-Situ Stress Field:

The stress field assumed for analysis is in accordance with the vertical stresses for full overburden and with the high horizontal stresses, which are anticipated (see Chapter 5.2.1).

Long-term Stress Field:

The long-term stress increase on the final lining due to rock-squeeze is considered in accordance with the assumptions given in Chapter 5.3.4.

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6 DESIGN ANALYSIS RESULTS

6.1 General

[Results in this section were developed for the proposal design and are included for information only. Appendices referenced in this section have been intentionally removed. The analyses in this section will be updated in detail design.]

6.2 FE-Analysis

6.2.1 General

The FE-calculations were performed using the following units:

Length : m
Force: kN
Deformations: mm

The main input and output data are given in the Appendices. In all of the results, compressive stresses and forces were taken to be negative, whereas tensile stresses and forces were taken to be positive.

6.2.2 3D FE-Calculations

The stress release ahead of tunnel face is determined on the basis of preliminary 3D-FE calculations.

Two calculations have been carried out:

Calculation	Horizon Model	Geological Formation	Support Class	Advance Length	steel - profile	shotcrete
2	deep	Queenston	VI	4 m	> 4m	>20m
3	shallow	Rochester	IV	4 m	> 4m	>20m

Table 17: Model Assumptions for 3D-FE Calculations

Following excavation steps have been applied:

- In-situ stress state
- Excavation (advance length 4 m)

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- Installation of lattice girders 4 m behind tunnel face
- Young shotcrete 20 m behind tunnel face

Equivalent 2D model have been created in order to fit pre-convergence (i.e. stress release) and load factors for loading of temporary support. The results are summarized in following Table 18:

3D Calculation	Horizon model	Geological Formation	Stress Release β_1	Load Factor β_2	Load Factor β_3	Load Factor β_4
1	deep	Queenston	0.8	0.85	0.9	1.0
2	shallow	Rochester	0.8	0.85	0.9	1.0

Table 18: Results of 3D-FE Calculations

The computer plots are attached to Appendix 02 and 03. The plots consist of:

1) Model Geometry - 3D Model
2) Cross section in tunnel axis
3) Convergence and Pre-Convergence Displacements in tunnel axis
4) Model Geometry - 2D Model
5) Evaluation of appropriate Stress Release Factor β_1
6) Evaluation of appropriate Load Factor β_2
7) Evaluation of appropriate Load Factor β_3

6.2.3 2D FE-Calculations

5 2D-FE calculations have been performed along the Diversion Tunnel alignment. The main input features are summarized in the Table 19 below:

section	station	elevation tunnel axis	rock mass type	initial support	final lining thickness	long-term grouting pressure	internal water pressure	elevation ground water
-	[m]	[el. m]	-	-	[mm]	[MPa]	[MPa]	[el. m]
B/0	0+080	133.0	Lockport	II	0.6	0.15	0.5	168.0
C/0	1+800	52.5	Upper Queenston	V	0.7	0.65	1.3	160.0
D/0	not specific	82.5	Queenston Q8/Q9	V	0.7	0.65	1.3	165.0
E/0	8+660	45.7	Queenston	VI	0.7	0.77	1.4	150.0

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F/0	8+920	45.5	Queenston	VI	0.7	0.77	1.4	150.0

Table 19: Model Assumptions for 2D-FE Calculations – Proposed Alignment

The computer plots are attached to the Appendices 11 to 15.

The typical plots consist of:

1) Model Geometry
2) Longitudinal Section
3) Virgin Stress Field
4) Stress Release
5) Secondary Stress State – Initial Lining Installation
6) Long – Term Grouting Pressure (Distribution)
7) Grouting Chart (Grouting Design)

Additional calculations were performed to check:

8) Internal Water Pressure (Distribution)
9) Initialisation Ground Water Pressure
10) Tunnel Dewatering

For calculation sections close to existing structures additional plots are provided in order to check changes in stress state:

11) Comparison of stress state before / after excavation of the new Diversion Tunnel

Within 2 calculations (Section C/1 and F) the rock-squeeze effect has been analysed additionally:

12) "Rock Squeeze Effect" – Ground Reaction Curves
13) Rock Squeeze – Calculation Assumption 1
14) Rock Squeeze – Calculation Assumption 2

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Results for the Proposed Alignment (Table 20 to 24)

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Calculation Phases	Design Feature	Influence on Tunnel Lining and Surrounding Rock	Influence on Existing Structures
Excavation and Initial Support			
Virgin Stress Field	vertical stresses	full overburden load ($\alpha = 1$)	-
	horizontal stresses	stress ratio of 11.3 for Lockport and DeCew formations	-
Existing Structures	-	-	-
Initial Support	support measures	support category II	-
	stress state	stress redistribution around tunnel	-
	design check	ok ($f_{NM}>1.0$)	-
	deformation behaviour	lining deformation <3mm; max. shear strain <0.52%; no mobilization of peak strength around new tunnel; no significant failure zones;	-
Final Lining Installation			
Final Lining	support measures	60 cm cast-in-place concrete, pre-stress pressure (long-term) = 0.15 MPa	-
Long-Term Grouting Pressure	stress state	effective stresses on tunnel interface ≈0.23 MPa; advanced stress redistribution around tunnel	-
	design check	ok ($f_{NM}>1.0$)	-
	deformation behaviour	radial deformation final lining <0.5mm; no significant failure zones;	-
	short-term Grouting Pressure	1.59 MPa short-term grouting pressure needed	-
Internal Water Pressure	water pressure	0.5 MPa	-
	stress state	effective stresses on tunnel interface ≈0.65 MPa; advanced stress redistribution around tunnel	-
	design check	ok ($f_{NM}>1.0$)	-
	deformation behaviour	radial deformation final lining <0.5mm; no significant failure zones;	-

Table 20: Results for Stress Analysis Calculation Section B0 "Section close to the Intake", Station 0+230

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Calculation Phases	Design Feature	Influence on Tunnel Lining and Surrounding Rock	Influence on Existing Structures
Excavation and Initial Support			
Virgin Stress Field	vertical stresses	full overburden load (α = 1)	-
	horizontal stresses	stress ratio of 12.0 for Thorold and 4.1 for Neahga and Reynales have been taken into account; due to widespread plastic zones during initial stress state, stress ratio has been reduced for Power Glen (4.8), Grimsby (10.2) and Rochester (9.2)	-
Existing Structures	-	-	modelling construction of Existing Tunnels 1 and 2
Initial Support	support measures	support category V	-
	stress state	well defined stress redistribution around tunnel	no significant increase of stresses around existing structures
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	lining deformation <19 mm; marginal shear strains (< 0.5%);	-
Final Lining Installation			
Final Lining	support measures	70 cm cast-in-place concrete, pre-stress pressure (long-term) = 0.65 MPa	-
Long-Term Grouting Pressure	stress state	effective stresses on tunnel interface ≈0.71 MPa; advanced stress redistribution around tunnel	no significant increase of stresses around existing structures
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	radial deformation final lining <2 mm;	-
	short-term Grouting Pressure	1.9 MPa short-term grouting pressure needed	-
Internal Water Pressure	water pressure	1.3 MPa	-
	stress state	effective stresses on tunnel interface ≈1.0 MPa; advanced stress redistribution around tunnel	no significant increase of stresses around existing structures
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	radial deformation final lining <1mm;	-
Ground Water Pressure	stress state	effective stresses on tunnel interface <0.15 MPa; advanced stress redistribution around tunnel	no significant increase of stresses around existing structures
	design check	ok (f_{NM}>1.0); (compressive strength of concrete f_c = 35 MN/m² required)	-
	deformation behaviour	radial deformation final lining <6 mm;	-
Dewatering of Tunnel	stress state	increase of effective stresses;	no significant increase of stresses around existing structures
	design check	ok (f_{NM}>1.0); (compressive strength of concrete f_c = 35 MN/m² required)	-
	deformation behaviour	radial deformation final lining <5mm; calculation results in small failure zones below the invert;	-

Table 21: Results for Stress Analysis Calculation Section C/0 "Below Existing Tunnels No. 1 and 2", Station 1+800

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Calculation Phases	Design Feature	Influence on Tunnel Lining and Surrounding Rock
Excavation and Initial Support		
Virgin Stress Field	vertical stresses	full overburden load (α = 1)
	horizontal stresses	stress ratio of 4.5 for Queenston
Variation Bedding Plane Level	-	3 bedding plane levels were considered: (a) 2 m above tunnel heading, (b) within tunnel - 3 m below heading, (c) in the centre of the tunnel opening A sensitivity analysis indicated that the bedding plane above the tunnel top heading (a) is most severe with respect to sectional forces within the tunnel lining; therefore this analysis is represented hereafter.
Stress Release	stress state	well defined stress redistribution around tunnel
	deformation behaviour	calculation results in widespread failure zones below the invert and atop the tunnel heading; shear displacement within bedding plane exceeds peak strength – therefore strain softening was introduced as soon as 10 mm shear displacement was reached in any point
Initial Support	support measures	support category VI
	stress state	continued stress redistribution around tunnel
	design check	ok (f_{NM}>1.0)
	deformation behaviour	lining deformation <10 mm; shear displacement within bedding plane reach approx. 20 mm
Final Lining Installation		
Final Lining	support measures	70 cm cast-in-place concrete, pre-stress pressure (long-term) = 0.5 MPa
Long-Term Grouting Pressure	stress state	advanced stress redistribution around tunnel
	design check	ok (f_{NM}>1.0)
	deformation behaviour	radial deformation final lining <5 mm;
	short-term Grouting Pressure	1.6 MPa short-term grouting pressure needed
Internal Water Pressure	water pressure	0.7 MPa
	stress state	advanced stress redistribution around tunnel
	design check	ok (f_{NM}>1.0)
	deformation behaviour	marginal increase of shear displacements within bedding plane (approx. 21 mm)
Ground Water Pressure on Bedding Plane; Tunnel Dewatered	method	water pressure to act on bedding plane
	stress state	Stresses within lining increase considerably.
	design check	ok (f_{NM}>1.0)
	deformation behaviour	marginal increase of shear displacements within bedding plane (approx. 21 mm)

Table 22: Results for Stress Analysis Calculation Section D/0 "Bedding Plane Q8/Q9"

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Calculation Phases	Design Feature	Influence on Tunnel Lining and Surrounding Rock	Influence on Existing Structures
Excavation and Initial Support			
Virgin Stress Field	vertical stresses	full overburden load (α = 1.0)	-
	horizontal stresses	stress ratio of 2 for Queenston below St. Davids Gorge;	-
Existing Structures	-	-	-
Initial Support	support measures	support category VI	-
	stress state	well defined stress redistribution around tunnel	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	lining deformation <5 mm; Failure along shear zones has not been observed – max. shear strains < 0.15 %;	-
Final Lining Installation			
Final Lining	support measures	70 cm cast-in-place concrete, pre-stress pressure (long-term) = 0.79 MPa	-
Long-Term Grouting Pressure	stress state	effective stresses on tunnel interface ≈0.76 MPa; advanced stress redistribution around tunnel	-
	design check	ok (f_{NM}>1.0); (compressive strength of concrete f_c = 35 MN/m² required)	-
	deformation behaviour	radial deformation final lining <2.5 mm;	-
	short-term Grouting Pressure	2.15 MPa short-term grouting pressure needed; during grouting, the failure zones reach further into the rock mass.	-

Table 23: Results for Stress Analysis Calculation Section E/0 "Under Gorge", Station 8+660

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Calculation Phases	Design Feature	Influence on Tunnel Lining and Surrounding Rock	Influence on Existing Structures
Excavation and Initial Support			
Virgin Stress Field	vertical stresses	1.2 x full overburden load (α = 1.2)	-
	horizontal stresses	stress ratio of 4.5 for Queenston; due to widespread plastic zones during initial stress state, stress ratio has been reduced for Grimsby (5.0) and Rochester (12.6)	-
Existing Structures	-	-	-
Initial Support	support measures	support category V	-
	stress state	well defined stress redistribution around tunnel	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	lining deformation <5 mm; Failure along shear zones has not been observed – max. shear strains < 0.4 %;	-
Final Lining Installation			
Final Lining	support measures	70 cm cast-in-place concrete, pre-stress pressure (long-term) = 0.6 MPa	-
Long-Term Grouting Pressure	stress state	effective stresses on tunnel interface ≈0.76 MPa; advanced stress redistribution around tunnel	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	radial deformation final lining <2 mm;	-
	short-term Grouting Pressure	2.05 MPa short-term grouting pressure needed; during grouting, the failure zones reach further into the rock mass.	-
Internal Water Pressure	water pressure	1.4 MPa	-
	stress state	effective stresses on tunnel interface ≈2.0 MPa;	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	radial deformation final lining <0.8mm;	-
Ground Water Pressure	stress state	effective stresses on tunnel interface ≈1.0 MPa; advanced stress redistribution around tunnel	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	deformation final lining ≈7 mm; calculation results in widespread areas of failure zones at the shoulders as well as underneath the invert.	-
Dewatering of Tunnel	stress state	increase of effective stresses;	-
	design check	ok (f_{NM}>1.0)	-
	deformation behaviour	radial deformation final lining <0.3mm;	-

Table 24: Results for Stress Analysis Calculation Section F/0 "Deepest Section", Station 8+920

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6.3 Beam-Spring Model

Linear elastic analyses are adequate for static loading of the tunnel lining from self weight, geo- hydrostatic, temperature, shrinkage, and live loads. The calculations result from a radial, elastic beam element method.

6.3.1 Geometry

The cross section of the tunnel is illustrated in (4). The outer diameter is 14.44 m, the shotcrete lining has a thickness up to 30 cm and the final lining thickness is 60 – 70 cm. For the subsequent calculations a representative tunnel diameter for the beam elements of 13.1 m has been assumed for modelling the final lining and respectively a tunnel diameter of 14 m for the initial support.

6.3.2 Performed Calculations and Calculation Parameters

The calculation parameters for the surrounding rock are in accordance with Chapter 5.2.2.

The ground reaction is taken into account by using an elastic-plastic subgrade reaction K (radial springs with tension cut-off criterion). Due to a waterproofing system between the initial support and final lining, tangential springs can be ignored.

The modulus of subgrade reaction K_R is calculated using the following formula:

$$K_R = \frac{E}{R}$$

For the following calculations short term grouting pressure is considered.

Calculation	short-term grouting pressure [MPa]	final lining thickness [m]	E-modulus rock [GPa]
1	1.70	0.70	16*)
2	1.70	0.70	4*)
3	1.35	0.60	11*)
4	1.25	0.60	24*)
5	1.4	0.60	11*)

Table 25: Final Lining Calculation: short-term grouting

*) …. no influence on the results because of tension cut off.

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For the subsequent calculation short term grouting pressure, thermal forces, shrinkage and creep as described in chapter 4.5 are considered.

Calculation	shortterm grouting pressure [MPa]	final lining thickness [m]	E-modulus rock [GPa]
6	1.25	0.70	24*)

Table 26: Final Lining Calculation: "Constrained Forces"

*) …. no influence on the results because of tension cut off.

Also the analysis of a "lossened slab of a thickness not less than 3 m" as a rock loading on the initial support will be considered using a Beam Spring Model.

Calculation	rock load	initial support	E-modulus rock [GPa]
7	from 3m slab	to be evaluated	24

Table 27: Initial Support Calculation: "3 m slab"

6.3.3 Results

Short-Term Grouting Pressure

The detailed results, plots and listings, are shown in the Appendix 04. The most important results are summarized hereafter. The safety factor for the short-term grouting pressure has been adopted as indicated in Chapter 4.7.3 (load factor $\alpha_L = 1.0$ and resistance factor concrete $\Phi_c = 0.7$). The design check requires a design factor $f_{NM} \geq 1.0$.

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Calculation	radial deformation [mm]	factor of safety f_{NM} [ ]
1	4.4	1.0
2	4.4	1.0
3	4.1	1.08
4	3.8	1.17
5	4.2	1.0

Table 28: Results for short-term grouting

The calculation results indicate that the maximum short-term grouting pressure on a 60 cm final lining has to be restricted with 1.4 MPa. Increasing the thickness to 70 cm allows a maximum short-term grouting pressure of 1.7 MPa. The required maximum grouting pressure of 2.15 MPa for the calculation section below St. David Gorge) can be reached assuming a higher compressive strength f_c' of the concrete. The above results consider a conservative compressive strength $f_c' = 27.5$ MPa (see Chapter 4.4.5). Assuming a compressive strength f_c' of 35 MPa (incorporating an E-modulus of 27 GPa) allows to pre-stress the 70 cm thick final lining with maximum 2.2 MPa grouting pressure.

Constrained Forces

The detailed results, plots and listings, are shown in the Appendix 05. Short term grouting pressure (1.25 MPa assumed) in combination with thermal forces, shrinkage and creep as described in chapter 4.5 result in:

Calculation	radial deformation [mm]	factor of safety f_{NM} [ ]
6	7.5	1.7

Table 29: Results for Constrained Forces

The evaluation of the ratio between applied short-term grouting pressure and resulting long-term grouting pressure depends mainly on the influence of creep, shrinkage and temperature (see Chapter 5.2.5). Compressive strain losses due to these factors are summarized in the Table 30 below:

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calculation 6	relative radial shortening [mm]	relative radial shortening [‰]
temperature	0.197	0.03
shrinkage	1.028	0.157
creep	3.109	0.47

Table 30: Expected Radial shortening due to Shrinkage, Creep and Temperature

The design of required short-term grouting pressure is attached to the Appendices of the FE-calculations. These grouting charts consider a loss due to creep and temperature of maximum 0.5 ‰ (radial shortening). Herein it is assumed that the influence due to shrinkage, i.e. migration of excessive water from the interior of the concrete mass, has been taken place before grouting.

"3m slab" on initial support

The calculations proof that a rock load due to a "3m slab" as defined in Chapter 5.4.2 can be supported by one of the subsequent initial support elements (The detailed results see below and in Appendix 06):
:

calculation 7	location	dimensions
steel profile	fullround	IPB 260, e = 1.2 HEB 160, e= 1.8
shotcrete	fullround	>20cm
rock dowels	crown, 0.9x2.0, l=6m	240 kN

Table 31: Dimensioning Initial Support for Rock Load of a "3 m Slab"

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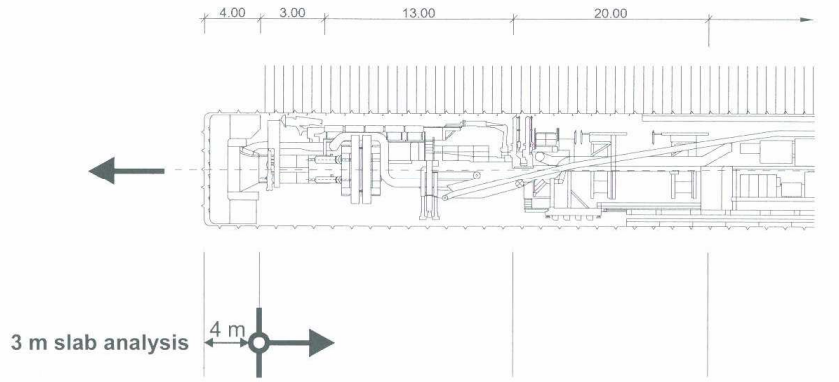
List of action items from Meeting Tuesday, July 5, 2005
Ad. 4.2) Review capacity of Type 5 support
Summary of calculations performed for Type 5 support



a) rock dowels, raster 0.9 m x 2.0 m, l = 6 m, F_{all} = 240 kN
b) IPB 160 (see page 06.1.5, document PR-00-4001)
c) shotcrete >20 cm
d) calculations of rock support elements (a), (b) or (c)
(see structural design analysis, document PR-00-4001)

ADDIONAL CALCULATIONS WITH RESPECT TO
„3m SLAB ANALYSIS" IN PR-00-4001
APPENDIX 06

ad a) raster 0.9 m × 2.0 m, l = 6 m, F_{all} = 240 kN

$F = 0.9 \times 2 \times 3 \times 26 = 140$ kN / anchor raster

$\Rightarrow \eta = \frac{240}{140} = 1.7$ ✓

ad b) see design check page 06.1.5, app. 06, PR-00-4001 ✓

ad c) member forces see appendix 06.2.1, app. 06, PR-00-4001
$\phi_c = 0.6$, $\alpha_L = 1.0$ for temporary state
f_c (2 days) = 9.5 MPa $\Rightarrow f_{cm,min} = 1,0$ ✓

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6.4 Wedge Analysis

For the analysis of the results the following simplifications was adopted:

Combinations of the four major joint sets resulted in unrealistic high and narrow wedges due to their steep dip angle. Downsizing them to a realistic height of a few meters resulted in unrealistic thin, needle like wedges. Truncation of the wedges by a forth plane (bedding plane) a few meters above the wedge base is not supported by the software. Therefore it is assumed that wedges formed by discontinuity combinations including the bedding plane also cover those truncated wedges in size, weight and position.

The analysis of the 60 possible combinations considering all major discontinuity sets and the change of the tunnel orientation along the alignment resulted in 87 potentially unstable wedges (not considering unrealistic high wedges). Table 32 shows one example for the block stability analysis carried out for the tunnel section below St. David's Gorge.

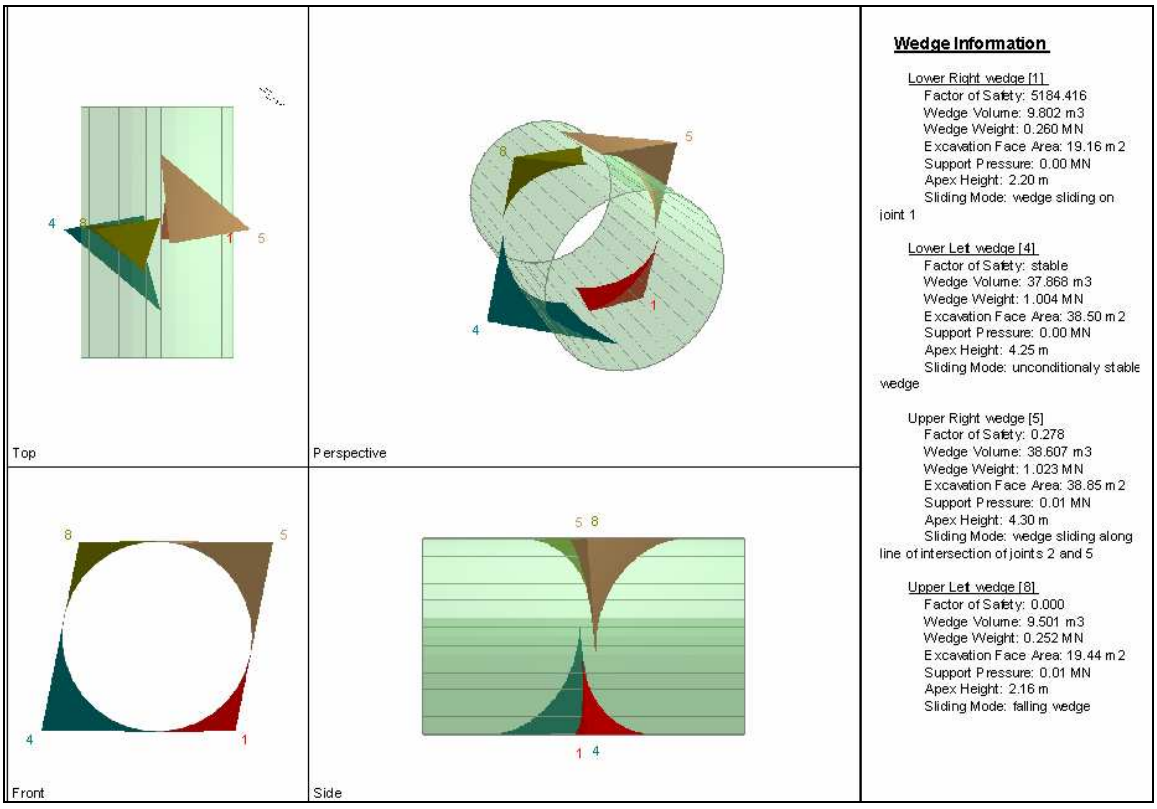

Table 32: Example for wedge analysis

The below table 33 lists all potentially unstable wedges identified for the Niagara Tunnel Facility Project.

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No.	Trend/ Plunge	Discont. Comb.	Wedge	Factor of Safety	Wedge Volume [m³]	Wedge Weight [MN]	Excavation Face Area [m²]	Apex Height [m]	Support Pressure [MN/m²]	Mode	Formation	Support Categories
Inlet Section: 0+000 to 2+168												
1	100/0	145	Far End wedge [10]	0,05	0,15	0,00	1,80	0,25	0,01	sliding on joint 5	Lockport De Cew	1, 2, 3, 5
2		125	Upper Left wedge [5]	0,28	50,90	1,35	61,26	4,21	0,01	sliding on joints 2 and 5		
3		125	Upper Right wedge [8]	0,00	14,51	0,39	28,39	2,28	0,02	falling wedge		
4		135	Upper Right wedge [8]	0,00	27,76	0,74	49,47	2,51	0,02	falling wedge		
5		145	Upper Right wedge [8]	0,00	72,54	1,92	123,11	2,61	0,02	falling wedge		
6		134	Upper Right wedge [6]	0,05	46,43	1,23	76,18	2,71	0,02	sliding on joint 3		
7		124	Upper Right wedge [6]	0,05	60,69	1,61	97,70	2,76	0,02	sliding on joint 2		
8		123	Upper Right wedge [6]	0,05	14,70	0,39	22,22	2,96	0,02	sliding on joint 2		
9		123	Upper Left wedge [7]	0,05	17,82	0,47	28,16	3,28	0,02	sliding on joint 3		
10		124	Upper Left wedge [7]	0,05	98,38	2,61	140,10	3,51	0,02	sliding on joint 4		
11		134	Upper Left wedge [7]	0,05	81,26	2,15	114,66	3,57	0,02	sliding on joint 4		
12		145	Upper Left wedge [5]	0,06	146,54	3,88	194,86	3,68	0,02	sliding on joints 4 and 5		
13		135	Upper Left wedge [5]	0,10	67,29	1,78	88,10	3,86	0,02	sliding on joints 3 and 5		
Central Section I: 2+168 to 2+868												
14	178/0	123	Upper Left wedge [7]	0,05	103,89	2,75	154,66	2,72	0,02	sliding on joint 3	Lockport De Cew, Rochester	2, 3, 4
15		124	Upper Left wedge [7]	0,05	115,35	3,06	170,03	2,73	0,02	sliding on joint 4		
16		125	Upper Left wedge [7]	0,05	132,93	3,52	191,30	2,77	0,02	sliding on joint 5		
17		134	Upper Left wedge [7]	0,05	15,75	0,42	26,59	2,93	0,02	sliding on joint 4		
18		145	Upper Right wedge [6]	0,05	20,09	0,53	30,09	2,93	0,02	sliding on joint 4		
19		135	Upper Right wedge [6]	0,05	39,04	1,04	55,32	3,06	0,02	sliding on joint 3		
20		135	Upper Left wedge [7]	0,05	39,23	1,04	57,59	3,10	0,02	sliding on joint 5		
21		125	Upper Right wedge [6]	0,05	183,28	4,86	225,82	3,22	0,02	sliding on joint 2		
22		134	Upper Right wedge [6]	0,05	19,98	0,53	26,99	3,27	0,02	sliding on joint 3		
23		145	Upper Left wedge [7]	0,05	25,16	0,67	37,07	3,29	0,02	sliding on joint 5		
24		124	Upper Right wedge [6]	0,05	170,10	4,51	207,11	3,29	0,02	sliding on joint 2		
25		123	Upper Right wedge [6]	0,05	155,44	4,12	189,51	3,32	0,02	sliding on joint 2		
Central Section II: 2+868 to 6+944												
26	178/1	123	Roof wedge [8]	0,00	0,02	0,00	1,79	0,03	0,00	falling wedge	Rochester to Queenston Q8	2, 3, 4, 5, 6
27		124	Roof wedge [8]	0,00	0,02	0,00	2,07	0,04	0,00	falling wedge		
28		125	Roof wedge [8]	0,00	0,03	0,00	2,35	0,04	0,00	falling wedge		
29		123	Upper Left wedge [7]	0,05	65,15	1,73	107,63	2,29	0,02	sliding on joint 3		
30		124	Upper Left wedge [7]	0,05	73,09	1,94	118,77	2,31	0,02	sliding on joint 4		
31		125	Upper Left wedge [7]	0,05	85,56	2,27	134,61	2,36	0,02	sliding on joint 5		
32		145	Upper Right wedge [6]	0,05	18,93	0,50	28,65	2,86	0,02	sliding on joint 4		
33		134	Upper Left wedge [7]	0,05	14,78	0,39	23,22	2,87	0,02	sliding on joint 4		
34		135	Upper Right wedge [6]	0,05	36,83	0,98	50,94	3,02	0,02	sliding on joint 3		
35		135	Upper Left wedge [7]	0,05	37,17	0,99	50,73	3,07	0,02	sliding on joint 5		
36		134	Upper Right wedge [6]	0,05	20,02	0,53	26,14	3,30	0,02	sliding on joint 3		
37		145	Upper Left wedge [7]	0,05	25,17	0,67	33,63	3,32	0,02	sliding on joint 5		
38		125	Upper Right wedge [6]	0,05	183,60	4,87	200,74	3,37	0,02	sliding on joint 2		
39		124	Upper Right wedge [6]	0,05	179,61	4,76	189,22	3,53	0,02	sliding on joint 2		
40		123	Upper Right wedge [6]	0,05	171,01	4,53	176,66	3,62	0,02	sliding on joint 2		
Central Section III 6+944 to 8+415												
41	195/1	123	Upper Left wedge [8]	0,00	83,16	2,20	121,99	2,55	0,02	falling wedge	Queenston Q8 to Q6	4, 5, 6
42		125	Upper Left wedge [8]	0,00	61,12	1,62	93,05	2,55	0,02	falling wedge		
43		124	Upper Left wedge [8]	0,00	72,81	1,93	107,54	2,60	0,02	falling wedge		
44		134	Upper Left wedge [7]	0,05	19,96	0,53	31,43	2,70	0,02	sliding on joint 4		
45		135	Upper Left wedge [7]	0,05	35,96	0,95	52,19	2,83	0,02	sliding on joint 5		
46		145	Upper Right wedge [6]	0,05	18,01	0,48	25,65	3,04	0,02	sliding on joint 4		
47		145	Upper Left wedge [7]	0,05	18,66	0,50	26,85	3,12	0,02	sliding on joint 5		
48		123	Upper Right wedge [5]	0,06	135,37	3,59	158,94	3,23	0,02	sliding on joints 2 and 3		
49		135	Upper Right wedge [6]	0,05	48,73	1,29	61,60	3,24	0,02	sliding on joint 3		
50		124	Upper Right wedge [5]	0,09	116,18	3,08	137,18	3,27	0,02	sliding on joints 2 and 4		
51		125	Upper Right wedge [5]	0,28	107,91	2,86	124,68	3,40	0,02	sliding on joints 2 and 5		
52		134	Upper Right wedge [6]	0,05	33,63	0,89	40,98	3,46	0,02	sliding on joint 3		
Central Section IV 8+415 to 8+865												
53	235/1	124	Far End wedge [10]	0,05	0,01	0,00	0,47	0,04	0,00	sliding on joint 2	Queenston Q7 and Q6	4, 5, 6
54		123	Far End wedge [10]	0,05	0,47	0,01	3,27	0,43	0,01	sliding on joint 2		
55		125	Upper Left wedge [8]	0,00	9,50	0,25	19,44	2,16	0,01	falling wedge		
56		125	Upper Right wedge [5]	0,28	38,61	1,02	38,85	4,30	0,01	sliding on joints 2 and 5		
57		124	Upper Left wedge [8]	0,00	28,92	0,77	47,58	2,43	0,02	falling wedge		
58		134	Upper Left wedge [8]	0,00	79,01	2,09	115,58	2,53	0,02	falling wedge		
59		135	Upper Left wedge [8]	0,00	68,51	1,82	100,68	2,58	0,02	falling wedge		
60		145	Upper Left wedge [7]	0,05	22,12	0,59	34,07	2,69	0,02	sliding on joint 5		
61		123	Upper Left wedge [6]	0,05	66,16	1,75	93,13	2,75	0,02	sliding on joint 2		
62		123	Upper Right wedge [7]	0,05	85,40	2,26	106,06	3,13	0,02	sliding on joint 3		
63		134	Upper Right wedge [5]	0,06	128,10	3,40	150,51	3,18	0,02	sliding on joints 3 and 4		
64		135	Upper Right wedge [5]	0,10	108,32	2,87	127,84	3,24	0,02	sliding on joints 3 and 5		
65		145	Upper Right wedge [6]	0,05	37,32	0,99	45,00	3,44	0,02	sliding on joint 4		
66		124	Upper Right wedge [5]	0,09	68,89	1,83	74,87	3,70	0,02	sliding on joints 2 and 4		
Outlet Section 8+865 to 10+364												
67	235/-4	124	Roof wedge [7]	0,05	0,00	0,00	0,22	0,02	0,00	sliding on joint 4	Queenston Q6 to Lockport	2, 3, 4, 5, 6
68		125	Roof wedge [7]	0,05	0,00	0,00	0,19	0,02	0,00	sliding on joint 5		
69		123	Roof wedge [8]	0,00	0,05	0,00	1,22	0,12	0,00	falling wedge		
70		135	Roof wedge [7]	0,05	0,14	0,00	2,75	0,17	0,00	sliding on joint 5		
71		125	Far End wedge [10]	0,05	0,95	0,03	11,96	0,24	0,00	sliding on joint 2		
72		134	Roof wedge [7]	0,05	0,38	0,01	4,79	0,24	0,00	sliding on joint 4		
73		135	Upper Left wedge [8]	0,00	9,95	0,26	27,50	1,24	0,02	falling wedge		
74		134	Upper Left wedge [8]	0,00	12,01	0,32	32,30	1,27	0,02	falling wedge		
75		123	Upper Left wedge [6]	0,05	9,63	0,26	25,73	1,30	0,02	sliding on joint 2		
76		124	Far End wedge [10]	0,05	7,36	0,20	16,93	1,31	0,02	sliding on joint 2		
77		123	Far End wedge [10]	0,05	7,12	0,19	12,61	1,69	0,02	sliding on joint 2		
78		125	Upper Left wedge [8]	0,00	6,60	0,18	12,76	1,92	0,02	falling wedge		
79		124	Upper Left wedge [8]	0,00	19,97	0,53	31,07	2,29	0,02	falling wedge		
80		145	Upper Right wedge [6]	0,05	19,87	0,53	26,41	2,78	0,02	sliding on joint 4		
81		134	Upper Right wedge [5]	0,06	71,80	1,90	82,68	2,95	0,02	sliding on joints 3 and 4		
82		124	Upper Right wedge [5]	0,09	36,66	0,97	42,86	3,06	0,02	sliding on joints 2 and 4		
83		135	Upper Right wedge [5]	0,10	96,86	2,57	91,26	3,61	0,02	sliding on joints 3 and 5		
84		125	Upper Right wedge [5]	0,28	34,61	0,92	30,93	4,29	0,02	sliding on joints 2 and 5		
85		145	Upper Left wedge [7]	0,05	21,69	0,58	28,02	2,88	0,03	sliding on joint 5		
86		123	Upper Right wedge [7]	0,05	102,42	2,71	89,01	3,94	0,03	sliding on joint 3		
87		134	Far End wedge [10]	0,05	1,19	0,03	4,48	0,80	0,04	sliding on joint 3		

Table 33: Results of the wedge analysis

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In order to evaluate the support requirements for each tunnel section concerning block failure the proposed support classes were applied on all blocks of each section. Support was increased till a factor of safety >1 was reached. The analyses were carried for support categories 2 to 4, which are applicable for support of block failure. For the analyses only rock bolts were considered since it is planed that shotcrete is going to be applied some distance behind the TBM. Therefore the bolts have to be able to take the full load of the blocks. Face blocks were not considered in the analyses.

The results show that in general support categories 2 to 4 are sufficient to support all rock loads produced by block failure. Restrictively it has to be mentioned that few blocks could no be adequately supported by pattern bolting due to their elongated shape and/or small size. Those few blocks will require additional spot bolting.

The following table 34 summarizes the results of the support analyses considering block failure.

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No.	Trend/ Plunge	Discont. Comb.	Wedge	Factor of Safety	Factor of Safety resulting from Support Category 2	Factor of Safety resulting from Support Category 3	Factor of Safety resulting from Support Category 4
Inlet Section: 0+000 to 2+168							
2		125	Upper Left wedge [5]	0,28	1,19	-	-
3		125	Upper Right wedge [8]	0,00	1,01	-	-
4		135	Upper Right wedge [8]	0,00	0,94	0,94	1,40
5		145	Upper Right wedge [8]	0,00	0,94	0,94	1,27
6		134	Upper Right wedge [6]	0,05	0,85	0,85	1,20
7		124	Upper Right wedge [6]	0,05	0,93	0,93	1,27
8		123	Upper Right wedge [6]	0,05	0,91	0,91	1,17
9		123	Upper Left wedge [7]	0,05	1,05	-	-
10		124	Upper Left wedge [7]	0,05	0,96	1,15	-
11		134	Upper Left wedge [7]	0,05	0,97	1,34	-
12		145	Upper Left wedge [5]	0,06	0,99	1,15	-
13		135	Upper Left wedge [5]	0,10	0,98	1,21	-
Central Section I: 2+168 to 2+868							
14		123	Upper Left wedge [7]	0,05	0,83	0,88	1,18
15		124	Upper Left wedge [7]	0,05	0,82	0,88	1,21
16		125	Upper Left wedge [7]	0,05	1,08	-	-
17		134	Upper Left wedge [7]	0,05	0,73	0,75	1,10
18		145	Upper Right wedge [6]	0,05	0,89	0,89	1,15
19	178/0	135	Upper Right wedge [6]	0,05	1,02	-	-
20		135	Upper Left wedge [7]	0,05	1,04	-	-
21		125	Upper Right wedge [6]	0,05	1,07	-	-
22		134	Upper Right wedge [6]	0,05	0,92	1,04	-
23		145	Upper Left wedge [7]	0,05	0,90	1,12	-
24		124	Upper Right wedge [6]	0,05	1,02	-	-
25		123	Upper Right wedge [6]	0,05	1,03	-	-
Central Section II: 2+868 to 6+944							
26		123	Roof wedge [8]	0,00	4,88	-	-
27		124	Roof wedge [8]	0,00	2,48	-	-
28		125	Roof wedge [8]	0,00	1,39	-	-
29		123	Upper Left wedge [7]	0,05	0,69	0,74	1,05
30		124	Upper Left wedge [7]	0,05	0,67	0,72	1,07
31		125	Upper Left wedge [7]	0,05	0,85	1,03	-
32		145	Upper Right wedge [6]	0,05	0,88	0,88	1,15
33	178/1	134	Upper Left wedge [7]	0,05	0,71	0,77	1,13
34		135	Upper Right wedge [6]	0,05	0,89	1,04	-
35		135	Upper Left wedge [7]	0,05	0,71	1,14	-
36		134	Upper Right wedge [6]	0,05	0,89	1,01	-
37		145	Upper Left wedge [7]	0,05	0,89	1,10	-
38		125	Upper Right wedge [6]	0,05	1,05	-	-
39		124	Upper Right wedge [6]	0,05	0,97	1,07	-
40		123	Upper Right wedge [6]	0,05	0,96	1,03	-
Central Section III: 6+944 to 8+415							
41		123	Upper Left wedge [8]	0,00	0,78	0,85	1,19
42		125	Upper Left wedge [8]	0,00	0,89	0,92	1,29
43		124	Upper Left wedge [8]	0,00	0,83	0,90	1,23
44		134	Upper Left wedge [7]	0,05	0,80	0,86	1,24
45		135	Upper Left wedge [7]	0,05	0,91	1,04	-
46	195/1	145	Upper Right wedge [6]	0,05	1,04	-	-
47		145	Upper Left wedge [7]	0,05	0,87	1,00	-
48		123	Upper Right wedge [5]	0,06	1,09	-	-
49		135	Upper Right wedge [6]	0,05	1,03	-	-
50		124	Upper Right wedge [5]	0,09	1,10	-	-
51		125	Upper Right wedge [5]	0,28	1,20	-	-
52		134	Upper Right wedge [6]	0,05	0,96	0,99	1,44
Central Section IV: 8+415 to 8+865							
55		125	Upper Left wedge [8]	0,00	1,02	-	-
56		125	Upper Right wedge [5]	0,28	1,21	-	-
57		124	Upper Left wedge [8]	0,00	0,91	0,98	1,34
58		134	Upper Left wedge [8]	0,00	0,75	0,82	1,17
59		135	Upper Left wedge [8]	0,00	0,83	0,89	1,22
60	235/1	145	Upper Left wedge [7]	0,05	0,80	0,85	1,26
61		123	Upper Left wedge [6]	0,05	0,81	0,84	1,16
62		123	Upper Right wedge [7]	0,05	1,12	-	-
63		134	Upper Right wedge [5]	0,06	1,09	-	-
64		135	Upper Right wedge [5]	0,10	1,10	-	-
65		145	Upper Right wedge [6]	0,05	0,99	0,99	
66		124	Upper Right wedge [5]	0,09	1,02	-	-
Outlet Section 8+865 to 10+364							
67		124	Roof wedge [7]	0,05	0,05	0,05	0,05
68		125	Roof wedge [7]	0,05	0,05	0,05	0,05
69		123	Roof wedge [8]	0,00	0,00	0,00	7,01
70		135	Roof wedge [7]	0,05	0,05	0,05	1,77
72		134	Roof wedge [7]	0,05	2,79	-	-
73		135	Upper Left wedge [8]	0,00	0,57	0,57	0,77
74		134	Upper Left wedge [8]	0,00	0,50	0,50	0,69
75		123	Upper Left wedge [6]	0,05	0,50	0,50	1,08
78	235/-4	125	Upper Left wedge [8]	0,00	0,99	1,04	-
79		124	Upper Left wedge [8]	0,00	0,65	0,72	1,08
80		145	Upper Right wedge [6]	0,05	1,05	-	-
81		134	Upper Right wedge [5]	0,06	0,74	0,99	1,36
82		124	Upper Right wedge [5]	0,09	0,95	1,13	-
83		135	Upper Right wedge [5]	0,10	0,79	0,98	1,43
84		125	Upper Right wedge [5]	0,28	1,27	-	-
85		145	Upper Left wedge [7]	0,05	0,74	2,79	-
86		123	Upper Right wedge [7]	0,05	0,82	0,89	1,14

Table 34: Analyses of the support requirements for block failure

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7 CONCLUSIONS

A double shell lining system consisting of an initial support and a final lining (cast in place) separated by a waterproofing system has been investigated. The waterproofing membrane system prevents seepage between inside and outside of the Diversion Tunnel and acts as a suitable corrosion protection for the final lining. The final lining will be installed once tunnel excavation is completed. High pressure interface grouting prevents tensile stresses mobilized through internal water pressure. Thus cracking of the lining concrete is avoided and water seepage along the outside surface of the tunnel is prevented.

Using a comprehensive stress analysis it has been proven that the proposed tunnel lining system is capable of adequately supporting all loads including those imparted on the lining from long-term effects.

* * *

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PR-00-4002, Rev 0
Structural Design Analysis for the Dewatering Shafts

ONTARIO POWER GENERATION
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NIAGARA TUNNEL FACILITY PROJECT

STRUCTURAL DESIGN ANALYSIS FOR THE DEWATERING SHAFTS

April 2005

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1 INTRODUCTION

This report provides a stability analysis for the proposed Dewatering Shafts for the Diversion Tunnel.

2 REFERENCES

2.1 Documents

[1] Ontario Power Generation (2005): Niagara Tunnel Facility Project, Geotechnical Data Report, Volume 1 to 12.

[2] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Owner´s Mandatory Requirements, Invitation to Submit Design/Building Proposals, App. 1.1.

[3] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Geotechnical Baseline Report, part of: Invitation to Submit Design/Building Proposals, App. 5.4.

[4] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Geotechnical Baseline Report, GBR-B.

[5] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Design Basis and Method Statements.

[6] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Structural Design Analysis for the Diversion Tunnel

2.2 Drawings

(1) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Plan and Longitudinal Section (PD-01-1001, PA-01-1001)

(2) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Geotechnical Longitudinal Section (PD-01-1002, PA-01-1002)

(3) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Dewatering System, Plan, Sections and Details (PD-01-1022, PA-01-1022)

2.3 Codes and Standards

[a] Canadian Standard Association, S16-01: Limit States Design of Steel Structures, December 2001.

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[b] Canadian Standard Association, A23.3-94: Design of Concrete Structures, December 1994 (reaffirmed December 2000).

[c] National Building Code of Canada (1995)

[d] The Building Code of Ontario (1997)

3 DEWATERING SHAFT SYSTEM

5 dewatering shafts will be located on the centreline of the tunnel at approx. km 8.9 measured from the intake of the Diversion Tunnel such, that the Owner's pumping equipment can be lowered into the tunnel. Each shaft is circular and drilled with a minimum diameter of 1.05 m in overburden and 0.915 m in rock to accommodate a min. 750 mm steel pipe as shown on the Proposal Drawings. The annulus around the pipe is grouted to prevent water seepage between different geological formations along the outside of the pipe.

4 GEOLOGY

Twelve stratigraphic formations are identified in the project area. They consist of sequences of sedimentary rock of Ordovician to Devonian age. These are namely the Guelph, Lockport, De Cew, Rochester, Irondequoit, Reynales, Neahga, Grimsby, Power Glen, Whirlpool and Queenston formations. Some of these formations are only a few meters thick. The shafts intersect eleven of the geological formations. The uppermost Guelph formation will not be affected by the construction of dewatering shafts. The lithological spectrum of the encountered formation covers limestone, dolostone, sandstone and shale (see chapter 3 of [5] for details).

5 GEOTECHNICAL INPUT PARAMETERS

The input parameters used in the analysis are in accordance with the evaluated calculation parameters included in the "Structural Design Analysis for the Diversion Tunnel" [6].

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6 GROUNDWATER

Three major groundwater flow regimes are encountered in the rock formations of the project area. The uppermost occurs in the Lockport and De Cew formations. This aquifer is connected to the surface water and shows the highest permeability of the entire sequence. A second flow regime is associated with the low permeability strata of the Rochester, Neahga, Power Glen and Queenston formations, forming a system of aquitards. A third flow regime is associated with the deeper permeable strata of the Irondequoit, Reynales, Thorold, Grimsby, Whirlpool and upper Queenston formations. These strata form deep lying aquifers. Groundwater elevations are reported to vary significantly from stratum to stratum and from location to location. Some groundwater heads encountered showed artesic behaviour with pressure heads above ground elevation.

7 EXCAVATION METHOD AND SUPPORT MEASURES

The dewatering shafts are drilled by raiseboring technique. In the overburden soil, large diameter holes are bored and supported by steel casing. For each shaft a pilot bore is lowered through the rock formations into the Diversion Tunnel. There a cutter head of suitable size is mounted on the drill rod and lifted to enlarge the pilot hole in upwards direction. The borehole section through the rock formations is considered to be stable without support until raiseboring is finished, the steel pipe installed for permanent support and the annulus filled with mortar grout.

8 CALCULATION MODEL

8.1 Design Loads

8.1.1 Structural and Dead Loads

Dead load of structural and non-structural elements is based on unit weight and computed volume of the materials. The following unit weights are used:

Unreinforced Concrete	24.0 kN/m^3
Structural Steel	78.5 kN/m^3
Rock / Soil	see [6]
Water	10.0 kN/m^3

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8.1.2 Hydrostatic Pressure

It has to be distinguished between the internal hydrostatic pressure and the external ground water pressure.

The applicable "internal water pressure" and "external water pressure" are shown in the geotechnical longitudinal section (2) and will be treated as basis for subsequent analysis.

8.1.3 Seismic Loads

Underground structures are generally less sensitive to seismic effects than surface structures, therefore no seismic loads are considered for preliminary design. At detail design stage a seismic analysis based on actual data will be carried out.

8.1.4 Long-term Rock Squeeze

8.1.4.1 Time Dependent Deformation Behaviour

It has to be emphasized that a time dependent deformation phenomenon is assumed for the Niagara area and described as **"rock squeeze"** and **"swelling"**. It is well recognized that these processes are interrelated, and the individual effects of each are difficult to distinguish. Both effects can continue for many years [4].

Squeeze is usually associated with the long-term creep behaviour of rock, initiated by the relief of high in situ horizontal stresses. There is a well documented history of rock 'squeeze' affecting surface excavations in the upper dolostones and dolomitic limestones. This squeeze, however, may include the effects of swelling of the shale interbeds in these rock units [4].

8.1.4.2 Swelling Behaviour

Swelling to be assumed for design purposes in the Queenston Formation is given in the Owner's Mandatory Requirements [2]. There is no available data regarding suppression of swell potential for the other formations.

Generally swelling involves a volume increase and is initiated by the relief of the high in situ stresses. However, swelling also requires the presence of fresh water. The process is associated with ionic diffusion of salts from the connate pore water in the rock. The swelling phenomenon can be suppressed under applied stresses.

For swelling to occur, the necessary conditions are:

- the relief of initial stresses, which serves as an initiating mechanism,
- the accessibility to fresh water,

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- an outward salt concentration gradient from the pore fluid of the rock to the ambient fluid.

According to the Owner´s Mandatory Requirements [2] a maximum swelling pressure of 5 MPa has to be applied to the calculations.

8.1.4.3 Rock Squeeze Behaviour

The rock expansion upon unloading observed in previous constructions [4] is not necessarily associated with the swelling of clay minerals, although in the presence of swelling clay minerals the time dependent deformation is generally greater.

Rock squeeze is defined as substantial time-dependent deformation in the vicinity of the tunnel as a result of load introduced by redistribution of stresses adjacent to the excavated tunnel.

8.1.5 Load Combinations

For load combinations not including earthquake, factored loads are determined in accordance with CSA S16-01 [a]. Herein the effect due to specified loads is multiplied by a load factor α. A load combination factor ψ and an importance factor γ is also considered:

$$\alpha_D D + \gamma \psi \left(\alpha_L L + \alpha_T T \right)$$

where:

- Load factors α for:

  - Dead loads: $\alpha_D = 1.25$
  - Live loads: $\alpha_L = 1.5$
  - Temperature loads: $\alpha_T = 1.25$

- Load combination factor ψ:

  - $\psi = 1.00$ when L or T is considered
  - $\psi = 0.7$ when a combination of L and T is considered.

- The importance factor is equal to 1.0 for all load combinations.

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8.2 Shaft Design

8.2.1 Steel Design

Steel is designed according to CSA S16-01 [a]:

- stress analysis with ø f = (α_L N) / A
- max. allowable unfactored radial pressure:

$$p_k = \frac{E}{4\left(1-\nu^2\right)}\frac{s^3}{r^3}$$

where
- s… required wall thickness [mm]
- r… radius of pipe [mm]
- E… modulus of elasticity [N/mm²]
- ν… Poisson´s ratio

- allowable factored radial pressure: $p_{all} = p_K / \Phi_B$

8.2.2 Design of Annular Grout

For loads not associated with water pressure, the annular grout ring is considered to contribute to the load bearing capacity of the shaft structures in addition to the steel pipes. Similar to unreinforced concrete the safety factor f_{NM} is used for the assessment of load bearing contribution of the annular grouting mortar. f_{NM} is the ratio of the design normal force N_{sd} and the resisting normal force N_{rd}, considering the calculated eccentricity $e = M_{sd} / N_{sd}$ of load reaction forces in the grouting mortar.

The minimum safety factors f_{NM} are listed as calculation results in chapter 5.

The following formula is used for the design:

$$N_{rd} = \phi_c \cdot f_c' \, d\left(1-2\frac{e}{d}\right)$$

N_{rd} is the resisting normal force with
- b = 1 m
- d …thickness of annular grout
- e …eccentricity (e = M/N)

The resistance factor of concrete Φ_c is assumed to be 0.60 according to CSA A23.3-94 [b]. The required design factor $f_{NM} = N_{sd} / N_{rd}$ for design check of the lining is:

$f_{NM} \geq 1$.

Herein the computed structural forces N will be multiplied by a factor $\alpha_L = 1.5$ according to CSA A16-01 [a] in order to get the design structural forces N_{sd}.

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In addition the maximum eccentricity is controlled by

$e / h_w \leq 0.33$.

h_w represents the structural height of the annular ring.

8.2.3 Safety factors

The following factors of material resistance are selected:

concrete $\Phi_c = 0.6$
steel $\Phi_s = 0.9$
buckling $\Phi_B = 2.5$

The load factors are generally $\alpha_L = 1.5$ according to CSA A16-01 [a]. Reduced factors are applied solely for following extraordinary load case:

a) worst-case scenarios of a groundwater pressure or a swelling pressure on the lining in combination with an unfrequent temporary operation state "Dewatering of Tunnel". Factors for such a load-combination "worst case – temporary state" have been assumed to be:
load factor $\alpha_L = 1.0$

9 DESIGN ANALYSIS RESULTS

Linear elastic analyses are adequate for static loading of the tunnel lining from self weight, geo- hydrostatic, temperature, shrinkage, and live loads.

9.1.1 Geometry

The cross section of the shaft is illustrated in (4). The inner diameter is 0.75 m.

9.1.2 Performed Calculations and Results

The following load cases are considered. The detailed results, plots and listings, are shown in the Appendices.

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	Load Case		Required Steel Wall Thickness [mm]
1	Swelling in Queenston without Internal Water Pressure	Worst Case	23
2	Swelling in Queenston & Internal Water Pressure	Standard Load Case	23
3	Swelling in Lockport without Internal Water Pressure	Worst Case	18
4	Swelling in Lockport & Internal Water Pressure	Standard Load Case	19
5	Internal Water Pressure	Standard Load Case	2.5
6	Rock Squeeze Queenston	Worst Case	29

Table 1: Results of Calculations

The Steel Lining of the shaft has to be constructed with a thickness of minimum 20 mm in the upper Geological Formations (Overburden and Lockport). Within the Queenston Formation the wall thickness has to be increased to 30 mm.

10 CONCLUSIONS

The structural design analysis has proven that the proposed shaft lining system is capable of adequately supporting all loads including those imparted on the lining from long-term effects.

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11 APPENDICES

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Appendix 1: Calculations

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Steel pipe dia 750 mm

$f = 420\ N/mm^2$

$\phi = 0.9$

1) Swelling in Queenston - Worst case scenario : $5\ N/mm^2$; $\alpha_L = 1.0$

Axial force : $N = P \cdot r = 5000\ kN/m^2 \cdot 0.375\ m = 1875\ kN$

$\phi f \geq \frac{N \times \alpha_L}{A}$ $\qquad A = l \cdot t$; $l = 1000\ mm$

$t_{min} \geq \frac{N \cdot \alpha_L}{\phi f \times 1000} = \frac{1875 \times 10^3 \times 1.0}{0.9 \times 420 \times 1000} = 4.96\ mm \doteq \underline{5\ mm}$

2) Swelling in Queenston + Internal water pressure

$P_{sw} = 5.N/mm^2$; $P_{IWP} = 1.4\ N/mm^2$; $\alpha_L = 1.5$

Axial force. $N = (P_{sw} + P_{IWP}) \cdot r = (5 - 1.4) \times 0.375 = 1350\ kN$

$\phi f \geq \frac{N \times \alpha_L}{A}$

$t_{min} \geq \frac{N \times \alpha_L}{\phi \times f \times 1000} = \frac{1350 \times 10^3 \times 1.5}{0.9 \times 420 \times 1000} = 5.35\ mm = \underline{5.5\ mm}$

3) Swelling in Lock Point - worst case scenario :

$P_{sw} = 2.5\ N/mm^2$; $\alpha_L = 1.0$

Axial force : $N = P_{sw} \times r = 2500\ kN/m^2 \times 0.375 = 937.5\ kN$

$t_{min} = \frac{N \times \alpha_L}{\phi \times f \times 1000} = \frac{937.5 \times 10^3 \times 1.0}{0.9 \times 420 \times 1000} = 2.48\ mm = \underline{2.5\ mm}$

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4) Swelling in Lock Pont + Internal water pressure:

$P_{SW} = 2.5\ N/mm^2$, $P_{IWP} = -0.5\ N/mm^2$; $\alpha_L = 1.5$

Axial force: $N = (P_{SW} + P_{IWP}) \times r = (2500 - 500) \times 0.375 = 750\ kN$

$$\phi_f \geq \frac{N \times \alpha_L}{A} \qquad A = L \times t \ ; \ L = 1000\ mm$$

$$t_{min} \geq \frac{N \times \alpha_L}{\phi_f \times 1000} = \frac{750 \times 10^3 \times 1.5}{0.9 \times 420 \times 1000} = 2.97\ mm \doteq \underline{3.0\ mm}$$

5) Internal water pressure (pipes beding is neglected)

$P_{IWP} = 1.4\ N/mm^2$ $\alpha_L = 1.5$

Axial force: $N = P_{IWP} \times r = 1400 \times 0.375 = 525\ kN$

$$\phi_f \geq \frac{N \times \alpha_L}{A} \qquad A = l \times t \ ; \ l = 1000\ mm$$

$$t_{min} \geq \frac{N \times \alpha_L}{\phi_f \times 1000} = \frac{525 \times 10^3 \times 1.5}{0.9 \times 420 \times 1000} = 2.08\ mm \doteq 2.5\ mm$$

6) In situ stress, σ_H Queenston

$\sigma_H = \sigma_V \cdot k_0$ $\qquad \sigma_V = h \times \rho = 128\ m \times 26\ kN/m^3 = 3328\ kN/m^2$

$k_0 = 4.5$

$\sigma_H = 3328 \times 4.5 = 14\,976\ kN/m^2$

Load split factor:

Steel pipe: Wall thickness ≈ 25 mm

$E = 200$ GPa

Grout: thickness ≈ 57 mm

$E = 25$ GPa

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Dewatering Shafts

Load split factor: $\frac{25 \times 100}{57 \times 25} \approx 3.5$

Load carried out by grout: $\frac{14979}{3.5} = 4279\ kN/m^2$

Load on the steel pipe: $14979 - 4279 = 10\,697\ kN/m^2$

Axial force: $N = 10\,697 \times 0.375 = 4\,011\ kN$

$\phi_f \geq \frac{N \cdot \alpha_L}{A}$ $\qquad A = l \cdot t$; $l = 1000\ mm$

$t_{min} \geq \frac{N \times \alpha_L}{\phi_f \times 1000} = \frac{4011 \times 10^3 \times 1.0}{0.9 \times 420 \times 1000} = 10.6\ mm \doteq \underline{\underline{11\ mm}}$

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CONSULTING ENGINEERS	Project:	OPG - Diversion Tunnel	Pre.:	Jiricny
	Object:	Dewatering Shafts	Checked:	Marcher
	Title:	Load case 1; α_L = 1.0	Datum:	Apr.05

BUCKLING OF CIRCULAR SHAPED MEMBERS:

$$p_K = \frac{E}{4 \times (1 - \nu^2)} \times \frac{s^3}{r^3}$$

Diameter:	D =	760	mm
Elastic modulus:	E =	200000	N/mm^2
Poison constant :	n =	0.3	
Required Wall Thickness:	s =	**23**	**mm**
Radius:	r =	368.7	mm
Safety Factor	α_B =	2.5	

Unfactored Radial Pressure:	p_k =	12.50	N/mm^2
Factored Radial Pressure:	p_{all} =	**5.00**	**N/mm^2**

CONSULTING ENGINEERS	Project:	OPG - Diversion Tunnel	Pre.:	Jiricny
	Object:	Dewatering Shafts	Checked:	Marcher
	Title:	Load case 2; α_L = 1.5	Datum:	Apr.05

BUCKLING OF CIRCULAR SHAPED MEMBERS:

$$p_K = \frac{E}{4 \times (1 - \nu^2)} \times \frac{s^3}{r^3}$$

Diameter:	D =	760	mm
Elastic modulus:	E =	200000	N/mm^2
Poison constant :	n =	0.3	
Required Wall Thickness:	s =	**23**	**mm**
Radius:	r =	368.5	mm
Safety Factor	α_B =	2.5	

Unfactored Radial Pressure:	p_k =	13.50	N/mm^2
Factored Radial Pressure:	p_{all} =	**5.40**	**N/mm^2**

CONSULTING ENGINEERS				
	Project:	OPG - Diversion Tunnel	Pre.:	Jiricny
	Object:	Dewatering Shafts	Checked:	Marcher
	Title:	Load case 3; α_L = 1.0	Datum:	Apr.05

BUCKLING OF CIRCULAR SHAPED MEMBERS:

$$p_K = \frac{E}{4 \times (1 - \nu^2)} \times \frac{s^3}{r^3}$$

Diameter:	D =	760	mm
Elastic modulus:	E =	200000	N/mm^2
Poison constant :	n =	0.3	
Required Wall Thickness:	s =	**18**	**mm**
Radius:	r =	371.0	mm
Safety Factor	α_B =	2.5	

Unfactored Radial Pressure:	p_k =	6.25	N/mm^2
Factored Radial Pressure:	p_{all} =	**2.50**	**N/mm^2**

CONSULTING ENGINEERS	Project:	OPG - Diversion Tunnel	Pre.:	Jiricny
	Object:	Dewatering Shafts	Checked:	Marcher
	Title:	Load case 4; α_L = 1.5	Datum:	Apr.05

BUCKLING OF CIRCULAR SHAPED MEMBERS:

$$p_K = \frac{E}{4 \times (1 - \nu^2)} \times \frac{s^3}{r^3}$$

Diameter:	D =	760	mm
Elastic modulus:	E =	200000	N/mm^2
Poison constant :	n =	0.3	
Required Wall Thickness:	s =	**19**	**mm**
Radius:	r =	370.5	mm
Safety Factor	α_B =	2.5	

Unfactored Radial Pressure:	p_k =	7.50	N/mm^2
Factored Radial Pressure:	p_{all} =	**3.00**	**N/mm^2**

CONSULTING ENGINEERS	Project:	OPG - Diversion Tunnel	Pre.:	Jiricny
	Object:	Dewatering Shafts	Checked:	Marcher
	Title:	Load case 6; α_L = 1.0	Datum:	Apr.05

BUCKLING OF CIRCULAR SHAPED MEMBERS:

$$p_K = \frac{E}{4 \times (1 - \nu^2)} \times \frac{s^3}{r^3}$$

Diameter:	D =	760	mm
Elastic modulus:	E =	200000	N/mm^2
Poison constant :	n =	0.3	
Required Wall Thickness:	s =	**29**	**mm**
Radius:	r =	365.6	mm
Safety Factor	α_B =	2.5	

Unfactored Radial Pressure:	p_k =	26.74	N/mm^2
Factored Radial Pressure:	p_{all} =	**10.70**	**N/mm^2**

PR-00-4003, Rev 0
Slope Stability Analysis for Excavations

ONTARIO POWER GENERATION
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NIAGARA TUNNEL FACILITY PROJECT

SLOPE STABILITY ANALYSIS FOR EXCAVATIONS

April 2005

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1 INTRODUCTION

This report provides the stability analysis for excavations including intake channel, outlet canal and the excavation for intake and outlet structure. Since all excavations are situated in the Lockport- DeCew- Rochester geological formations and identical parameters are therefore applicable, only the deepest excavation located at the outlet is analysed in detail.

2 REFERENCES

2.1 Documents

[1] Ontario Power Generation (2005): Niagara Tunnel Facility Project, Geotechnical Data Report, Volume 1 to 12.

[2] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Owner´s Mandatory Requirements, Invitation to Submit Design/Building Proposals, App. 1.1.

[3] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Geotechnical Baseline Report, part of: Invitation to Submit Design/Building Proposals, App. 5.4.

[4] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Geotechnical Baseline Report, GBR-B.

[5] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Design Basis and Method Statements.

2.2 Drawings

(1) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Outlet Canal TBM Launch – Plan and Longitudinal Section (PD-03-1013, PA-03-1013)

(2) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Outlet Structure – Plan and Longitudinal Section(PD-03-1011, PA-03-1011)

2.3 Codes and Standards

[a] National Building Code of Canada (1995)

[b] The Building Code of Ontario (1997)

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3 CALCULATION SECTION

The deepest section close to the Diversion Tunnel is the excavation for the Outlet Structure. The slope has a total height of approx. 40 m. The excavation boundary for the outlet structure consists of a vertical wall of maximum 32 m height. This vertical wall ends with a berm at el.176 m followed by an inclined slope with approx. 8 m height.

4 GEOLOGY

The excavation for the Outlet Structure will be within four stratigraphic formations. They consist of overburden material and the sequences of sedimentary rock: Lockport, De Cew and Rochester.

5 GEOTECHNICAL INPUT PARAMETERS

5.1 Overburden Material

Following geotechnical parameters are applied for the overburden material (based on data presented in [4]):

$\gamma = 20$ kN/m^3

$c = 20$ kN/m^2

$\varphi = 15°$

5.2 Rock Units

The rock mass parameters are based on the Geotechnical Baseline Report [4]. The strength properties to be expected are summarized in Table 1.

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Formation	ϕ [°]	c [MPa]
Lockport	34	7.9
DeCew	34	8.0
Rochester	32	2.5

Table 1: Rock Mass Strength Parameters

The following Rock Properties are selected for the slope stability analysis:

$\gamma = 24$ kN/m^3

$c = 500$ kN/m^2

$\varphi = 34°$

5.3 Bedding Planes and Joints between Rock Formations

Sheared, weak bedding planes exist between rock formations.

The following parameters based on test data presented in the GDR [1] and GBR [4] are used for modelling the planes:

Formation	ϕ [°]	c [MPa]	Orientation with respect to outlet canal
Joints	30	0.0	approx. vertical
Bedding Planes	24	0.45	approx. horizontal

Table 2: Geotechnical Parameters for Bedding Planes and Joints.

During excavation of the canal, wedges may slide into the canal where joints and bedding planes act as sliding planes. The resisting forces on the sliding planes are calculated using friction angle and cohesion of the bedding planes. Full separation of the joints will not be considered. Assuming A_{total} as the total area of the slide plane at the face and $A_{separated}$ as the real joint plane area which takes into account the persistency of joints, the degree of separation κ of the sliding wedge is described by:

$$\kappa = A_{separated} / A_{total}.$$

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Hence the resisting forces of a possible sliding wedge can be analysed using:

$$\kappa \times \text{strength}_{\text{joints}} + (1 - \kappa) \times \text{strength}_{\text{rock}}$$

As a conservative approach $\kappa = 0.7$ is selected (i.e. a persistency of 70 % has been assumed for the subsequent calculations). This results in an equivalent joint strength of:

$c = 150$ kN/m^2

$\varphi = 31.5°$

6 GROUNDWATER

Three major groundwater flow regimes are encountered in the rock formations of the project area. The uppermost occurs in the Guelph, Lockport and De Cew formations. This aquifer is connected to the surface water and shows the highest permeability of the entire sequence of geological formations.

7 EXCAVATION METHOD AND SUPPORT MEASURES

Smooth blasting techniques will be employed to excavate the sides of the outlet canal. Any exposed shaly rocks (e.g. the Rochester Formation) or shale layers which are susceptible to deterioration upon exposure to wetting and drying cycles and large temperature differences will be protected by sealing shotcrete.

The vertical walls to be constructed in the rock units generally will not be supported.

The overburden soils will have a slope inclination of 1:2.

A grouting curtain behind the excavation walls is installed prior to excavation in order to avoid excessive water inflow during construction.

The analysis of slope stability is carried out without modelling any rock support measures.

8 CALCULATION MODEL

The calculations are carried out using the EDP program LARIX-4S.

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8.1 Slope stability analysis according BISHOP/KREY

The used method by Krey is an iteration method, in the course of which the slip circles are varied until the smallest safety is determined. Starting from an inclination of the slip lines to the horizontal of 45 + φ/2, a tangential gradient will be considered in the calculation.

8.2 Slope stability analysis according JANBU

The occurrence of discrete slip surfaces are analyzed using the method according to Janbu. This slip surfaces are determined by the horizontal bedding planes and joints that are almost perpendicular to the bedding plane. For the calculation model, the analytical solution for the sliding of a rigid body on an inclined surface is taken as a basis.

The thickness of ground layers, the distance between the joint planes and the lengths of the slip surfaces are presently not known. The calculations are carried out for the worst case when the slip surface cuts through the base of the slope and start developing behind the grout curtain.

8.3 Load assumptions

Dead loads of structural and non-structural elements are based on unit weight and computed volume of the materials.

Live load is assumed to consist of a mobile crane of total weight of 25 tons loaded on a plane of approx. 2 x 3 m. In the calculations the crane load is modelled as a uniform distributed load of approx. 42 kN/m^2 (placed 2 m from the existing berm).

The Water table is assumed to be at el.178.2 m (based on NF – 42). Due to the grout curtain installed around the outlet canal a lowest ground water elevation of 174.0 m is considered.

The analysis is performed without water pressure inside the Outlet Canal (dewatered).

8.4 Safety Factors

Ultimate Limit State is considered for the Slope Stability Analyses. Due to uncertainties with respect to appropriate strength parameters a conservative approach for the partial safety factors is chosen.

- Active Load factors α for:

  - Dead loads: $\alpha_D = 1.1$
  - Live loads: $\alpha_L = 1.5$

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- Resistance factor γ:

  - γ_cohesion = 1.6
  - γ_friction = 1.25

A model factor γ_mod is introduced in addition:

γ_mod = 1.1 and therefore $R_D / S_D \geq 1.1$ has to be fulfilled.

9 ANALYSIS RESULTS

The following calculations were performed for the slope stability of the overburden material:

Calculation	Slope Inclination	Safety $R_D / S_D \geq 1.1$	Appendix
1	1:1.5	1.25	1.1
2	1:1.5	1.10	1.2
3	1:2	1.35	1.3
4	1:2	1.29	1.4

Table 3: Results of Slope Stability Analysis for the Overburden Material (Bishop/Krey).

Additional calculations are provided for the slope stability of the vertical wall within the rock units:

Calculation	Method	Safety $R_D / S_D \geq 1.1$	Appendix
5	Slip circle (Bishop/Krey)	2.01	2.1
6	Slip circle (Bishop/Krey)	2.12	2.2
7	Slip Planes (Janbu)	1.26	2.3
8	Slip Planes (Janbu)	1.31	2.4
9	Slip Planes (Janbu)	3.07	2.5
10	Slip Planes (Janbu)	2.93	2.6

Table 4: Results of Slope Stability Analysis for the Vertical Rock Wall.

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10 CONCLUSIONS

The analysis proves, that the stability of excavations is guaranteed without installation of support measures, when the proposed geotechnical parameters are applied.

It is recommended to use slope inclinations of maximum 1:2 within the overburden material.

Adopting conservative calculation parameters it can be concluded, that the vertical walls within the rock units are stable. Care has to be taken to ensure, that the rock beyond the excavation limits is not damaged or destabilized by blasting. Any damaged rock has to be removed to ensure stability of the excavation.

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11 APPENDICES

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Appendix 1: Slope Stability Analysis for the Overburden Material

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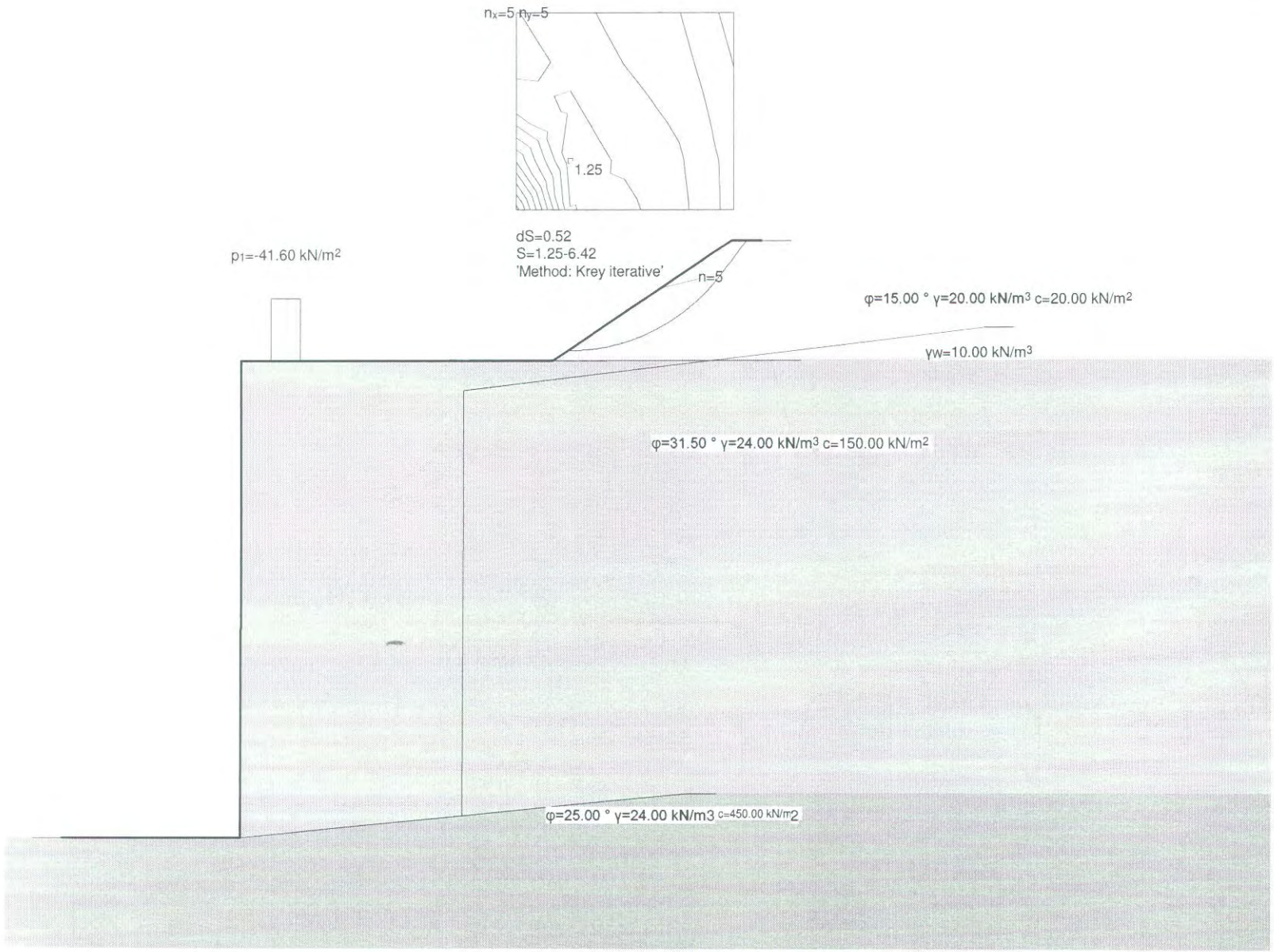
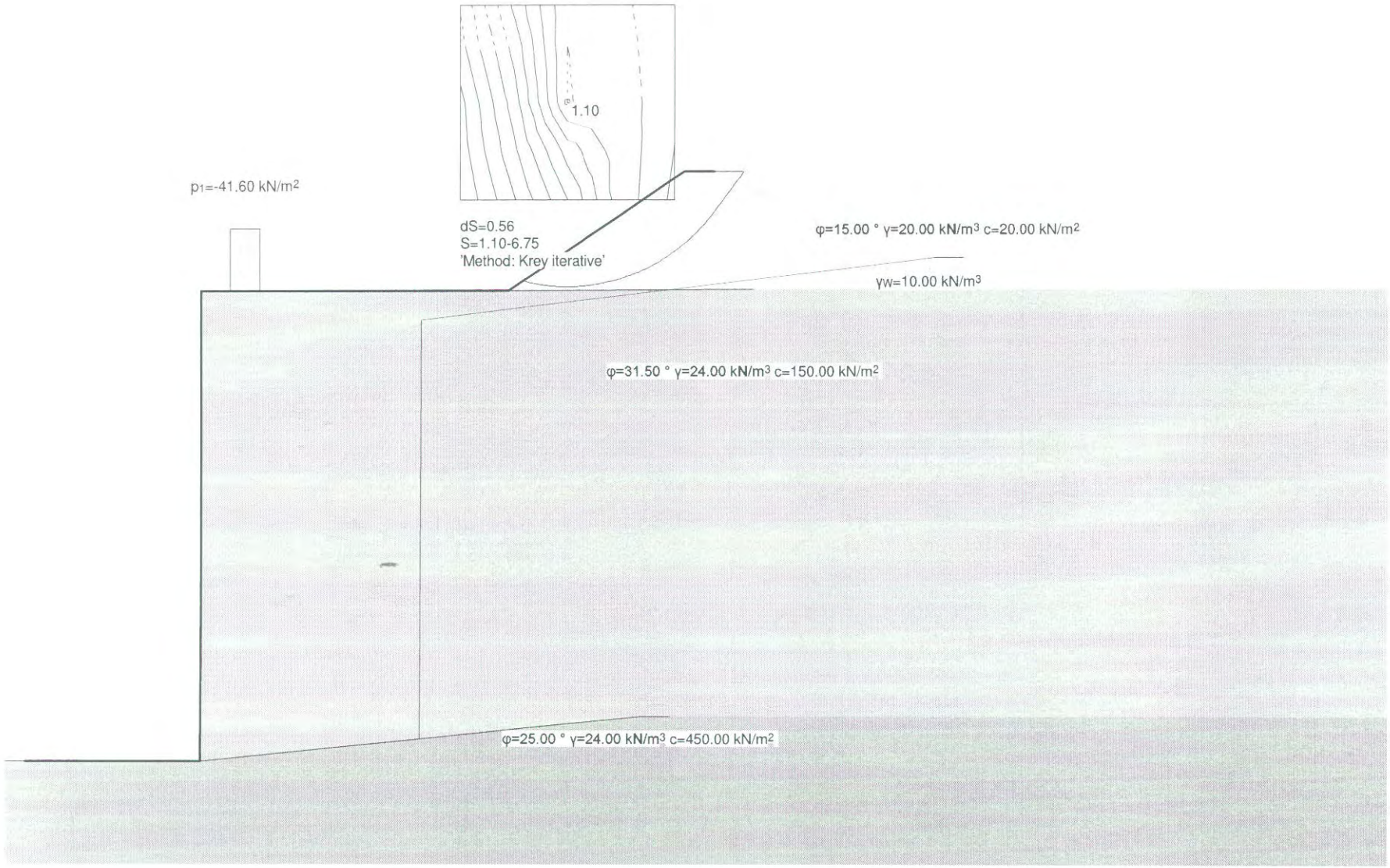
Critical slip surface

Scale 1 :404.0 (-5.38,136.94..78.58,201.03)



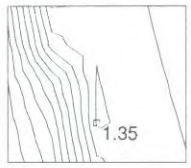
Critical slip surface

Scale 1 :403.0 (-2.94,137.38..90.08,201.32)

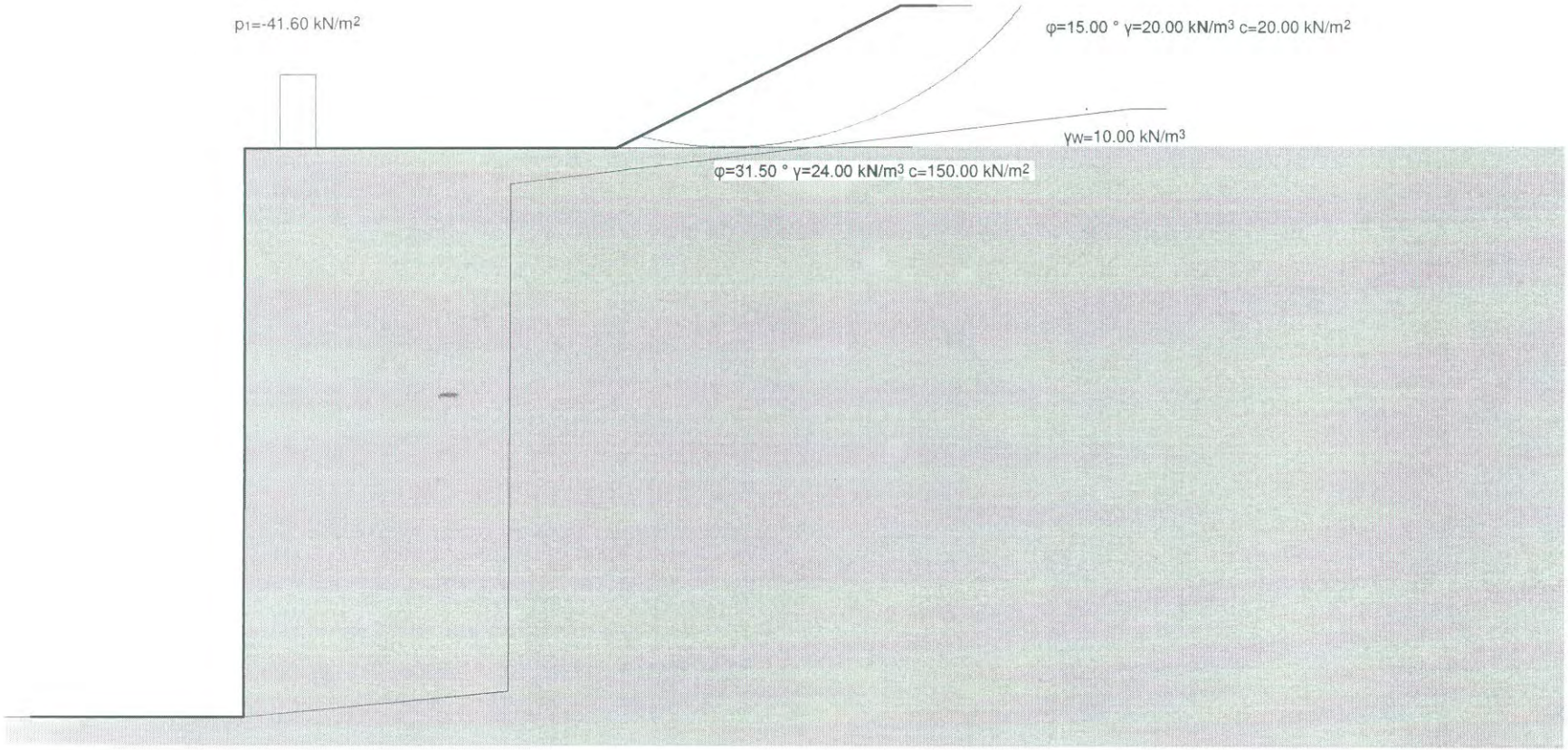


Critical slip surface

Scale 1 :385.9 (-3.11,142.79..83.64,204.00)

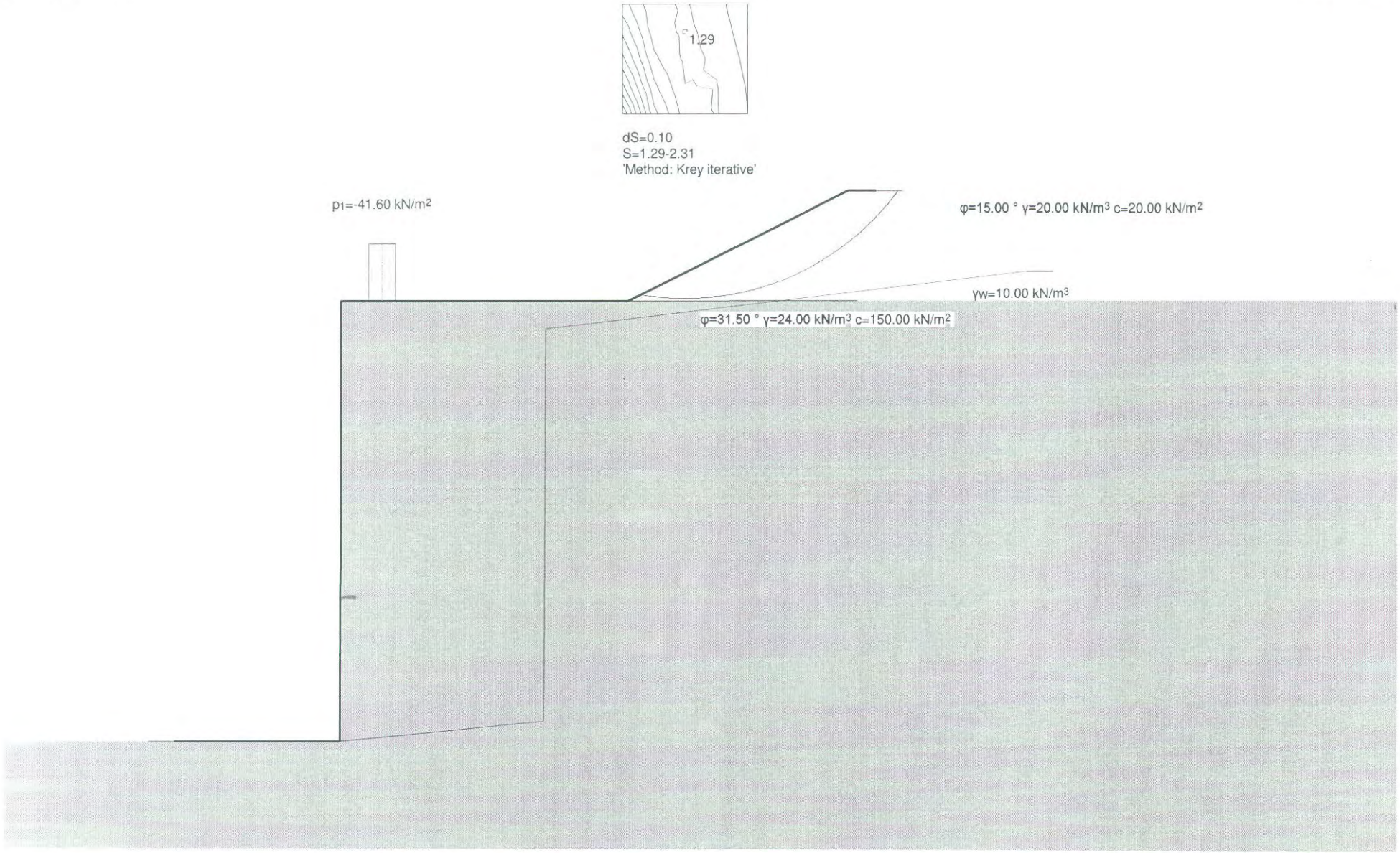


dS=0.35
S=1.35-4.86
'Method: Krey iterative'



Critical slip surface

Scale 1 :396.0



Appendix 2: Slope Stability Analysis for the Rock Formations

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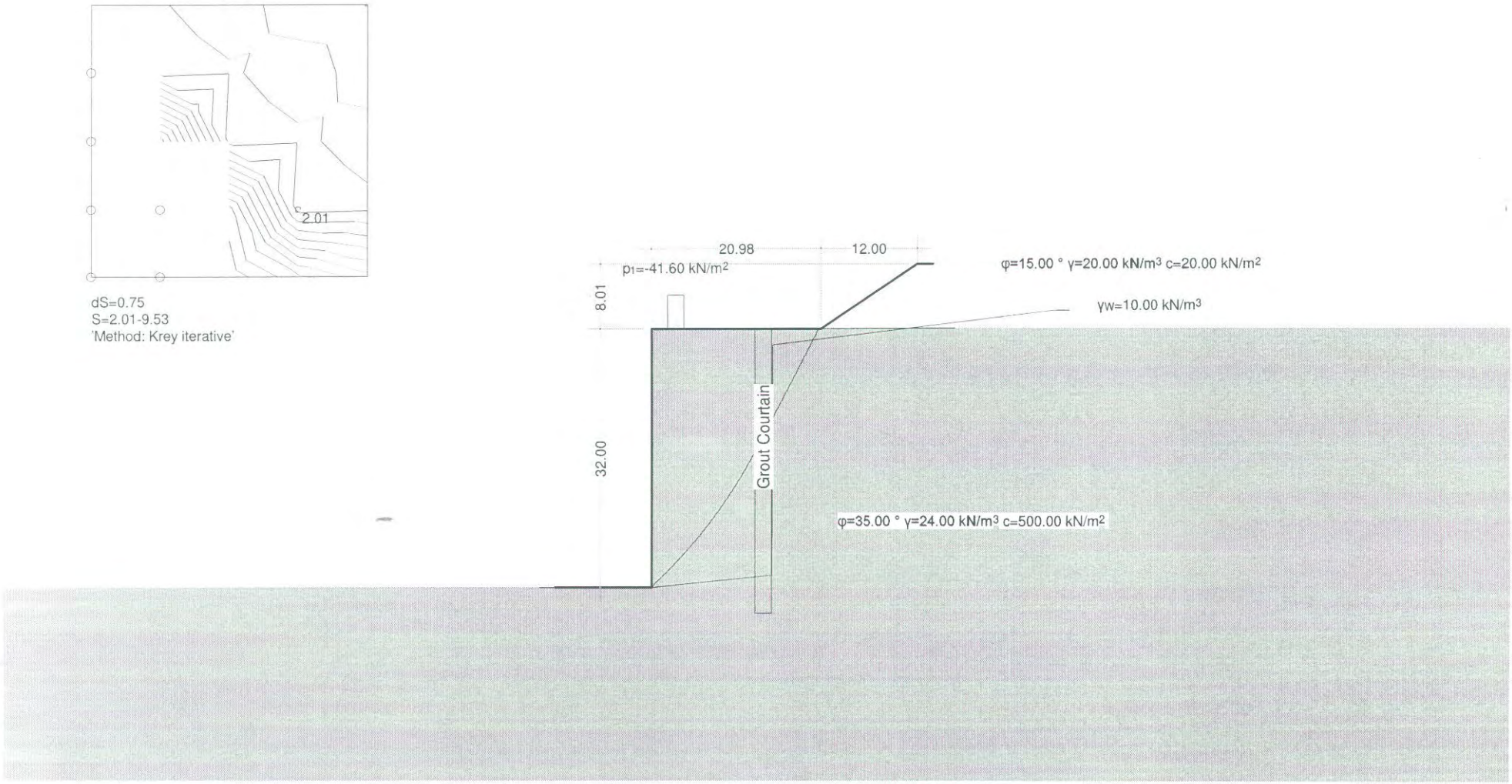
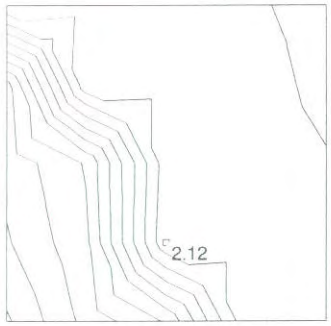
Critical slip surface

Scale 1 :723.8 (-69.87,120.73..115.95,231.32)

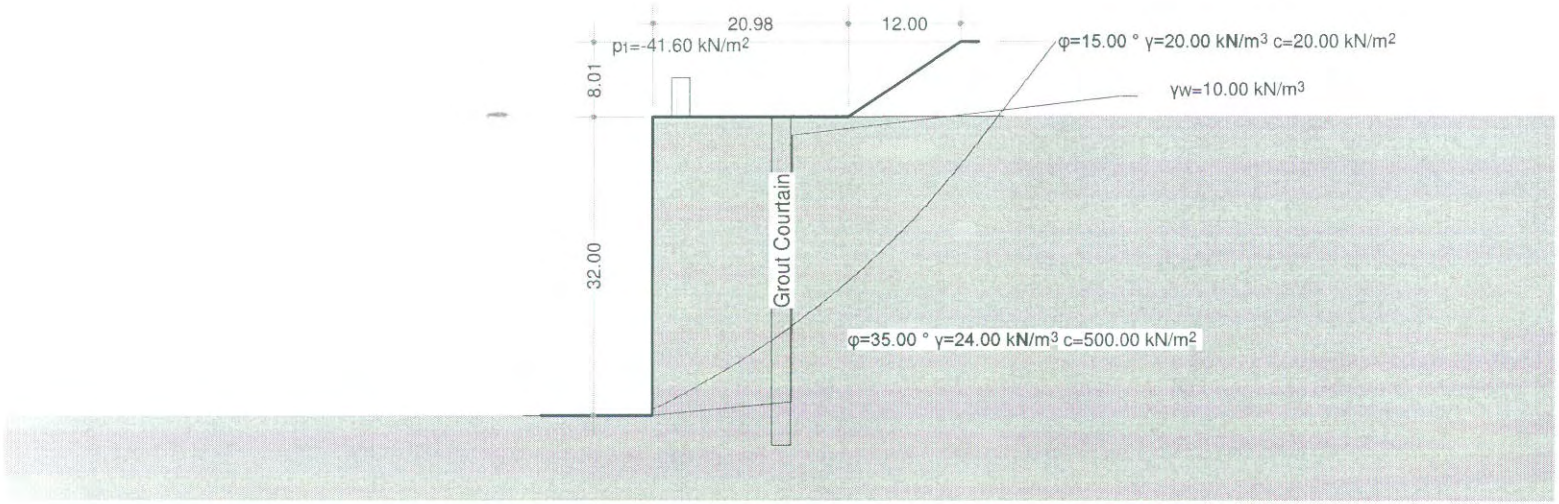


Critical slip surface

Scale 1 :811.5 (-58.80,135.67..105.24,264.41)

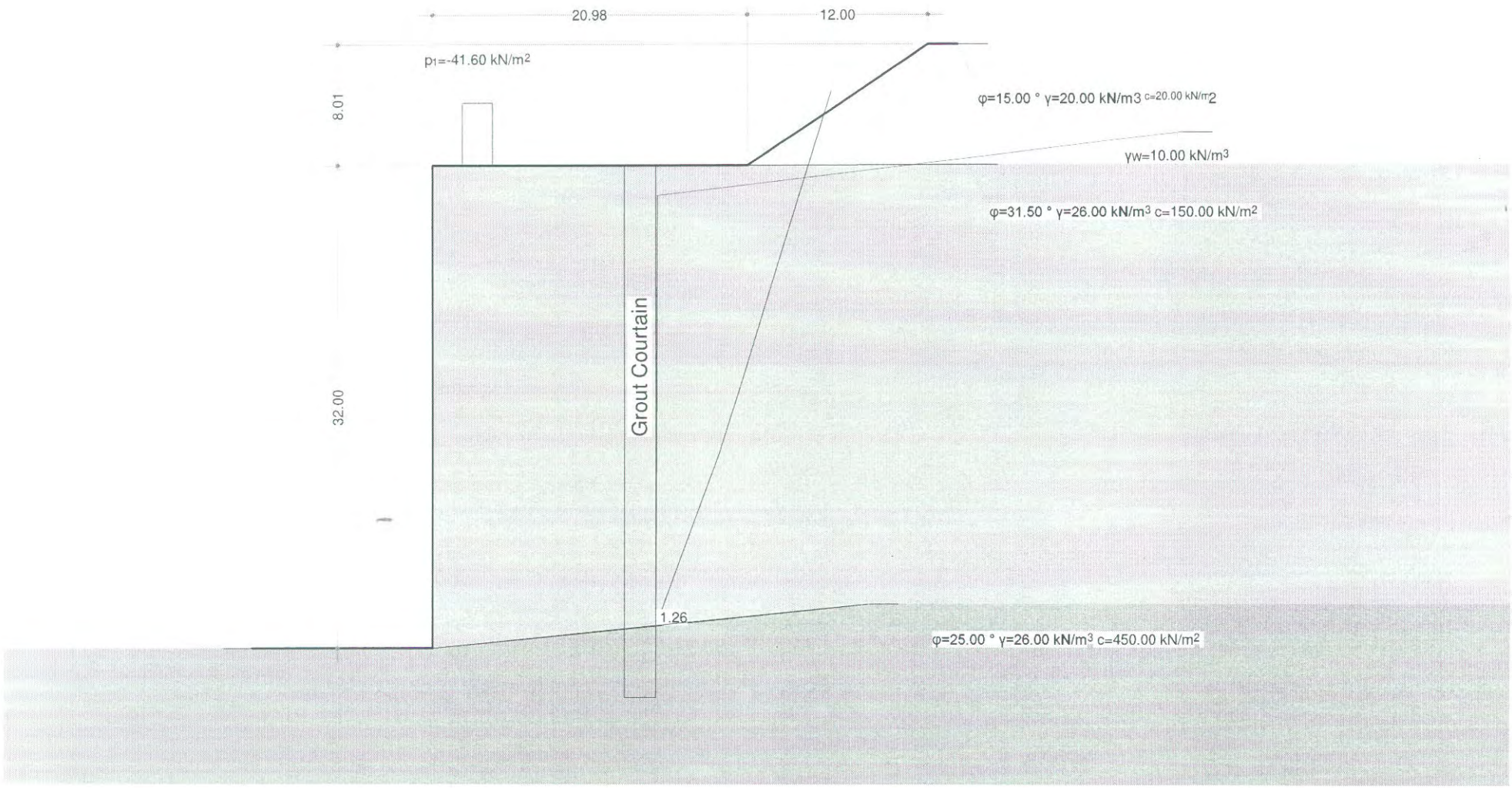


dS=0.51
S=2.12-7.26
'Method: Krey iterative'



Critical slip surface

Scale 1 :387.9 (-18.18,135.32..81.40,194.78)

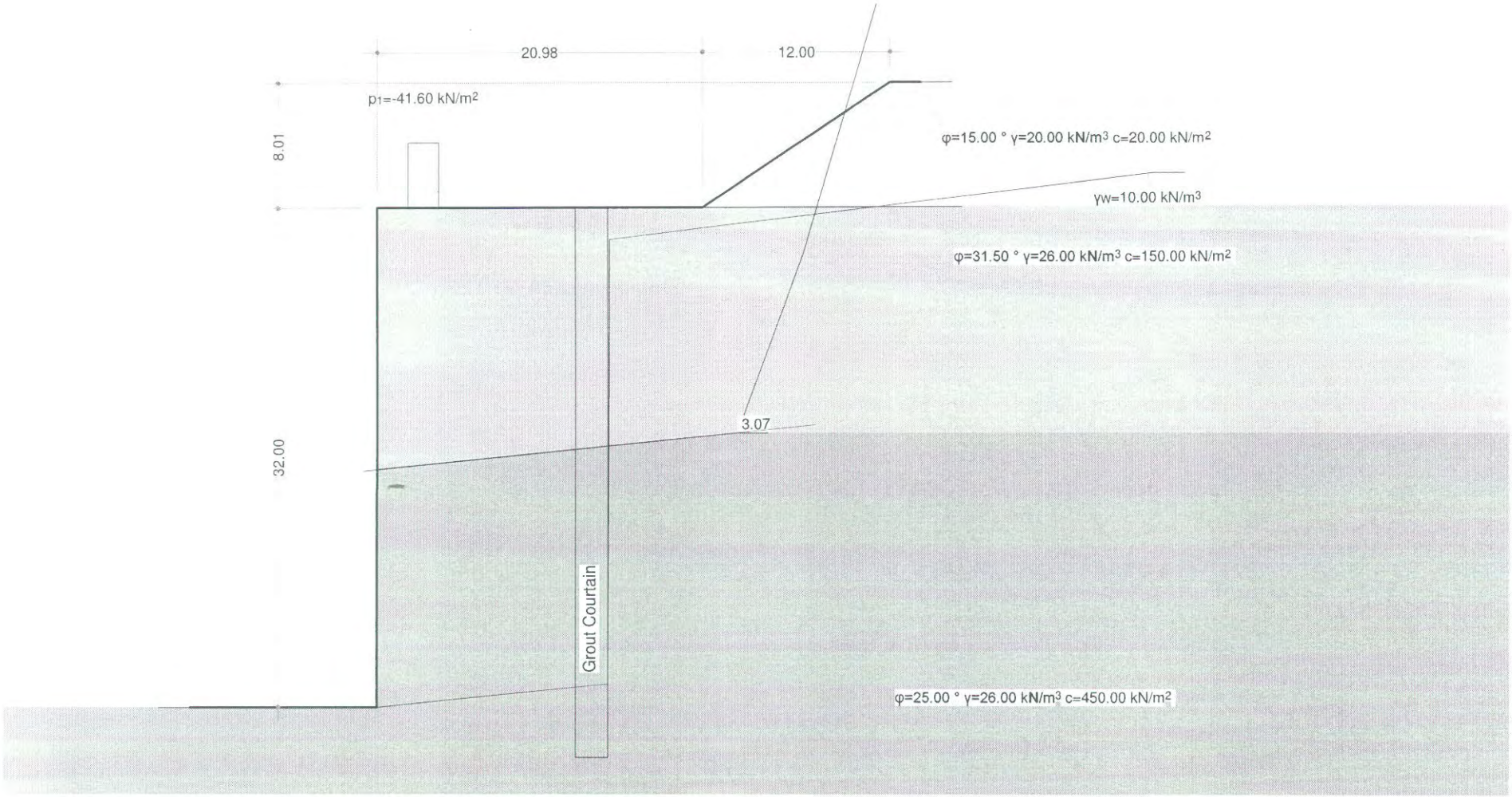


Critical slip surface

Scale 1 :387.9 (-18.18,135.32..81.40,194.78)

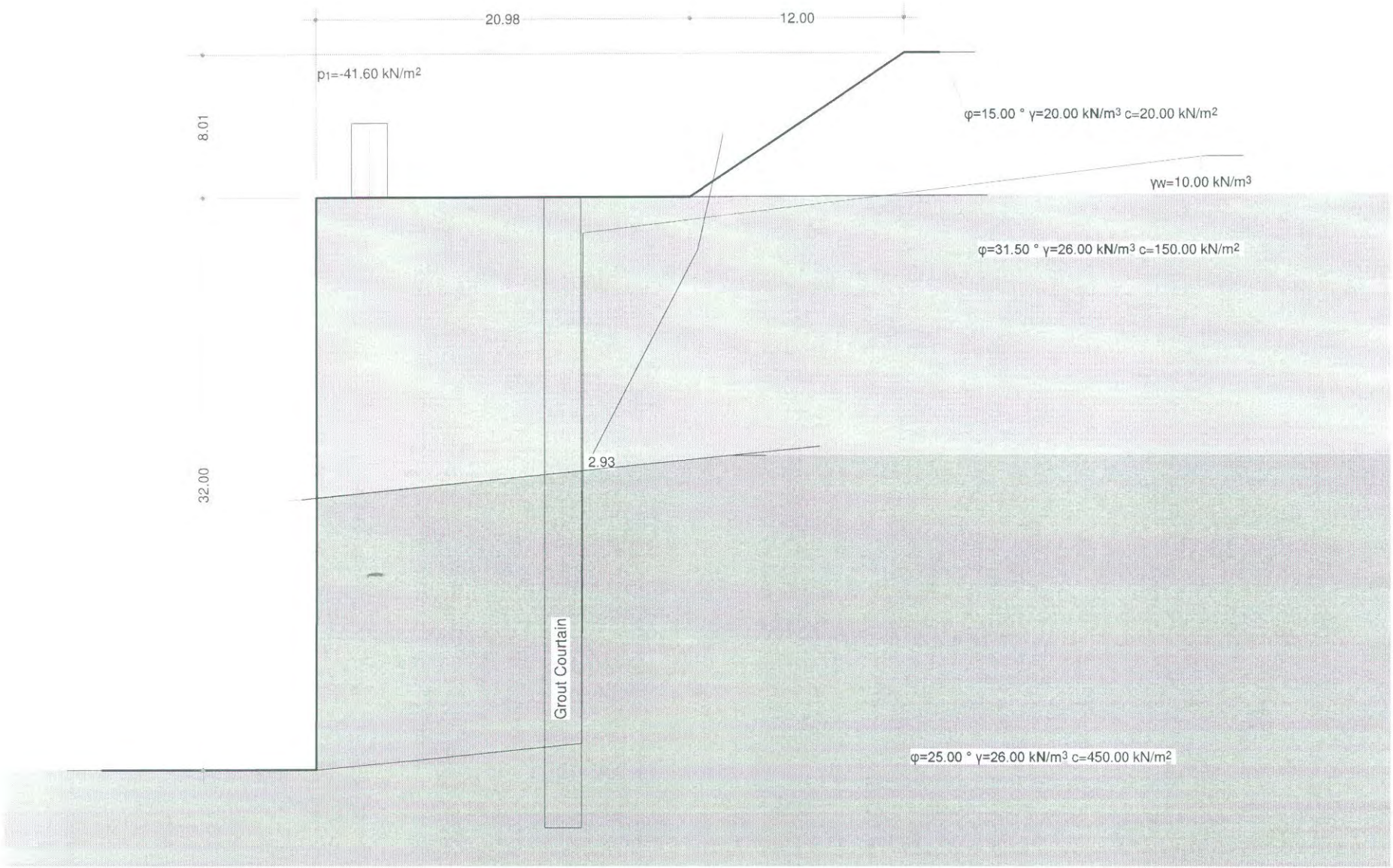
Critical slip surface, hazard scenario Standard-Gefährdungsbild

Scale 1 :387.9 (-13.65,138.80..81.95,200.33)



Critical slip surface

Scale 1 :318.7 (-7.21,138.92..69.48,189.48)



PR-00-4004, Rev 0
Preliminary Structural Design Analysis for the Intake and Outlet Structure

ONTARIO POWER GENERATION
OPG

NIAGARA TUNNEL FACILITY PROJECT

PRELIMINARY STRUCTURAL DESIGN ANALYSIS FOR THE INTAKE AND OUTLET STRUCTURE

May 2005

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1 INTRODUCTION

This report provides a preliminary stability analysis for the proposed Intake and Outlet Structure of the Niagara Tunnel Facility Project..

2 REFERENCES

2.1 Documents

[1] Ontario Power Generation (2005): Niagara Tunnel Facility Project, Geotechnical Data Report, Volume 1 to 12.

[2] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Owner´s Mandatory Requirements, Invitation to Submit Design/Building Proposals, App. 1.1.

[3] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Geotechnical Baseline Report, part of: Invitation to Submit Design/Building Proposals, App. 5.4.

[4] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Geotechnical Baseline Report, GBR-B.

[5] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Design Basis and Method Statements. (Doc. PR 00 3001)

[6] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Structural Design Analysis for the Diversion Tunnel (Doc. PR 00 4001)

[7] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Outline Specification – Concrete for the final structure of Intake / Outlet (Doc. PR 00 5010)

2.2 Drawings

(1) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Plan and Longitudinal Section (PD-01-1001, PA-01-1001)

(2) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Geotechnical Longitudinal Section (PD-01-1002, PA-01-1002)

(3) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Outlet Structure, Plan, Sections and Details (PD-01-1011)

(4) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Outlet Structure, Cross Sections (PD-01-1012)

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(5) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Intake Structure, Plan, Sections and Details (PD-01-1015)

(6) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Outlet Structure, Cross Sections (PD-01-1016)

2.3 Codes and Standards

[a] Canadian Standard Association, S16-01: Limit States Design of Steel Structures, December 2001.

[b] Canadian Standard Association, A23.3-94: Design of Concrete Structures, December 1994 (reaffirmed December 2000).

[c] National Building Code of Canada (1995)

[d] The Building Code of Ontario (1997)

[e] German Standard DIN 1045-1

3 OUTLET STRCUTRE

The outlet structure is a rectangular shaft building between the end of the diversion tunnel and the outlet canal. The outlet structure is 26 m long, 19.3 m wide and approx. 32 m high. The walls on the tunnel side and on channel side has square openings with dimensions of approx. 6.4 m clearance width and height for water flow.

The outlet structure is built of reinforced concrete. The thickness of the floor is 3 m, the thickness of the walls ranges between 2 m at the channel side, 3.9 m at the tunnel side and 3.26 m at the sidewall. To prevent loadings caused by underground pressure from the structure during structure design lifetime a flexible layer with a thickness of 10 cm is arranged at the sidewalls between the structure's backside and the excavated face of the ground.

Behind the outlet structure the diversion tunnel cross section changes from a square cross section to a circular cross section within a length of 20 m. This transition zone is an individual structure with changing cross section and changing dimensions of its wall thickness. It will be preliminary analysed within this document.

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4 INTAKE STRUCTURE

The intake structure is a similar building as the outlet structure. The dimensions of the structure are:

Length:	8 m
Width:	approx. 19 m
Height:	approx. 36 m
Thickness wall Channel side:	2.50 m
Thickness wall Tunnel side:	2.03 m
Thickness Sidewalls:	1.49 m

5 GEOLOGY

Twelve stratigraphic formations are identified in the project area. They consist of sequences of sedimentary rock of Ordovician to Devonian age. These are namely the Guelph, Lockport, De Cew, Rochester, Irondequoit, Reynales, Neahga, Grimsby, Power Glen, Whirlpool and Queenston formations. Some of these formations are only a few meters thick.

The intake structure is mainly located in the Lockport formations, while the outlet structure is laying in the Rochester and the Lockport formation. The lithological spectrum of the encountered formation covers limestone, dolostone, sandstone and shale (see chapter 3 of [5] for details).

6 GEOTECHNICAL INPUT PARAMETERS

The input parameters used in the analysis are in accordance with the evaluated calculation parameters included in the "Structural Design Analysis for the Diversion Tunnel" [6].

7 GROUNDWATER

Because of the neighbourhood of the regarded structures to the Niagara River and other water bearing structures the groundwater level close to the structure is assumed at the underground surface level (on the safe side).

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8 EXECUTION MEASURES

The pits for the outlet and intake structure are excavated by drilling and blasting. The rock mass is assumed as stable enough, that generally no support of the excavated surface is necessary. In individual cases a shotcrete sealing of the excavation surface against weathering might be approbriate.

The structures are concreted in different steps. Details are given in the corresponding outline specification [7]. The walls will be concreted in adequate segments. The segments are designed in that way, that generally no additional design loads has to be considered on the structure, caused by the construction procedure.

9 CALCULATION MODEL

9.1 Design Loads

9.1.1 Structural and Dead Loads

Dead load (D) of structural and non-structural elements is based on unit weight and computed volume of the materials. The following unit weights are used:

Reinforced Concrete	25.0 kN/m^3
Rock / Soil	see [6]
Water	10.0 kN/m^3

9.1.2 Hydrostatic Pressure

Hydrostatic pressure is considered as a life load (L). It has to be distinguished between the internal hydrostatic pressure and the external ground water pressure.

The applicable “internal water pressure” and “external water pressure” are shown in the geotechnical longitudinal section (2) and will be treated as basis for subsequent analysis.

9.1.3 Seismic Loads

Underground structures are generally less sensitive to seismic effects than surface structures, therefore no seismic loads are considered for preliminary design. At detail design stage a seismic analysis based on actual data will be carried out.

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9.1.4 Underground pressures

The structures will be protected against any kind underground pressures by a flexible layer, arranged between the structure's backside and the excavation surface. Details about the layer are given in the corresponding outline specification [6].

9.1.5 Load Combinations

For load combinations not including earthquake, factored loads are determined in accordance with CSA A23.3-94 [a]. Herein the effect due to specified loads is multiplied by a load factor α. A load combination factor ψ and an importance factor γ is also considered:

$$\alpha_D D + \gamma\psi(\alpha_L L + \alpha_T T)$$

where:

- Load factors α for:
  - Dead loads : $\alpha_D = 1.0$; (0,85 if dead load resists uplift)
  - Live loads: $\alpha_L = 1.5$
  - Temperature loads: $\alpha_T = 1.25$
- Load combination factor ψ:
  - $\psi = 1.00$ when L or T is considered
  - $\psi = 0.7$ when a combination of L and T is considered.
- The importance factor γ is equal to 1.0 for all load combinations.

9.2 Outlet Structure Design

Structural data

Length:	26 m
Width:	19.3 m
Height:	32 m
Thickness wall Channel side:	2.00 m
Thickness wall Tunnel side:	3.9 m
Thickness Sidewalls:	3.26 m
Thickness Floor	3.00 m

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For the preliminary design of all structural elements it is assumed that the gates are closed and the tunnel is pumped out for maintenance. Therefore the uplift and water pressure, caused by the outside water level and the weight of the structure are active.

9.2.1 Uplift

For design 85 % of the structure weight (dead load) has to be equal the maximum possible water pressure beneath the structure floor.

Maximum possible uplift force:
$A = 32 \times 26 \times 19{,}3$ [m] x 10.0 kN/m³ = 160,576 kN

Structure Weight.
$D = (26 \times 19{,}3 \times 3$ [m³] + $2 \times (26 \times 29 \times 3.26$ [m³]) + $12.8 \times 29 \times (2{,}0+3.9)$ [m³] – $6.39^2 (3{,}9+2{,}0)$ [m³]) x 25.0 kN/m³ = 209,266 kN

0,85 x D = 177,876 kN > 160,576 kN = A ✓

9.2.2 Preliminary Design of Bottom Plate

Loads: D = 3 m x 25.0 kN/m³ = 75 kPa
W = 32 x 10 kN/m³ = 320 kPa

Combination: C = 1.0 x 1.0 x (1.25 x 320 - 1.0 x 75) = 325 kPa

Assumption: plate, flexible supported on four sides; $L_x / L_y = 26 / 19{,}3 \approx 1{,}3$

Bending Moment (max.) $M = 325 \times 26^2 / 30{,}9 = 7{,}110$ kNm / m

Design (acc. to DIN 1045-1), Concrete strength = 35 MPa:

$k_d = 300 / 7{,}110^{1/2} = 3{,}55$; req. $a_s = 2{,}27 \times 7{,}110 / 300 \approx 54$ cm² / m

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. $a_s = 0{,}2 \times 35^{1/2} / 500 \times 300 \times 100 \approx 46$ cm² / m < 54 cm² / m

9.2.3 Preliminary Design of Side Walls

Loads: W = 32 x 10 kN/m³ = 320 kPa

Combination: C = 1.0 x 1.0 x 1.25 x 320 kPa = 400 kPa

Assumption: plate, flexible supported on four sides; $L_x / L_y = 29 / 25 \approx 1{,}2$

Bending Moment (max.) $M = 400 \times 29^2 / 29{,}1 = 11{,}560$ kNm / m

Corresponding Normal Force (pressure):
N = - 3.26 m x 29 m x 25.0 kN/m³ = -2,364 kN / m

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Design (acc. to DIN 1045-1), Concrete strength = 35 MPa:

M_{dEs} = 11,560 + 2,364 x 1.58 = 15,295; k_d = 326 / 15,295$^{1/2}$ = 2,63;
req. a_s = 2,32 x 15,295 / 326 – 2,364 / 45 ≈ 56 cm^2 / m

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. a_s = 0,2 x 35$^{1/2}$ / 500 x 326 x 100 ≈ 77 cm^2 / m > 56 cm^2 / m

9.2.4 Preliminary Design of Channel Side Wall

The load bearing is assumed in the wide side direction. The edges of the wall are assumed to be rigid connected to the sidewalls.

Loads: W = 12,5 x 10 kN/m^3 = 125 kPa

Combination: C = 1.0 x 1.0 x 1.25 x 125 kPa = 156 kPa

Bending Moment (Edge): M = 156 x 16 ^{2} / 12 = 3,328 kNm / m
(Field): M = 156 x 16 ^{2} / 24 = 1,664 kNm / m

Design (acc. to DIN 1045-1), Concrete strength = 35 MPa:

k_d = 200 / 3,328$^{1/2}$ = 3,46; req. a_s = 2,27 x 3,328 / 200 ≈ 38 cm^2 / m

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. a_s = 0,2 x 35$^{1/2}$ / 500 x 200 x 100 ≈ 47 cm^2 / m > 38 cm^2 / m

9.2.5 Preliminary Design of Tunnel Side Wall

The loads on the tunnel side wall are lower than on the above mentioned sidewalls, but the wall is thicker than these. Therefore it is assumed, that the minimum reinforcement are valid for design.

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. a_s = 0,2 x 35$^{1/2}$ / 500 x 390 x 100 ≈ 92 cm^2 / m

9.3 Intake Structure Design

Structural data

Length:	8 m
Width:	18,9 m
Height:	36 m

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Thickness wall Channel side: 2.50 m
Thickness wall Tunnel side: 2.03 m
Thickness Sidewalls: 3.00 m
Thickness Floor 3.00 m

For the preliminary design of all structural elements it is assumed that the gates are closed and the tunnel is pumped out for maintenance. Therefore the uplift and water pressure, caused by the outside water level and the weight of the structure are active.

9.3.1 Uplift

For design 85 % of the structure weight (dead load) has to be equal the maximum possible water pressure beneath the structure floor.

Maximum possible uplift force:
$A = 36 \times 8 \times 18{,}9$ [m] $\times 10.0$ kN/m³ $= 54{,}432$ kPa

Structure Weight.
$D = (8 \times 18{,}9 \times 3.0$ [m³] $+ 2 \times (8 \times 33 \times 3{,}0$ [m³]) $+ 12.9 \times 33 \times (2.5 + 2.03)$ [m³] $-$
$6.39^2 (2.5 + 2.03)$ [m³]) $\times 25.0$ kN/m³ $= 94{,}526$ kPa

$0{,}85 \times D = 80{,}347$ kPa $> 54{,}432$ kPa $= A$ ✓

9.3.2 Preliminary Design of Bottom Plate

Loads: $D = 3$ m $\times 25.0$ kN/m³ $= 75$ kPa
$W = 36 \times 10$ kN/m³ $= 360$ kPa

Combination: $C = 1.0 \times 1.0 \times (1.25 \times 360 - 1.0 \times 75) = 375$ kPa

Assumption: plate, flexible supported on four sides; $L_x / L_y = 15{,}9 / 8 \approx 2{,}0$

Bending Moment (max.) $M = 375 \times 15{,}9^2 / 40{,}3 = 2{,}352$ kNm / m

Design (acc. to DIN 1045-1), Concrete strength = 35 MPa:

$k_d = 300 / 2{,}352^{1/2} = 6{,}18$; req. $a_s = 2{,}22 \times 2{,}352 / 300 \approx 17$ cm² / m

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. $a_s = 0{,}2 \times 35^{1/2} / 500 \times 300 \times 100 \approx 46$ cm² / m > 17 cm² / m

9.3.3 Preliminary Design of Side Walls

Loads: $W = 33 \times 10$ kN/m³ $= 330$ kPa

Combination: $C = 1.0 \times 1.0 \times 1.25 \times 330$ kPa $= 413$ kPa

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Assumption: plate, flexible supported on four sides; $L_x / L_y = 33 / 8 \approx 4,1$

Bending Moment (max.) $M = 413 \times 33^2 / 40,3 = 11,160$ kNm / m

Corresponding Normal Force (pressure):
$N = -3.00 \text{ m} \times 33 \text{ m} \times 25.0 \text{ kN/m}^3 = -2,475$ kN / m

Design (acc. to DIN 1045-1), Concrete strength = 35 MPa:

$M_{dEs} = 11,160 + 2,475 \times 1.40 = 14,625$; $k_d = 300 / 14625^{1/2} = 2,48$;
req. $a_s = 2,29 \times 14,625 / 300 - 2,475 / 45 \approx 57$ cm² / m

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. $a_s = 0,2 \times 35^{1/2} / 500 \times 300 \times 100 \approx 71$ cm² / m > 57 cm² / m

9.3.4 Preliminary Design of Channel Side Wall

The load bearing conditions are assumed to be similar than at the outlet structure. Therefore it is assumed, for the preliminary design that the minimum required reinforcement is valid for design.

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. $a_s = 0,2 \times 35^{1/2} / 500 \times 250 \times 100 \approx 59$ cm² / m

9.3.5 Preliminary Design of Tunnel Side Wall

The load bearing conditions and the dimensions are similar to the Channel side wall. Therefore it is assumed, for the preliminary design that the minimum required reinforcement is valid for design.

Minimum required reinforcement (acc. to CSA 23.3.-94):

req. $a_s = 0,2 \times 35^{1/2} / 500 \times 203 \times 100 \approx 48$ cm² / m

9.4 Diversion Tunnel, Transition Area

As described above, the cross section within the Diversion Tunnel transition area changes from a square cross section to a circular cross section. Therefore the structure's contour changes from a frame to a ring.

For preliminary analysis the most unfavourable conditions are regarded. This is a frame contour at the entrance.

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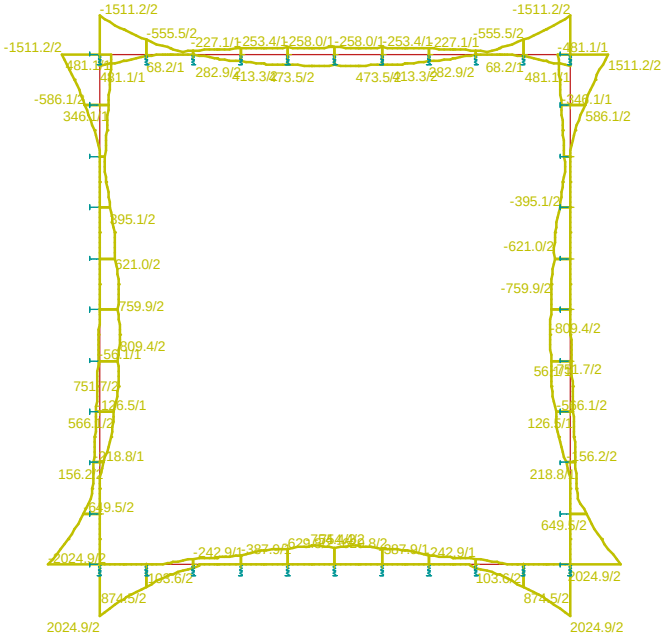
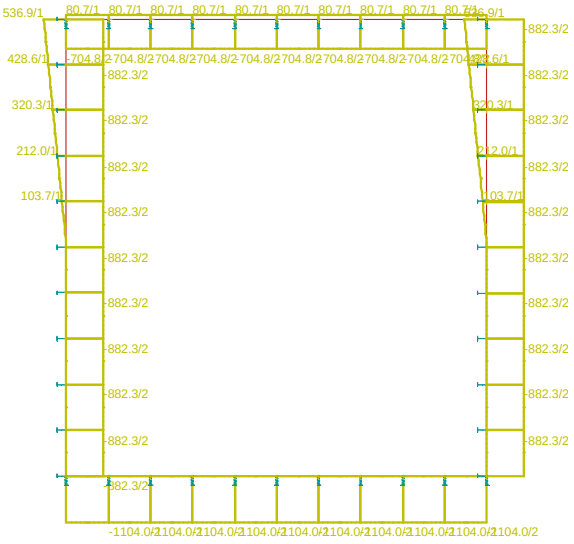
Similar to the intake and outlet structure the structure of the transition area is covered with a flexible material layer all around, to prevent stresses, caused by any kind of underground reactions. Therefore only the structural dead weight and the suitable water pressure are valid for the preliminary design. The dimensions are given in the corresponding drawing (4), (6). With respect to this conditions, the structure is loaded as shown below:



Bending moments



Normal Forces

The required reinforcement are calculated as listed below.

Structural Segment	Crossbar	Bottom	Sidewall
Thickness	2.17 m	3.00 m	2.85 m
Design Bending Moment [kNm / m]	473 (inside) 1,511 (outside)	745 (inside) 2,024 (outside)	809 (inside) 2,024 (outside)
Corresponding Normal Force [kN / m]	-705 -705	-1,104 -1,104	-882 -882
Required reinforcement area [cm^2 / m]	1,6 (inside) 7,4 (outside)	< req. minimum reinforcement	< req. minimum reinforcement
Required minimum reinforcement [cm^2 / m]	51 (each side)	71(each side)	67(each side)

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PR-00-4005, Rev 0
Preliminary Structural Design Analysis for Pipes, Culverts and Minor Items

ONTARIO POWER GENERATION
OPG

NIAGARA TUNNEL FACILITY PROJECT

PRELIMINARY STRUCTURAL DESIGN ANALYSIS FOR Pipes, Culverts and Minor Items

May 2005

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REVISION

0					
Rev.	Date	Issue, Modification	Prepared	Checked	Approved

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1 INTRODUCTION

This report provides a preliminary stability analysis for the pipes, culverts and minor items of the Niagara Tunnel Facility Project.. In detail this will be

- The water collection sump at the top of the shafts of the dewatering system
- The collection pipe with an inside diameter of 1,000 mm
- The culvert at the outlet of the collection pipe

2 REFERENCES

2.1 Documents

[1] Ontario Power Generation (2005): Niagara Tunnel Facility Project, Geotechnical Data Report, Volume 1 to 12.

[2] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Owner´s Mandatory Requirements, Invitation to Submit Design/Building Proposals, App. 1.1.

[3] Ontario Power Generation (2005), Niagara Tunnel Facility Project, Geotechnical Baseline Report, part of: Invitation to Submit Design/Building Proposals, App. 5.4.

[4] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Geotechnical Baseline Report, GBR-B.

[5] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Design Basis and Method Statements. (Doc. PR 00 3001)

[6] STRABAG/ILF (2005): Niagara Tunnel Facility Project, Structural Design Analysis for the Diversion Tunnel (Doc. PR 00 4001)

2.2 Drawings

(1) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Plan and Longitudinal Section (PD-01-1001, PA-01-1001)

(2) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Diversion Tunnel, Geotechnical Longitudinal Section (PD-01-1002, PA-01-1002)

(3) STRABAG/ILF (2005): Niagara Tunnel Facility Project – Dewatering Outfall and Pipe, Plan, Sections and Details (PD-01-1023)

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2.3 Codes and Standards

[a] Canadian Standard Association, A23.3-94: Design of Concrete Structures, December 1994 (reaffirmed December 2000).

[b] National Building Code of Canada (1995)

[c] The Building Code of Ontario (1997)

[d] German Standard DIN 1045-1

3 WATER COLLECTION SUMP

The water collection sump has a circular contour with a inside diameter of 3.05 m and is 3.75 m deep. It is made of concrete. Its wall is designed with a thickness of 45 cm. The water collection sump is installed in a pit and backfilled with granular filling material.

For design the parameters of the backfill material are assumed with $\gamma = 22$ kN/m^3 (specific weight) and $\varphi = 30°$ (angle of friction). With that the earth pressure is given to approx. 20 kN / m^2. Considering a compaction pressure during backfill with 40 kPa, the pressure within the concrete will be about 176 kPa. Therefore the wall thickness is enough. Reinforcement is required for constructional tasks only.

4 COLLECTION PIPE

The collection pipe will have a inside diameter of 1,000 mm and will be approximately 227 m long. It will be laid in a ditch with a maximum depth of 4.0 m. The pipe will be embedded in a 20 cm thick sand layer and backfilled. With the above mentioned assumptions the overburden weight pressure will be approximately 80 kPa and the force within the ring will be 40 kN / m.

5 DEWATERING OUTFALL

The dewatering outfall structure is installed at the end of the above mentioned collection pipe where the water is flowing in a concrete lined open ditch and from that to the Ontario Hydro Channel. The outfall structure consists of a concrete wing wall against the ground

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with foundation. The wall is approximately 10 m long and 3.3 m high. The wall thickness is 60 cm at the bottom and 45 cm at the crown. The foundation is limited to the centre of the structure, arranged in front and beneath of the wall, with a length of 3.3 m, a width of 3.45 m and a thickness of 90 cm. Reference is made to (3)

The underground will be regarded with $\gamma = 22$ kN/m^3 (specific weight) and $\varphi = 30°$ (angle of friction). Considering this, the earth pressure will be approx. 23 kPa.

Regarding sliding of the construction, the active force (caused by earth pressure) shall be less than the ground resistance force in the joint beneath the foundation. This ground resistance force is caused by the dead weight of the construction.

Regarding only the weight of the foundation this will be 3.3 x 3.45 x 0.90 [m^3] x 25 kN/m^3 = 256 kN. The ground resistance force will be 256 kN x tan 30° = 148 KN

With respect to the construction the maximum earth pressure force is 130 kN

Therefore the safety against sliding is given to 1.14 under this assumptions, laying on the conservative side. Detailed analysis and the adequate validation of the underground behaviour is required while construction.

For the concrete structure design a Concrete with a strength of 35 MPa is assumed. With that the static required reinforcement will be approximately 8 cm^2 / m at the foundation / wall section and at the beginning of the wing walls. The minimum required reinforcement is given to 10 cm^2 / m.

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MH-4002-00
Preliminary Design for Temporary Facilities, Roads and Parking, Fencing, Gates, Barriers, Stockpiles and Water Treatment Facilities

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-4002-00

Preliminary Design for Temporary Facilities, Roads and Parking, Fencing, Gates Barriers, Stockpiles and Water Treatment Facilities

May 11, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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1.0 SCOPE

The civil works included in this plan are primarily site facilities comprising:

1. Roads and Parking;
2. Fencing, Gates and Barriers; and
3. Stockpiles, disposal and water treatment facilities.

2.0 PRELIMINARY DESIGN

2.1 Preliminary Design Drawings

Preliminary design drawings, Nos. MH-6008 and MH-6009, were prepared to illustrate the result of the design, which will be finalized at the detailed design stage. The drawings are included in Chapter 6 of the Technical Proposal.

2.2 References and Design Methods

The preliminary design was conducted in accordance with document MH-3002: "Design Basis and Method Statements for Design and Construction Facilities at the Intake and Outlet Areas" prepared for this project and included in previous chapters.

The Contractor and the Specialist Subcontractors of the group have been and will continue to be contacted throughout the entire design and contract preparation process to provide valuable construction input to ensure that the design is useful, constructable and economical, without compromising the quality of the final work.

2.2.1 Temporary Facilities

- Intake Temporary Facilities:

  At the intake a construction laydown area will be placed to the south of Niagara Parkway. This facility will be used in conjunction with all associated works at the intake. This site will be approximately 182 m x 76 m. It will be fenced and a lockable gate provided for security. Their surface will be graded stone and maintained throughout the project life. The facing side to Niagara Parkway of the lay down area shall also have a screen wall erected to downplay the activity within the compound and the public activity along the parkway. For additional reference, refer to Drawing No. MH-6008-00.

- Outlet Temporary Facilities:

  At the outlet the construction offices will be located adjacent north south portion of the temporary access road. This area is fully fenced and will be approximately 400 m x 50 m. This site will be fully serviced by temporary utilities from Stanley Avenue. In addition Material Yards will be placed throughout the site and will be fully accessible and within the fenced construction area. Their surface will be graded stone and maintained throughout the project life. For additional reference, refer to Drawing No. MH-6009-00.

2.2.2 Roadways

- Intake Roadways:

  At the intake site a temporary roadway is being constructed to allow access to the site from Portage Road to the construction laydown area and across Niagara Parkway to the construction area at the intake. This will eliminate any need for construction traffic to utilize Niagara Parkway. Roadside ditches will be provided to carry any surface water generated from the roadway into the existing and natural drainage system. A temporary traffic signal will be installed at the intersection of the Access Road and Niagara Parkway to alleviate conflict with construction traffic crossing Niagara Parkway. For additional reference, refer to Drawing No. MH-6008-00.

  The existing recreation trail will be relocated to a new location as shown on the drawing to minimize interference of visitors to the area and the construction.

- Outlet Roadways:

  At the outlet site a new permanent paved access road is being constructed form Stanley Avenue to provide access to the work zones. However only a 180 m section of this road will be built, and beyond this section a temporary roadway is being constructed to provide access to the material stockpiling area and the outlet location. These roadways will be in place until the end of the project and then removed and the area restored to original conditions. Roadside ditches will be provided along these roadways to carry surface drainage from the roadway and other site locations to a detention/settling basin for eventual discharge into the canal system. For additional reference, refer to Drawing No. MH-6009-00.

  All roadway design, horizontal and vertical alignments, road widths, surface details, drainage, intersection details, and the like, will comply with highway design requirement appropriate to the class of the road as provided in the above-quoted references.

2.2.3 Fencing

Fencing providing boundary separation and security to the sites will be primarily chain link fences. This will help to eliminate any potential interference between the public and the construction activities. At the intake area, some of the work zones will be fenced off using full height hoardings to afford even better separation and minimize the impact on the appearance of this tourist area.

For additional reference and specific locations, refer to Drawing Nos. MH-6008 and MH 6009.

2.2.4 Stockpiles

During the excavation of the tunnel a large quantity of material primarily rock will be stockpiled between the two power canals as shown on MH-6009. These stockpiles will be between approximately 5 m to 6 m in height with proper and safe side slopes and with the top surface level and graded.

The stockpiles shall be piled in lifts of not more than 300 mm. The stockpile will be setback at a minimum 20 m from the canals and a perimeter trench will be implemented to gather any surface runoff from the stockpiles, collected in a settling basin and discharged through filter cloth into the canal. The ditch surface shall be protected by seeding, and strawbale flow-checks will be provided at 250 m intervals, and before every culvert and intersecting ditch. When the grade of the ditch is steeper than 10%, rockfill check dam will be installed. No stockpile is within 5 m from any part of the tower structures or the location in plan of the overhead transmission lines. A temporary construction pad will be provided for holding materials suspect of contamination. The runoff will be suitably treated prior to discharge. Excavated materials suitable for aggregate production or other uses will be stockpiled separately.

As stated previously, the specifications for stockpiles are located in the Draft Design/Build Agreement and Concept Drawings and also in OPG's "Management of Excavated Material" document dated December 2004 and OPG's "Management Plan for BTEX" dated December 2004. If the specifications in the Draft Design/Build Agreement and Concept Drawings prevail, then the following will be implemented. A temporary stockpile will be located between the canals and a runoff pond provide for runoff from the excavated materials. This will be used for specific contaminated materials from the tunnel excavation. The runoff will be pumped to the water treatment facility prior to final discharge. The runoff pond and the temporary stockpile will be lined with synthetic material or a minimum of an impervious material to eliminate ground contamination.

If the design is to meet the requirements in OPG's "Management of Excavated Material" and "Management Plan for BTEX", then certain rock formations have specific temporary and/or permanent storage requirements based on the information provided by the Reuse of Excavated Materials Committee. The limestones/dolomites above the Rochester Shale formation are to be segregated and stockpiled separately for reuse by the Project. The shales potentially containing BTEX (Rochester, Grimsby and Power Glen formations) are to be isolated permanently in the main disposal area with a perimeter drain leading to the retention pond. The Queenston Shale may be used by the clay/brick industry at a later date and therefore should be stored in the main disposal area separate from the other rock for easy access when required. All other rock types are to be placed in the main disposal area for permanent disposal separately from the other in this area.

The storage area for the excavated material potentially contaminated with BTEX will be approximately 400 m long by 100 m wide and will either have a compacted clay base or impermeable geotextile lining. Within this area, there will be a 10 m wide buffer area around the perimeter which will contain the drainage ditch/outside berm. The shale will be stockpiled in lifts less than 300 mm and the slope will be no greater than two horizontal to one vertical (2:1). The run-off will be directed towards the retention pond for treatment, if required.

3.2.5 Disposal

The disposal will be conducted in compliance with the Owner's Mandatory Requirements, section 3.

As stated above, the specifications for stockpiles are located in the Draft Design/Build Agreement and Concept Drawings and also in OPG's "Management of Excavated Material" dated December 2004 and OPG's "Management Plan for BTEX" dated December 2004. On-site permanent disposal of excavated material is required for rock from the Rochester, Grimsby and Power Glen formations and rock other than Queenston formation and limestones/dolomites. The Queenston shale will be temporarily stored at the main disposal area and the limestones/ dolomites will be reused. The section of the permanent disposal area storing the Rochester, Grimsby and Power Glen formations will be either lined with clay or geotextile to reduce potential soil and groundwater contamination. Runoff will be collected and discharged to the retention pond for sampling and treatment, if required, for final discharge.

Any excavated materials suitable for aggregate production will be stockpiled separately and used where applicable. Any surplus will be removed from the site at the end of the contract. No excavated material or discharge of water prior to treatment will be spilled or placed into any watercourse at the site.

3.0 DESIGN ANALYSIS

3.1 CODES, STANDARDS AND SPECIFICATIONS

The facilities will be designed in compliance with the codes, standards and specifications listed in Section 6 above.

3.2 DESIGN METHODS AND PROCEDURES

The civil works will be designed by using recognized methods and procedures, which include the established and industry standard software in performing in the installation of all work.

MH-4003-00
Preliminary Design for Cofferdams and Temporary Dock

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-4003-00

Preliminary Design for Cofferdams and Temporary Dock

May 11, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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2.0 COFFERDAM 1
3.0 TEMPORARY DOCK 1

1.0 SCOPE

This document provides information regarding the Strabag group's preliminary design layout and arrangements for the cofferdams and the temporary dock, both are to be used at the intake area.

The information was supplied by specialist contractors as described below.

2.0 COFFERDAM

Preliminary Design Drawings and Method Statement were designed by Bermingham Foundations in conjunction with Isherwood Geostructural Engineers, attached in the appendix of this document.

3.0 TEMPORARY DOCK

Layout of the Barge Unloading Dock at the Intake area as part of the approach wall system prepared by McNally Construction Inc. is also enclosed in the appendix of this document.

As discussed in document MH-3001, the additional loading imposed by the extraordinary construction loading on the approach wall at this location has been adequately accounted for.

APPENDIX TO MH-4003
from
MCNALLY CONSTRUCTION AND BERMINGHAM FOUNDATIONS

MH-4004-00
Preliminary Design for Demolition and Disposal of Dewatering Structure and Relocation of Waterline

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-4004-00

Preliminary Design for Demolition and Disposal of Dewatering Structure and Relocation of Waterline

May 11, 2005
Project No.: 1051006.00

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1.0 GENERAL

The document will described preliminary design issues relating to:

1. Demolition and Disposal of Dewatering Structure at the PGS; and

2. Relocation of the Waterline as a result of item 1.

2.0 PRELIMINARY DESIGN PROCESS

The design will make reference to document no. MH-3002: "Design Basis and Method Statements for Temporary Construction Facilities at the Intake and Outlet Areas" included in Chapter 3 of this proposal. Due to nature of the work, and a number of available options for the work to be determined during the detailed design and construction, no drawing is considered required to illustrate the work at this stage.

Input from the Contractor and the Specialist Subcontractors have been and will continue to be sought to supplement the design to ensure that the solution selected will address all issues and will be efficient, constructable and economical.

Due to the many impact of these works on the operation of the PGS, as well as areas where the waterline is supplying, the input from related staff of OPG will also be sought as the design proceeds.

3.0 CODES AND STANDARDS

The design of these 2 components will be mainly based on the Owner's Mandatory Requirements and Questions and Answers issued related to the work. Other references will include:

1. OPSS (Ontario Provincial Standard Specifications)
2. CSA Standard Z107.0-00 (Standard for Certification of Noise Barriers February 2000)
3. CAN/CSA-S6-00 (Canadian Highway Bridge Code)
4. Other CAN standards, see applicable specifications included
5. Other CSA Standards, see applicable specifications included
6. Niagara Tunnel Facility Project - Invitation to submit Design/Build Proposals, Ontario Power Generation (Amendment 1, February 2005)
7. Ontario Provincial Standard Drawings (OPSD)

4.0 PRELIMINARY DESIGN DESCRIPTION

4.1 Demolition of the Dewatering Structure

The existing dewatering structure at the PGS Canal is a 45 m long, 6 span reinforced concrete structure, with a 6.7 m wide walking surface on the top. The 5 piers in the water are tall concrete piers with a wide base but tapering up towards the top but all are up to 17 m in height and are sitting on the rock surface of the bottom of the canal, including some embedment into the rock stratum. It is not known whether the structure is manufactured from precast units, but from the information provided, there is definitely a possibility of this and as such it may help to remove the component in convenient chunks instead of breaking into small debris using a concrete breaker.

The 6 span openings are actually gate openings used to close the canal from the main HEP canal for dewatering purposes, though according to information provided to the Proponent, the structure has not been used. OPG provided additional information on the condition of the structure through inspection reports, and suggested that there are damages to certain parts of the structure especially at the abutments and one of the piers (pier 1), and does not use the structure for vehicular traffic anymore.

The method of demolition will be such as to minimize impact on the operation of the PGS and coordination with the timing and duration, as well as the proposed method of removal, will be discussed with OPG and agreed prior to implementation. Sufficient advance notification will be provided to ensure all preparative work be made and all affected personnel informed of the impending work.

The entire superstructure will be removed and the remaining abutment and exposed rock surface stabilized where necessary and where confirmed by the engineer. The pier will be removed up except the last 300 mm which should be intact and firmly fixed into the rock.

It is expected that the deck will be sawcut or flame cut into large pieces that could be handled by a crane seated on the bank with sufficient reach and capacity. The piers and the abutment units designated for removal will then be cut out and removed in pieces. Some underwater work will be required to remove submerged portions of the piers up to 300mm above the canal bed. All loose abutment and rock slopes exposed will be stabilized using bolts, anchors or other appropriate techniques.

Debris catching device will be implemented together with use of barges, at the endorsement of OPG, to minimize concrete debris falling into the water. All sawcutting operations will be controlled and effluent removed using vacuum machine. Large cut reinforced concrete chunk will be removed by lifting from the banks and carting away in truck to designated disposal areas.

4.2 Waterline Relocation

During construction an existing waterline (apparently 8” diameter, as shown on the as-built drawings) will be relocated from the existing PGS dewatering structure prior to the demolition of the structure. The relocation can either be a surface laid/ buried waterline laid along the banks of

the PGS Canal, and cross the canal at the roadway located outside the PGS station, or on a new utility bridge over the canal at its existing location. Both alternatives will be evaluated, considering cost, timing, impact to other work, etc., and discussed with OPG staff prior to selecting the suitable approach.

The relocated waterline will be constructed to the same standards and details as the existing waterline.

4.3 Disposal

The disposal will be conducted in compliance with the Owner's Mandatory Requirements, section 3.

Concrete debris will not be subject to be reused, and will be removed off site to designated disposal areas.

5.0 CONSTRUCTION TECHNIQUES AND EQUIPMENT

The work will be completed primarily utilizing standard construction methods. The equipment used for the demolition of the PGS dewatering structure include the use of sawcutting or flame cutting equipment, barges, lifting equipment and debris collecting setup. When necessary, underwater work may be required to retrieve concrete components submerged in the water at the bottom of the canal.

MH-4001-00
Preliminary Structural Design Analysis for Intake Approach and Accelerating Walls

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-4001-00

Preliminary Structural Design Analysis for Intake Approach and Accelerating Walls

May 11, 2005
Project No.: 1051006.00

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1.0 INTRODUCTION

1.1 GENERAL

The Intake Approach and Accelerating Walls, which form part of the Niagara Tunnel Facility Project, are located upstream of the INCW Structure. The layout, alignment, geometric dimensions, and top elevations of these walls follow the concept plan defined by OPG.

The purpose of the Intake Approach and Accelerating Walls is to direct a continuous supply of water to the Diversion Tunnel through the Intake Structure. In carrying out this function, specific hydraulic and environmental requirements must be met under all operating conditions.

1.2 SCOPE

This report provides a summary of the key results of structural analysis carried out for the preliminary design of the proposed Intake Approach and Accelerating Walls.

The preliminary design parameters, codes and standards and methods of analysis are presented to illustrate the design process used for developing the design as shown in the drawings contained in the Proposal submission (see Sub-section 2.2 below).

The preliminary structural design of other components of the Niagara Tunnel Project is addressed by other relevant documents elsewhere in the Proposal submission.

2.0 REFERENCES

2.1 DOCUMENTS

The following documents form the basis of the design of the Intake Approach and Accelerating Walls:

1. Ontario Power Generation (2005), Niagara Tunnel Facility Project, Owner's Mandatory Requirements, part of Invitation to Submit Design/Build Proposals, Appendix 1.1 (pp).
2. Ontario Power Generation (2005), Niagara Tunnel Facility Project, Geotechnical Baseline Report, part of Invitation to Submit Design/Build Proposals, Appendix 5.4.
3. Ontario Power Generation (2005), Niagara Tunnel Facility Project, Concept Drawings, part of Invitation to Submit Design/Build Proposals, Appendix 1.1 (h).
4. Morrison Hershfield (2005), Niagara Tunnel Facility Project, Draft Design Basis and Method Statements for Design and Construction of Intake Approach and Accelerating Walls.

2.2 DRAWINGS

The engineering design of the Intake Approach and Accelerating Walls is shown in the following drawings:

1. Morrison Hershfield (2005), Niagara Tunnel Facility Project, Intake Works – General Notes, document MH-6001
2. Morrison Hershfield (2005), Niagara Tunnel Facility Project, Intake Works – West Approach Wall, document MH-6002.
3. Morrison Hershfield (2005), Niagara Tunnel Facility Project, Intake Works – East Approach Wall, document MH-6003
4. Morrison Hershfield (2005), Niagara Tunnel Facility Project, Intake Works – New Accelerating Wall and Pier 5 Modification, document MH-6006.

2.3 CODES AND STANDARDS

The requirements of the codes, regulations and guidelines where applicable as follows:

1. National Building Code of Canada (1995)
2. The Building Code of Ontario (1997)
3. CSA Standard CAN3-A23.3-94: Design of Concrete Structures
4. Lakes and Rivers Improvement Act, Government of Ontario (1986)
5. Dam Safety Regulation under the Lakes and Rivers Improvement Act (Proposed Draft), Ministry of Natural Resources (November 2001)
6. Dam Safety Guidelines, Canadian Dam Association (January 1999)
7. Guidelines and Criteria for Approval under the Lakes and Rivers Improvement Act, Ministry of Natural Resources (Draft, May 1997)

The preliminary design was also carried out in accordance with the following standards and specifications:

1. Niagara Tunnel Facility Project - Invitation to submit Design/Build Proposals, Ontario Power Generation (2005)
2. CSA Standard CAN3-A23.1-94: Concrete Materials and Method of Concrete Construction
3. CSA Standard CAN3-A23.2-94: Methods of Test for Concrete
4. USACE EM1110-2-2000: Standard Practice for Concrete for Civil Works Structures, US Army Corps of Engineers (March 2001)
5. USACE EM1110-2-2104: Strength Design for Reinforced Concrete Hydraulic Structures, US Army Corps of Engineers (August 2003)
6. USACE EM1110-2-2200: Engineering and Design – Gravity Dam Design, US Army Corps of Engineers (June 1995)
7. USACE EM1110-2-2502: Engineering and Design – Retaining and Flood Walls, US Army Corps of Engineers (September 1989)

During detailed design, it is expected that the above-named references will continue to be used as bases for design and construction of the proposed work.

3.0 DESIGN DESCRIPTION

3.1 PRECAST CONCRETE MODULAR SYSTEM

The Intake Approach and Accelerating Walls have been developed based on the precast reinforced concrete modular design concept. Each wall is constructed with a series of structurally independent reinforced concrete modules, filled with rock-fill materials and capped with concrete cover slab over the full length of the wall.

The individual wall will be constructed by stacking up either two or three units high as required to form a continuous wall to direct the water flow.

4.0 DESIGN DATA

4.1 DESIGN LOADS – PRELIMINARY DESIGN

At the proposal stage, a preliminary design has been conducted on the structures based on available information and design references as given in this section. The design will obviously need development during the detailed design stage, when investigation and other design data will be made available to the designer.

The structures were designed to withstand all temporary, permanent, construction, environmental, normal, unusual and extreme loads, in all possible combinations.

All structural components were checked to provide adequate capacity to safely sustain the prescribed design loads. The types of loads for which the structures have been designed to withstand, and will continue to be addressed during the detailed design stage, include the following:

4.1.1 Structural and Dead Loads (D)

All permanent masses of the structural components and all permanent construction materials including the permanently located attachments and equipment systems.

The unit weights used for computing the dead loads are:

- Concrete 24.0 kN/m^3
- Back-fill 22.0 kN/m^3
- Rock-fill 20.0 kN/m^3
- Water 10.0 kN/m^3

4.1.2 Hydrostatic Pressures

Water surface elevations in the GIP given in Table 1 (based on NAD83 system) have been used to compute hydrostatic pressures on the wall structure. These values will be reviewed and continue to be used in the detailed design stage.

Hydrostatic loads are imposed under the following conditions:

(a) Operating Water Pressures (H)
The external water pressure exerted by water above ground is governed by the specified maximum water levels. When used as stabilizing force acting on the structure in a stability analysis, these forces must be conservatively estimated. See Table 1 for appropriate design water elevations.

(b) Design Flood (F)
The water level under inflow flood scenario varies between the 200-year flood and the Probable Maximum Flood (PMF) as prescribed in the OPG Invitation document. See Table 1 for appropriate design flood elevations.

TABLE 1: DESIGN WATER LEVELS AT GIP

Conditions	Descriptions	Elevation (m)
Normal Operating	Normal Maximum	171.65
	Normal Minimum	170.74
Flood	200-Yr. Flood	172.11
	PMF	173.17

4.1.3 Soil Pressures (S)

Earth pressures due to soil or rock back-fill will be imposed against the Intake Approach Wall structure.

For preliminary design purpose, a granular back-fill with the following properties is assumed for the design analysis:

- Moist Unit Weight 22.0 kN/m^3
- Submerged Unit Weight 12.0 kN/m^3
- Angle of Internal Friction $\Phi = 35^0$
- Cohesion C = 0

Since the wall modules are not bonded to the foundation, active pressure is likely to mobilize rather than pressure at "rest". In such case, Coulomb's equation may be used for the determination of earth pressure coefficients which are then used for determining pressures and forces acting on the retaining wall.

For preliminary design purpose, a conservative value of $K_a = 0.4$ is assumed for analysis.

The pressure and forces below the water table will take into account the submerged unit weight of the same material.

Soil data and any other pertinent parameters used in the design analysis shall be evaluated in consultation with the geotechnical engineer before being adopted for the final design.

4.1.4 Ice Load (I)

The structure has also been designed to withstand the forces generated by ice movement against it. Ice forces may include dynamic loads generated by ice floes striking the structure, and static loads generated by thermal expansion or contraction of the ice and by fluctuations in the water levels.

The magnitude of thermal ice load is governed by a number of controlling factors such as ice thickness, shoreline confinement, water velocity, water level fluctuation, rate of temperature rise, etc. Normally, thermal ice loads range from 37 kN/m to 146 kN/m. For the Niagara site, design ice load of 73 kN/m acting 0.3m below water level is taken for preliminary design purpose.

4.1.5 Seismic Loads (E)

The earthquake loadings used in the design of the structure are based on design earthquakes and associated ground motion parameters determined from seismological evaluation for the specific site. Where site specific study has not been conducted, seismic zone maps of the National Building Code proposed for the 2005 revision are to be used.

Two levels of seismic loads are usually considered for the design: (a) the Maximum Design Earthquake (MDE) having an extremely low probability of annual exceedence, and (b) the Operating Basis Earthquake (OBE) used in conjunction with ice loading and having a probability of annual exceedence of 1 in 200. See Table 2 for recommended design response spectra generated by a probabilistic seismic hazard analysis conducted for the Niagara region.

TABLE 2: DESIGN EARTHQUAKES – UNIFORM RESPONSE SPECTRA

Natural Frequencies	OBE (1: 200/yr) PSA (cm/s^2)	MDE (1: 2500/yr) PSA (cm/s^2)	NBCC Proposed 2005 Edition
0.5	1.4	7.6	21
1.0	4.0	21	70
2.0	11	66	196
5.0	36	202	402
10.0	66	373	
20.0	94	567	
PGA	38	246	294
PGV	0.68	3.8	13

Note:

PSA = Peak Spectral Acceleration
PGA = Peak Ground Acceleration in cm/s^2
PGV = Peak Ground Velocity in cm/s

4.1.6 Construction Loads (C)

Construction lifting loads included dead weights in air or under water plus 50% for impact allowance during handling, lowering, barging, launching and controlled sinking operations of the precast modules.

Construction loads due to a 40 Tonnes crane is also considered at a segment of the wall at a location near the Intake or temporary dock facility, as requested by the Contractor for storage and handling of precast units.

4.2 LOAD COMBINATIONS

During detailed design, all combinations of loads that may act simultaneously during construction, normal plant operation or abnormal environmental conditions shall be considered.

The loading conditions considered in concrete structure designs and overall structural stability analysis shall include but not limited to the following:

1. Loading Case No. 1 – normal loading condition – Construction
   Any combination of loads that may act simultaneously during the construction period, including lifting and handling loads, crane loads for construction activities, etc.

2. Loading Case No. 2 – normal loading condition – Summer Operating
   Any combination of loads that may act simultaneously during normal operation.

3. Loading Case No. 3 – normal loading condition – Ice Load
   Any combination of loads that may act simultaneously due to ice loading effects on the structural components.

4. Loading Case No. 4 – unusual loading condition – IDF[1]
   Any combination of loads that may act simultaneously during a 200-year flood.

5. Loading Case No. 5 - extreme loading condition – PMF[2]
   Any combination of loads that may act simultaneously during this extreme environmental event which has a low probability occurrence.

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[1] IDF = Inflow Design Flood

[2] PMF = Probable Maximum Flood

6. Loading Case No. 6 – extreme loading condition – MDE[3]
   The Intake Approach and Accelerating Walls, being a conventional structure (i.e. not dam safety related), shall be designed to satisfy the requirements stipulated in the National Building Code of Canada.

5.0 STABILITY ANALYSIS

5.1 GRAVITY METHOD OF ANALYSIS

Stability of the wall structures has been verified by limit equilibrium method using un-factored loads. The computed factors of safety against sliding, and resulting stresses along any critical sections within the structure or at the base shall not exceed the minimum acceptable factors of safety and allowable working stresses specified for the normal, unusual and extreme load combinations.

5.1.1 Sliding

Factor of safety against sliding along any horizontal plane has been calculated based on the following:

- Factor of Safety (Sliding) = $\mu \sum V / \sum H$
  where μ = coefficient of friction at the plane considered
  $\sum V$ = total vertical load acting on the plane
  $\sum H$ = total net horizontal load acting on the plane

5.1.2 Location of Resultant

The factor of safety against overturning acting on the plane under consideration has been computed as follows:

- Factor of Safety (Overturning) = $\sum M_R / \sum M_O$

Alternately, the location of the resultant acting on the plane under consideration shall be calculated as follows:

- Distance from the toe = $(\sum M_R - \sum M_O) / \sum V$
  Where $\sum M_R$ = sum of restoring or stabilizing moments about toe
  $\sum M_O$ = sum of overturning moment about toe
  $\sum V$ = total vertical load acting on the plane

[3] MDE = Maximum Design Earthquake

5.1.3 Contact Stresses

It is expected that the stresses acting on the foundation under all the loading conditions are likely to be small. Since these walls will be founded on solid rock, the stresses are not critical either for the concrete or the foundation and therefore these are not a design concern.

In the final design stage, a geotechnical investigation based on field inspections and analysis will be carried out to the extent deemed necessary.

5.1.4 Acceptance Criteria

Most critical load cases have been developed and considered in computing the factors of safety against sliding, overturning, etc.

The Owner's Mandatory Requirements stipulated that the following conservative assumptions:

1. There is no cohesion at the concrete-rock interface.
2. Passive pressure due to back-fill shall not be considered.
3. Rock anchors to provide structural stability shall not be allowed.

The acceptance criteria for sliding stability of concrete gravity structures are given in Table 3.

TABLE 3: MINIMUM FACTORS OF SAFETY

Load Combination	Resultant Location at Base	Factor of Safety for Sliding and Stresses
Normal	Middle 1/3	1.5
Unusual	Middle 1/2	1.3
Extreme	Within base	1.0

Note:

Analysis shall be based on zero cohesion across the prospective failure plane as stipulated by OPG.

5.2 SEISMIC ANALYSIS

Unlike earth structures which often are susceptible to liquefaction and large deformation due to slip circle failure, well designed and constructed concrete gravity structures should be able to withstand even very strong earthquake motions. The experience data based on observations of historical earthquake damages demonstrated that indeed concrete gravity structures are generally safe.

This is mainly because explicitly earthquake forces are transient oscillatory in nature. These forces will vary with time and alternate between one directions to opposite direction. Furthermore, the inertia forces are usually not expected to be applied in the same direction for a

sufficiently long period of time to induce significant rotational or sliding displacements that are actually detrimental to the overall structural stability of the gravity structure.

Therefore, it is now well established that traditional static analysis which does not recognize the dynamic response of the structural system prescribed by previous codes and practices is meaningless. As a result, factors of safety against overturning and sliding are no longer required to be computed.

In fact, it has been verified by seismic studies that potential deformations of simple concrete gravity structures induced by earthquake ground motions are most likely to be small even under the most severe seismic event. Hence, it is concluded herein that further seismic analysis is not necessary at this design phase.

5.3 REINFORCED CONCRETE DESIGN

The reinforced concrete hydraulic structures have been designed in accordance with the Strength Design Method, and this shall continue be adopted during detailed design. The structural members will have a required strength to resist design loads and the factored load combinations specified in Sub-Section 4.1 and 4.2.

The load factors as prescribed in CSA A23.3 shall be applied and the total factored design load shall be increased by the hydraulic factor $H_f = 1.3$. The hydraulic factor is used to improve crack control for massive hydraulic structures which usually are lightly reinforced.

The hydraulic factor is not applicable for sliding or overturning stability analysis.

5.3.1 Design Strength

The strength of a structure or individual member must exceed the demand (required strength) for all foreseeable loads without failure or significant distress. The nominal strength must be reduced by a resistance factor to account for the variability in the strength. For this purpose, the resistance factors prescribed in CSA A23.3-94 have been applied and shall continue to apply during detailed design.

6.0 DESIGN ANALYSIS RESULTS

In the design of the Intake Approach and Accelerating Walls, various load combinations as specified in the Design Basis and Method Statement document are considered.

The critical load combinations for different segments of these walls differ from one another because of the individual wall location, width and height. The most critical load combinations which have been found governing the design of different segments in general terms are describe below. In each case, the design has been verified for performance under these critical load combinations. Table 4 summarizes the key results of these stability analyses.

TABLE 4-1: RESULTS OF STABILITY ANALYSIS – WEST INTAKE APPROACH WALL

Critical Load Combination	Computed Factor of Safety - Overturning	Computed Factor of Safety - Sliding
Construction Phase: (D + S)	2.3	1.8
Summer Normal Operating: (D + S + H)	2.2	1.7
Usual/Extreme Flood: (D + F)	3.2	2.3
Extreme Seismic: (D + S + H + E)	NA	NA

TABLE 4-2: RESULTS OF STABILITY ANALYSIS – EAST INTAKE APPROACH WALL

Critical Load Combination	Computed Factor of Safety - Overturning	Computed Factor of Safety - Sliding
Construction: (D + S + H + C)	2.8 – 3.8	1.7 – 2.2
Summer Normal Operating: (D + S + H)	4.6	2.3
Usual/Extreme Flood: (D + S + F)	4.6	2.3
Extreme Seismic: (D + S + H + E)	NA	NA

TABLE 4-3: RESULTS OF STABILITY ANALYSIS – ACCELERATING WALL

Critical Load Combination	Computed Factor of Safety - Overturning	Computed Factor of Safety - Sliding
Summer Normal Operating: (D + H)	10.0	8.3
Winter Normal Operating: (D + H + I)	1.7 - 3.2	1.5 - 2.7
Usual/Extreme Flood:	∞	∞

(D + F)		
Extreme Seismic: (D + H + E)	NA	NA

7.0 CONCRETE CONSTRUCTION

The concrete material to be used for the construction of these structures shall be in accordance with the appropriate specification, standards and manuals listed in Sub-Section 2.3.

7.2 OUTLINE SPECIFICATIONS

All concrete shall be normal density concrete and conforming to the following Table 5.

TABLE 5: OUTLINE SPECIFICATIONS - CONCRETE

Location	Exposure Class	Minimum Compressive Strength f'_C (MPa)	Cement Type	Maximum Aggregates Nominal Size (mm)
Precast Modules	F – 1	50	10 (SF)	32
Cover Slabs	F – 1	30	10	32
Reinforced Piers	F – 1	35	10	75
Concrete In-fill	F – 1	25	10	75
Tremie Concrete	N	25	10	20

8.0 CONCLUSIONS

The structural design analysis demonstrates that the Intake Approach and Accelerating Walls as designed and presented in this proposal submission are fully capable of withstanding the loadings under all operating conditions required for the project, based on the information provided in the proposal and relevant codes and practices.

More in-depth analysis during the detailed design stage will be required to finalize the design and to reflect new information obtained through investigations and research.

Appendix 1.1(s)
Draft Drawings

Appendix 1.1(s) - Draft Drawings

[See attached]

GENERAL NOTES

1.0 SCOPE OF WORK (INTAKE WORKS)

1.1 CONSTRUCT NEW ACCELERATING WALL
1.2 EXCAVATE INTAKE CHANNEL
1.3 EXTEND PIERS 1 AND 2 OF INCW STRUCTURE
1.4 CONSTRUCT INTAKE APPROACH WALL
1.5 REMOVE EXISTING ACCELERATING WALL

2.0 GENERAL

2.1 THESE DRAWINGS REPRESENT THE PRELIMINARY DESIGN OF THE WORK SCOPE WHICH MAY BE USED FOR BUDGETING PURPOSE. MORE ACCURATE DETAILED DESIGN DRAWINGS WILL BE PROVIDED IN DUE COURSE.

2.2 THE GENERAL NOTES ARE APPLICABLE TO ALL PARTS OF THE INTAKE WORKS OF THE PROJECT AND SHALL BE READ IN CONJUNCTION WITH THE DRAWINGS AND SPECIFICATIONS.

2.3 THE CONTRACTOR HAS THE RESPONSIBILITY TO VERIFY ALL DETAILS AND DIMENSIONS OF THE EXISTING SITE AND ADJACENT STRUCTURES, AND TO OBTAIN ALL SITE DIMENSIONS. IF DURING THE COURSE OF WORK, EXISTING CONDITIONS ARE FOUND TO BE DIFFERENT FROM THOSE SHOWN, NOTIFY THE ENGINEERING CONSULTANT IMMEDIATELY BEFORE PROCEEDING WITH THE WORK.

2.4 DETAILS ARE SHOWN TO SHOW THE END RESULT OF DESIGN. ANY MODIFICATIONS TO SUIT FIELD DIMENSIONS AND CONDITIONS SHALL BE SUBMITTED TO ENGINEERING CONSULTANT FOR REVIEW PRIOR TO WORK.

3.0 FOUNDATIONS

3.1 INFORMATION REGARDING SUBSURFACE CONDITIONS AND ELEVATIONS ARE PROVIDED IN CONCEPT DRAWING NO. NAW130-DDE-29310-0007 R3 PROVIDED BY ONTARIO POWER GENERATION.

3.2 FOUNDATION AREAS SHALL BE CLEARED OF LOOSE, SOFT COMPRESSIBLE MATERIALS BEFORE PLACING PRECAST CONCRETE CELLULAR MODULES.

3.3 PRECAST CONCRETE CELLULAR MODULES MUST BE ACCURATELY LEVELLED AND POSITIONED TO ENSURE PROPER ALIGNMENT.

3.4 DEVIATION OF FOUNDATION CONTOURS MUST BE BROUGHT TO THE ATTENTION OF ENGINEERING CONSULTANT FOR POSSIBLE ADJUSTMENT OF DESIGN.

4.0 EXCAVATION

4.1 THE SIDES OF THE INTAKE CHANNEL EXCAVATION SHALL BE LINE-DRILLED. AND CONTROLLED BLASTING SHALL BE EMPLOYED TO ENSURE THAT THE ROCK BEYOND THE EXCAVATION LIMITS IS NOT DAMAGED OR DESTABILIZED. ANY DAMAGED ROCK OUTSIDE THE REQUISITE EXCAVATION LINES SHALL BE REMOVED AND BACKFILLED WITH CONCRETE ADEQUATELY TIED BACK TO SOUND ROCK.

4.2 EXCAVATION OF THE INTAKE CHANNEL SHALL BE DONE IN TWO STAGES. THE FIRST STAGE CONSISTS OF EXCAVATION OF THE TWO SHALLOW APPROACH SECTIONS IN THE WET UP TO ELEVATION 162.20. THE SECOND STAGE WILL BE DONE IN THE DRY CONDITION PROVIDED BY THE COFFERDAM.

5.0 GROUTING

5.1 THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE DESIGN OF MULTIPLE GROUT CURTAINS TO ENSURE DEEPER EXCAVATING AREA IS SUFFICIENTLY DRY THROUGHOUT THE PERIOD FOR THE INTAKE CHANNEL EXCAVATION AND CONSTRUCTION OF THE CONCRETE INTAKE STRUCTURE.

6.0 CONCRETE

6.1 CONFORM TO THE REQUIREMENTS OF CSA STANDARD A23.1-00.

6.2 ALL CONCRETE TO BE FIELD TESTED IN ACCORDANCE WITH THE REQUIREMENTS OF A23.1-00 AND A23.2-00.

6.3 ALL CONCRETE IS TO HAVE THE SPECIFIED 28 DAY COMPRESSION STRENGTH, WATER CEMENTING MATERIAL RATIO, AND AIR CONTENT IN ACCORDANCE WITH THE REQUIREMENTS OF CSA STANDARD A23.1-00.

6.4 ALL CONCRETE SHALL BE NORMAL DENSITY CONCRETE AND CONFORMS TO THE FOLLOWING:

LOCATION	EXPOSURE CLASS	MIN. f'_C (MPa)	CEMENT TYPE	MAX. AGGR. NOMINAL SIZE (mm)
PRECAST MODULES ⚠2	F-1	50	10 (SF)	32
REINFORCED PIERS	F-1	35	10	75
MASS CONCRETE & IN-FILL	F-1	25	10	75
COVER SLABS	F-1	30	10	32
TREMIE CONCRETE	N	25	10	20

7.0 REINFORCING STEEL

7.1 ALL REINFORCING STEEL BARS SHALL BE DEFORMED AND SHALL CONFORM TO CAN/CSA STANDARD G30.18M92 (R1998).

7.2 REINFORCING STEEL SHALL BE GRADE 400 UNLESS OTHERWISE SPECIFIED.

8.0 BACK-FILLING

8.1 NO BACKFILL SHALL BE PLACED BEHIND THE CONCRETE APPROACH WALL UNTIL ROCKFILL HAS BEEN PLACED UP TO THE DESIRED TOP LEVEL AND CAPPED WITH CONCRETE COVER SLAB.

8.2 BACKFILL MATERIALS ARE TO BE CLEAN, AND FREE-DRAINING.

9.0 ROCK FILL

9.1 ROCK FILL MATERIALS TO BE PLACED WITHIN THE PRECAST CONCRETE CELLULAR WALL MODULES SHALL CONSIST OF CLEAN ROCK FRAGMENTS AND SHALL BE FREE FROM ORGANIC MATERIAL.

9.2 ROCK FILL SHALL BE REASONABLY UNIFORMLY GRADED IN SIZE UP TO A MAXIMUM OF 500mm AND SUCH THAT NOT MORE THAN 10 % BY WEIGHT SHALL BE LESS THAN 150mm AND MORE THAN 50 % BY WEIGHT SHALL CONSIST OF PARTICLES 300mm OR LARGER IN SIZE.

10.0 SEQUENCES OF CONSTRUCTION ⚠2

10.1 IT IS ESSENTIAL THAT AT LEAST ONE ACCELERATION WALL IS IN PLACE AT THE EXISTING OR NEW LOCATIONS DURING THE WINTER MONTHS TO SEPARATE THE FAST FLOW AT THE INCW AND THE LOW FLOW AREAS OUTSIDE THE WALL. THE CONTRACTOR SHALL ORGANIZE AND PLAN HIS WORK TO ENSURE THAT THIS IS COMPLIED WITH STRICTLY OR WILL BE RESPONSIBLE FOR ALL CONSEQUENCES RESULTING FROM HIS FAILURE TO DO SO.

10.2 REMOVAL OF EXISTING ACCELERATING WALL AND CONSTRUCTION OF THE NEW ACCELERATING WALL SHALL BE COMPLETED PRIOR TO INSTALLATION OF THE COFFERDAM AT THE INTAKE.

10.3 CONSTRUCTION OF THE EAST INTAKE APPROACH WALL CAN BE DONE INDEPENDENTLY AT ANY TIME PENDING ON OTHER CONSTRUCTION CONSIDERATIONS.

10.4 EXTENSION OF THE PIERS 1 AND 2 OF THE INCW STRUCTURE AND PART OF THE WEST APPROACH WALL SHALL BE DONE IN THE DRY.

10.5 REMOVAL AND DISPOSAL OF THE GROYNE SHALL BE COMPLETED PRIOR TO REMOVAL OF INTAKE AREA COFFERDAM.

10.6 THE TEMPORARY COFFERDAMS SHALL BE REMOVED AFTER THE SECTIONAL SERVICE GATES FOR THE INTAKE ARE IN PLACE AND WITH BALANCED WATER PRESSURE ON EACH SIDE OF THE COFFERDAMS.

10.7 COMPLETION OF THE WEST APPROACH WALL AND BACKFILL BEHIND THE WALL SHALL BE UNDERTAKEN AFTER THE REMOVAL OF THE ICE PROTECTION GROYNE AND COFFERDAM.

11.0 CONSTRUCTION NOTES

11.1 THE CONTRACTOR SHALL CARRY OUT SITE SURVEYS INCLUDING HYDROGRAPHIC SURVERYS TO DETERMINE THE EXISTING ELEVATIONS OF THE RIVER BED AT THE NEW ACCELERATING WALL LOCATION.

11.2 THE CONTRACTOR SHALL VERIFY ALL ELEVATIONS AND DIMENSIONS OF THE EXISTING WORK AND ALL DETAILS ON SITE AGAINST THE PROPOSED WORK AND REPORT ANY DISCREPANCIES TO THE ENGINEERING CONSULTANT BEFORE PROCEEDING WITH THE WORK.

11.3 THE CONTRACTOR SHALL REFER TO THE SET OF REFERENCE DRAWINGS PROVIDED BY OPG FOR DETAILS OF THE EXISTING STRUCTURES (INCW PIERS, EXISTING ACCELERATING WALL, EXISTING APPROACH WALL, ETC.)

11.4 FOR PERFORMANCE OF THE RELEVANT WORK IN THE INCW PART PROJECT SITE, CONSTRUCTION ACTIVITIES WILL BE CO-ORDINATED CLOSELY WITH ONTARIO POWER GENERATION REGARDING ACCESS, WATER CONTROL, PERIOD OF TIME, ETC FOR ANY IN-RIVER WORK.

11.5 THE CONTRACTOR IS RESPONSIBLE FOR DESIGN OF ANY TEMPORARY SHORING, AND THE STEEL CASING WITH ASSOCIATED STRUT SYSTEMS AS REQUIRED FOR THE BRIDGING COMPONENTS AND THE NOSE SECTION OF THE ACCELERATING WALL.

11.6 PRIOR TO THE PLACEMENT OF MASS CONCRETE IN-FILL, THE AREA SHALL BE CLEANED OF SILT AND DEBRIS.

11.7 WHEN THE MASS CONCRETE IN-FILL AREA CANNOT BE KEPT WATER FREE, PROCEDURES FOR UNDERWATER CONCRETING SHALL BE ESTABLISHED TO INCLUDE CONCRETE MIX DESIGN, APPROPRIATE ADMIXTURES, PLACEMENT SCHEMES, INSPECTION PLAN, AND CONCRETE SAMPLING PLAN TO ENSURE COMPETENT CONCRETE IS ACHIEVED. WHEN THE CONCRETE SURFACE HAS BEEN BROUGHT ABOVE THE WATER LINE, REGULAR CONCRETE SHALL BE PLACED IN THE DRY AFTER ALL THE LAITANCE HAS BEEN REMOVED FROM THE SURFACE OF THE CONCRETE.

11.8 FOR EXTENDING THE PIERS, DEMOLISHED CONCRETE SURFACES SHALL BE THOROUGHLY SCALED. AND, PRIOR TO THE PLACEMENT OF NEW CONCRETE, THE ENTIRE SURFACE OF THE EXISTING CONCRETE SHALL BE THOROUGHLY CLEANED BY SANDBLASTING, FOLLOWED BY AN AIR-WATER JET TO REMOVE ALL LOOSE AND ADHERING CONTAMINATING MATERIAL TO ENSURE FULL BONDING.

11.9 ALL REINFORCING STEEL ANCHORS INTO ROCK SHALL BE INSTALLED USING EITHER CEMENTITIOUS OR RESIN-TYPE GROUT WITH PROCEDURES RECOMMENDED BY THE MANUFACTURER.

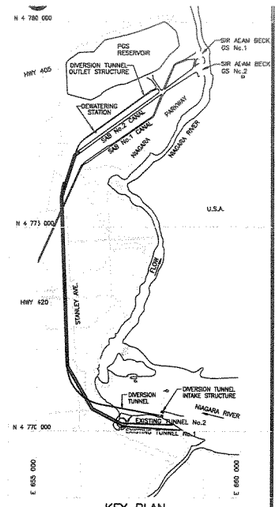
11.10 THE CONTRACTOR SHALL ADHERE TO ALL ENVIRONMENTAL REQUIREMENTS AND PRESCRIBED WORKING CONDITIONS NOTED ON PERMITS AND APPROVALS FROM AGENCIES IN CONSTRUCTION OF ALL TEMPORARY AND PERMANENT WORK.

12.0 DEWATERING STRUCTURE AT PUMP GENERATION STATION (PGS)

12.1 FOR REMOVAL OF DEWATERING STRUCTURE AT PGS REFER TO AS-BUILT DRAWING PROVIDED BY ONTARIO POWER GENERATION.

13.0 QUANTITIES

13.1 THE CONTRACTOR SHALL USE THE MOST UP-TO DATE QUANTITY ESTIMATES ASSOCIATED WITH THESE DRAWINGS FOR BUDGETING PURPOSE. THESE QUANTITIES REPRESENT THE WORK COMPLETED AT A PRELIMINARY DESIGN LEVEL, BASED ON DESIGN INFORMATION PROVIDED AND DIRECTIONS RECEIVED FROM THE CONSTRUCTION TEAM, AND WILL BE SUBJECT TO MODIFICATION AND UPDATING AS THE DETAILED DESIGN AND CONSTRUCTION ARE PROCEEDED.



KEY PLAN

LIST OF DRAWINGS

INTAKE WORKS:

1. GENERAL NOTES
2. WEST APPROACH WALL
3. EAST APPROACH WALL
4. INTAKE CHANNEL
5. PIERS 1 AND 2 EXTENSION
6. NEW ACCELERATION WALL AND PIER 5 MODIFICATION
7. EXISTING ACCELERATING WALL REMOVAL

CIVIL WORKS:

8. CONSTRUCTION FACILITIES INTAKE AREA
9. CONSTRUCTION FACILITIES OUTLET AREA

DATE: 11 MAY 05

mf no/ number	rev no	date	revisions	by	appd
	⚠2	05/05/05	GENERAL REVISION	BT	
	⚠1	05/04/05	GENERAL REVISION	BT	

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS - GENERAL NOTES

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

dsn	designed by	B	
dtld		I	
date yr/month/day 05/05-11	design approved	M	plot scale
			dtld. scale
scale AS SHOWN	mylar/sepia		CAD file type
dwg no MH - 6001			rev 00

SURVEY DATUM
ELEVATIONS ARE IN METRES AND ARE BASED ON NAD83 SYSTEM

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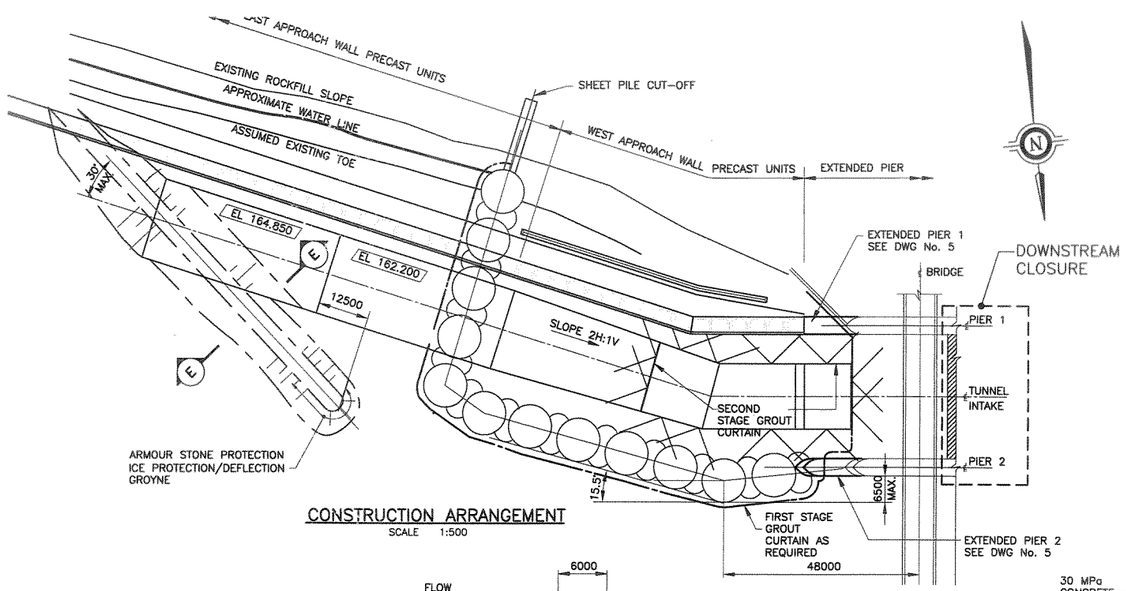
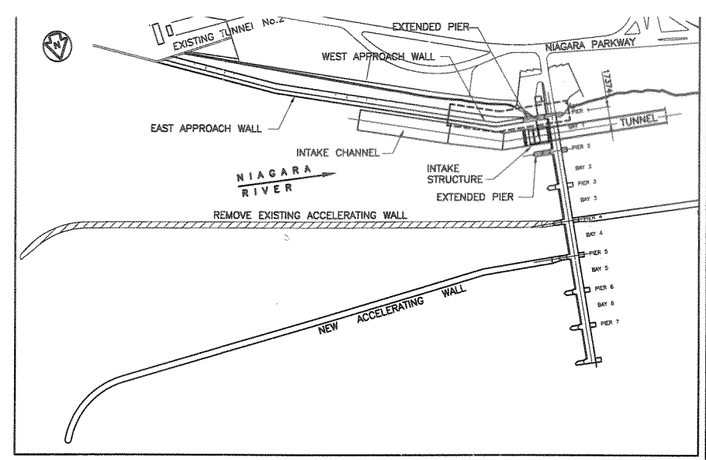
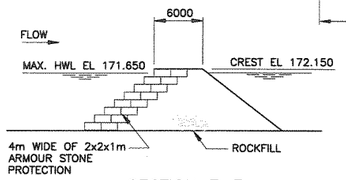
PLOT DATE: 2005/05/11 08:53:44 AM

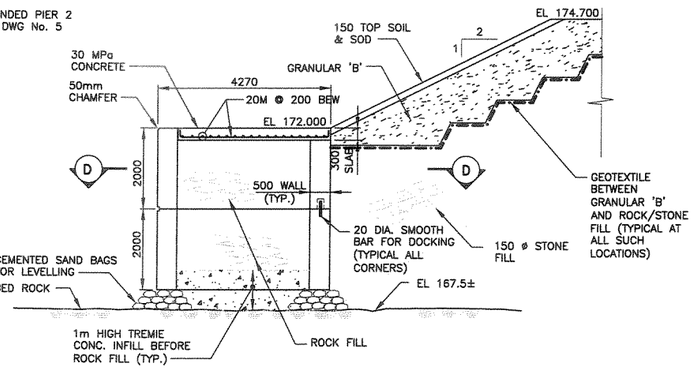


CONSTRUCTION ARRANGEMENT
SCALE 1:500

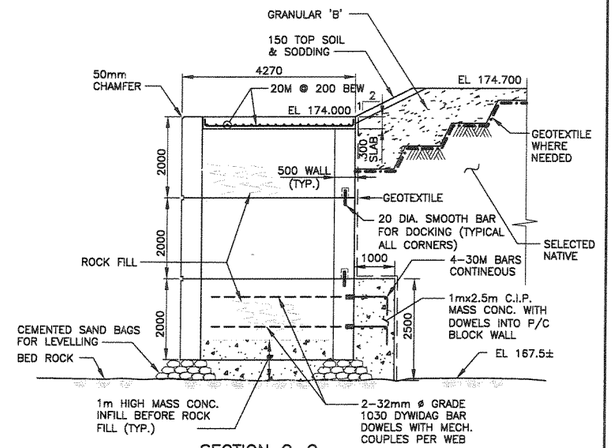




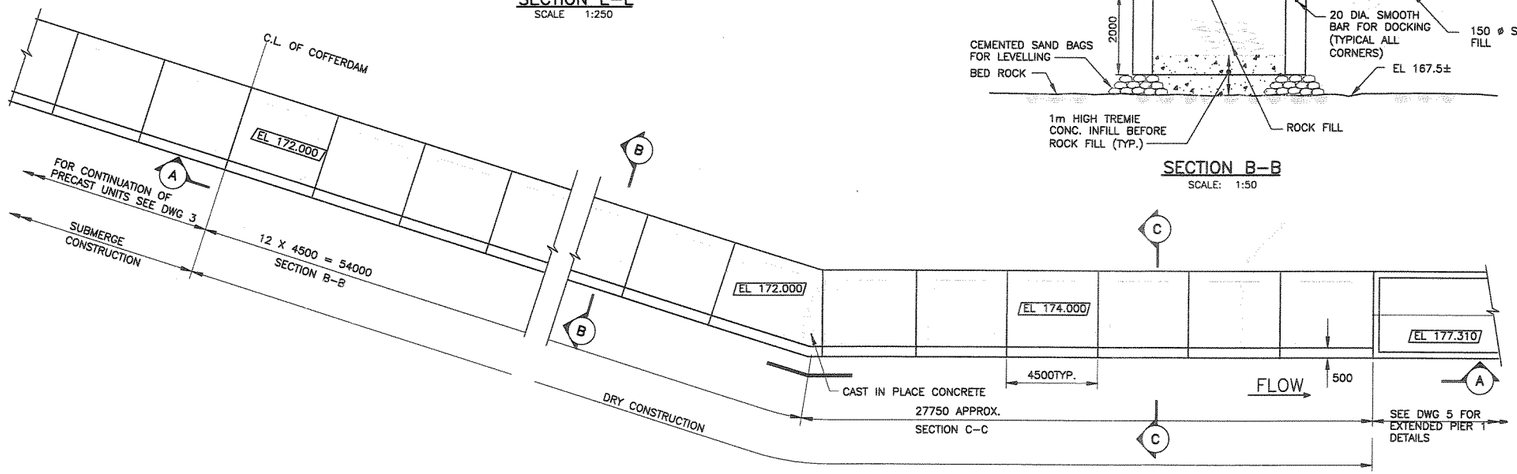
SECTION E–E
SCALE 1:250

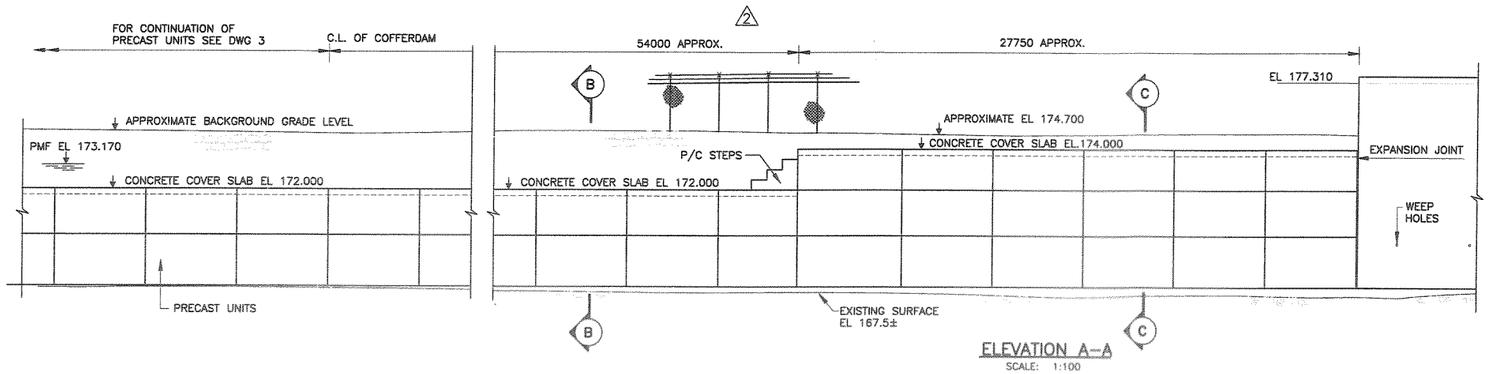


SECTION B–B
SCALE: 1:50

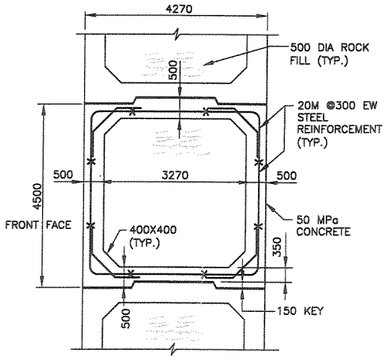


SECTION C–C
SCALE: 1:50





ELEVATION A–A
SCALE: 1:100



SECTION D–D
SCALE: 1:50

APPROX. WT. = 40 Tonnes/Unit

DATE: 11 MAY 05

2	09/05/05	GENERAL REVISION	DT	
1	25/04/05	MISC. REVISION	DT	
mf roll number	ver no	date	particulars	draw / chkd	appd

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS -
WEST APPROACH WALL

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

dsn	designed by		
chkd			
date yr/month/day 05/05-11	design approved		plot scale
scale AS SHOWN	authorised		plot. code
			CAD file type
dwg no MH - 6002			rev 00

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1:200	0	4	8	12	16	20	m
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1:500	0	10	20	30	40	50	m

DO NOT SCALE DRAWING

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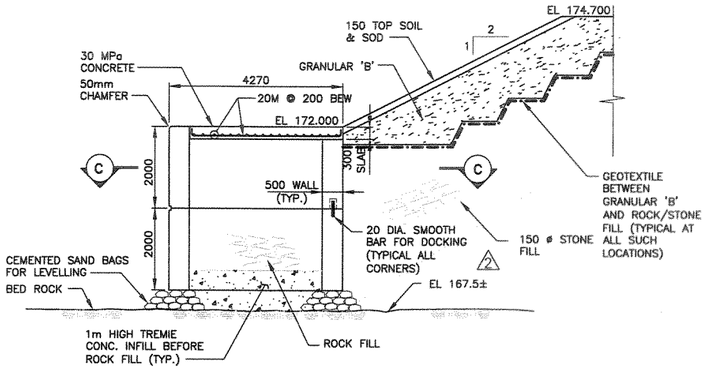
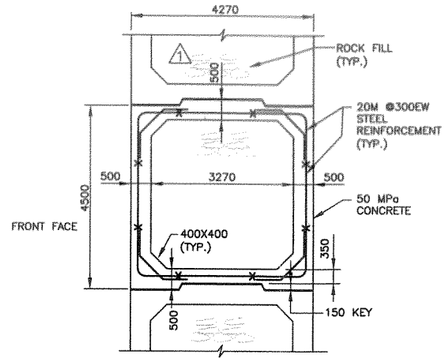
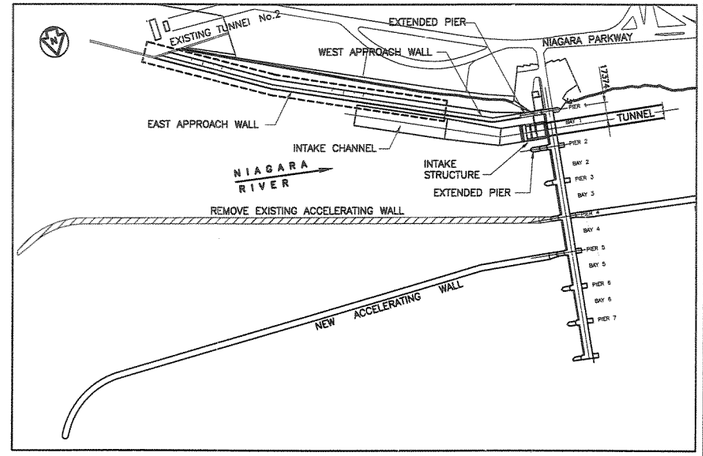


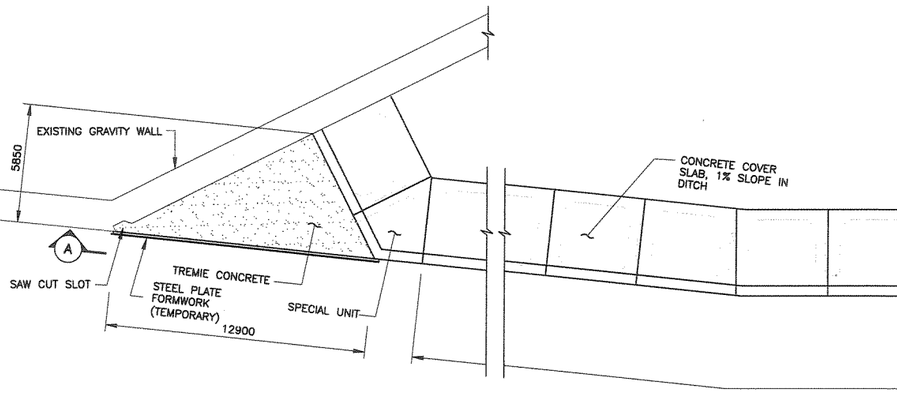
SECTION B–B
SCALE: 1:50

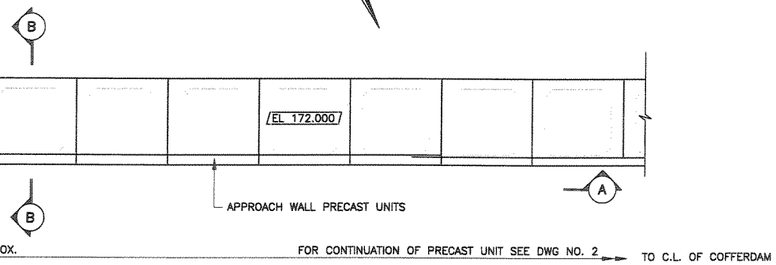


SECTION C–C
SCALE: 1:50

APPROX. WT. = 40 Tonnes/Unit



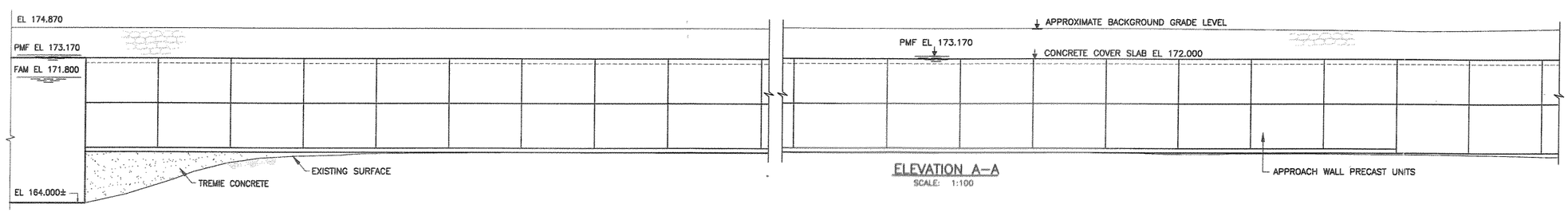




PLAN
SCALE: 1:100

61 X 4500 = 274500 APPROX.
SECTION B–B

FOR CONTINUATION OF PRECAST UNIT SEE DWG NO. 2 → TO C.L. OF COFFERDAM



ELEVATION A–A
SCALE: 1:100

DATE: 11 MAY 05

2	09/05/05	GENERAL REVISION	DT		
1	29/04/05	MISC. REVISION	DT		
mf roll number	ver no	date	particulars	des chkd	appd

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS -
EAST APPROACH WALL

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — Morrison Hershfield

des	designed by	size	
chkd			
date yr/month/day	design approved		plot scale
05/05-11			plot. code
scale AS SHOWN	authorized		CAD file type
dwg no MH - 6003			rev 00

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DO NOT SCALE DRAWING

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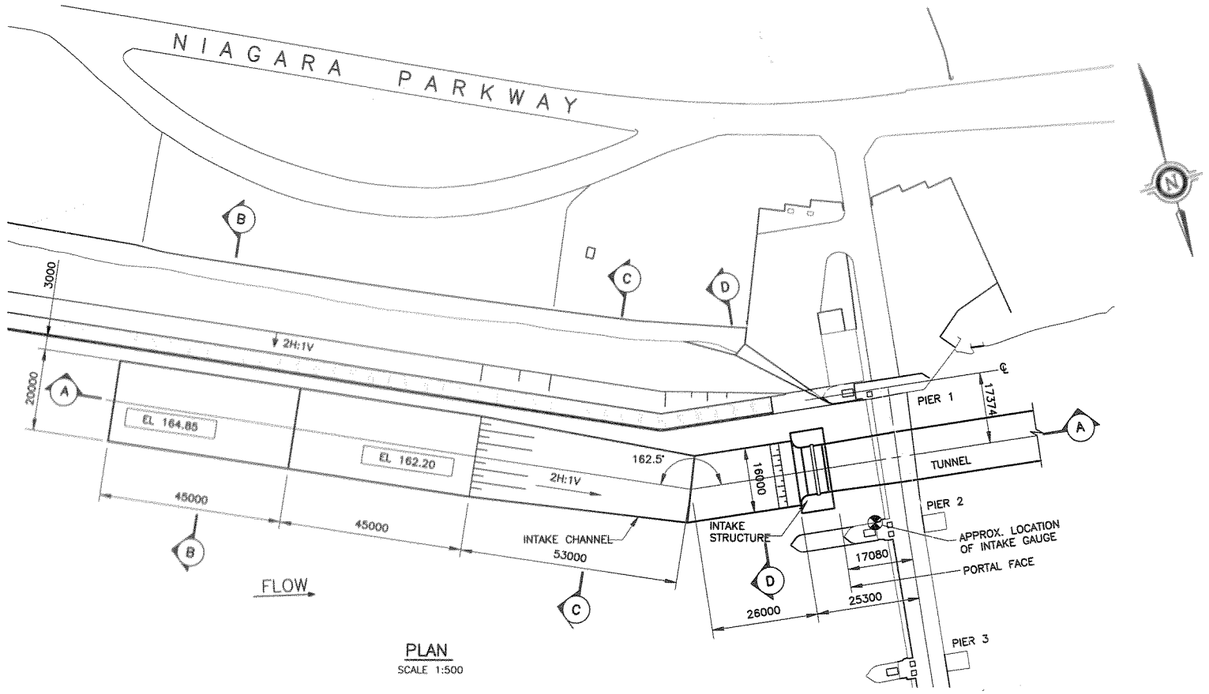

PLAN
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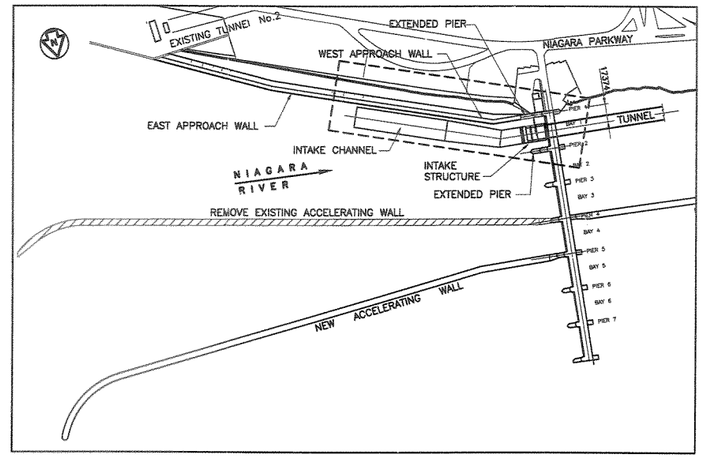

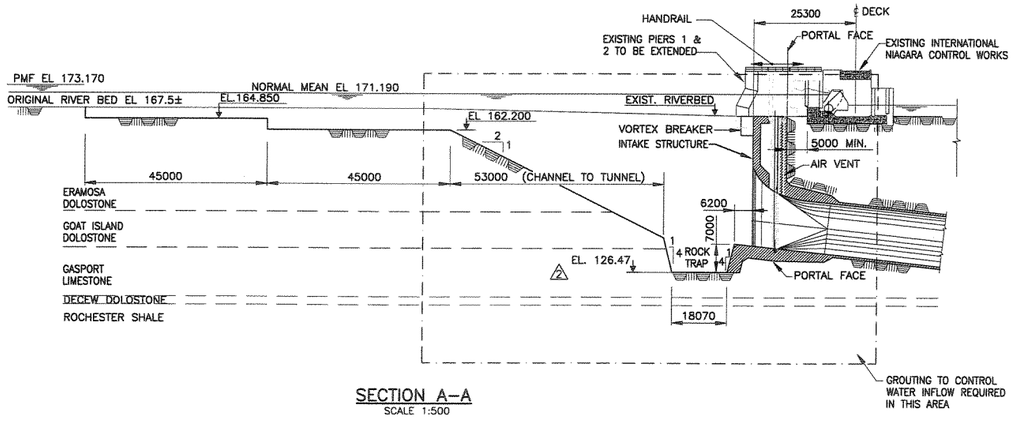

SECTION A–A
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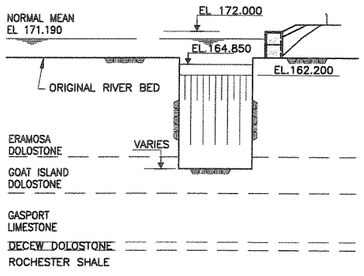

SECTION C–C
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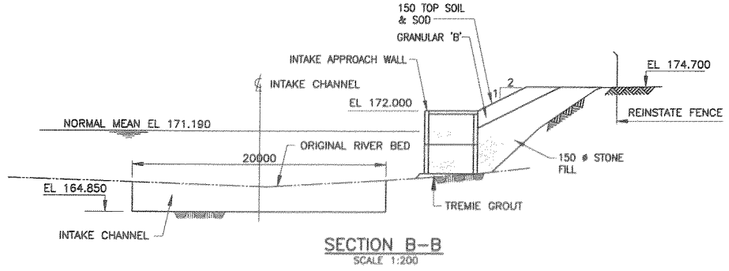
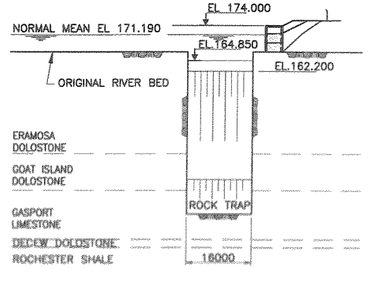


SECTION B–B
SCALE 1:200



SECTION D–D
SCALE 1:500

DATE: 11 MAY 05

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	1	29/04/05	NO CHANGE	DT	
ref rel number	ver no	date	particulars	drwn / chkd	appd

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS - INTAKE CHANNEL

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

dwn	designed by		
chkd			
date yr/month/day 05/05-11	design approved	plot scale	
scale AS SHOWN	authorized	dwg. code	
		CAD file type	
dwg no MH - 6004			rev 00

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1:200	0	4	8	12	16	20	m
1:250	0	5	10	15	20	25	m
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DO NOT SCALE DRAWING

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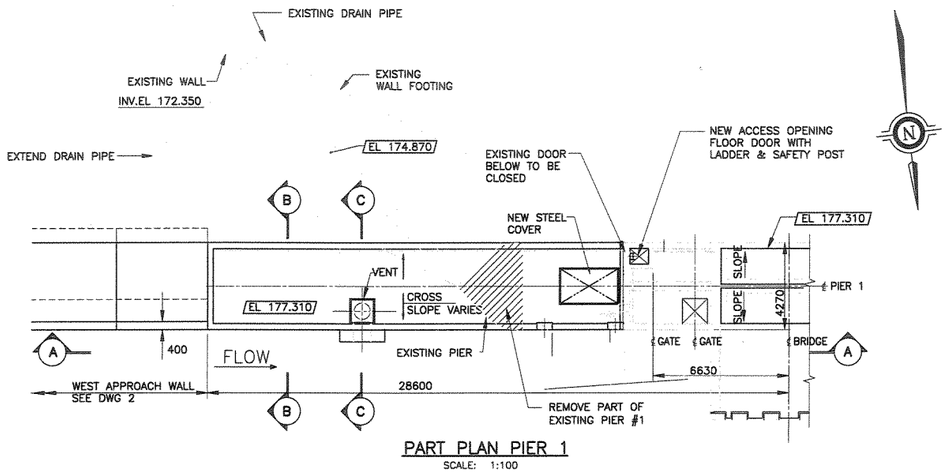
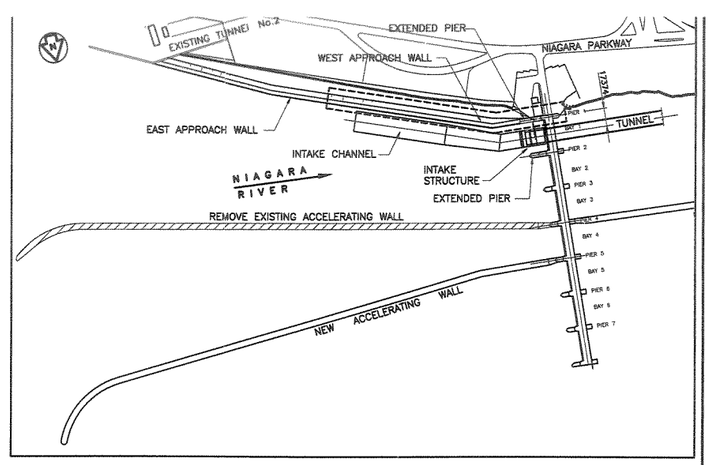
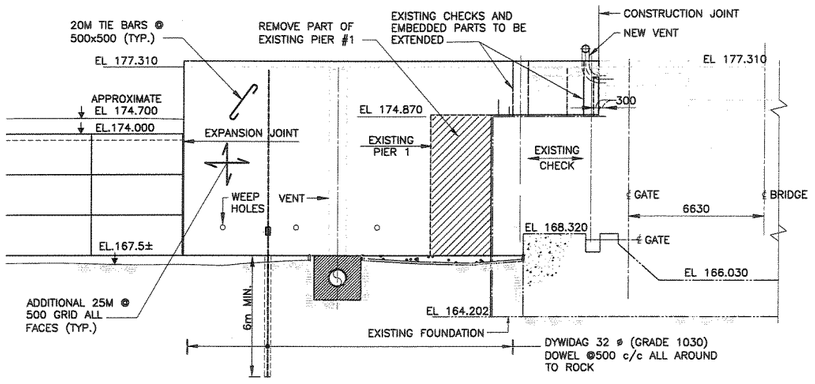


PART PLAN PIER 1

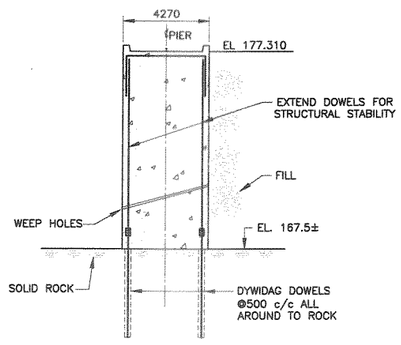
SCALE: 1:100





ELEVATION A–A

SCALE: 1:100



SECTION B–B

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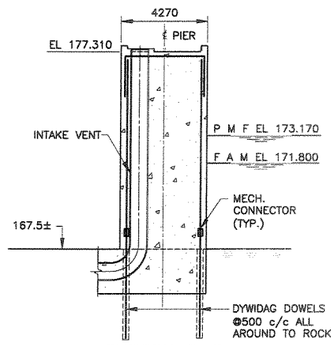
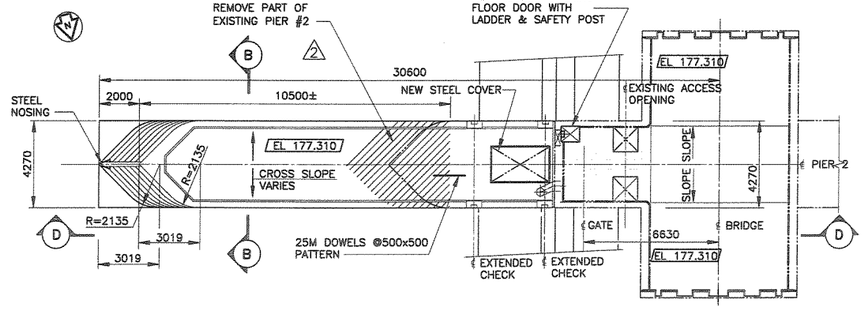


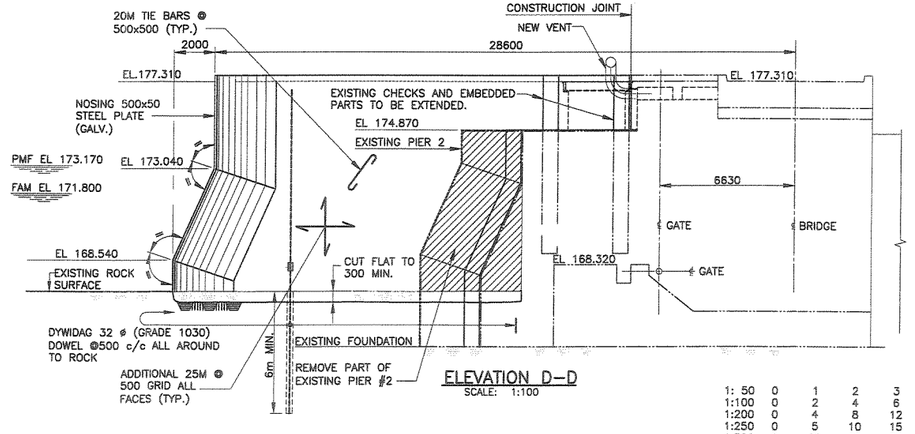
SECTION C–C

SCALE: 1:100



PLAN AT PIER 2

SCALE: 1:100



ELEVATION D–D

SCALE: 1:100

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1:100	0	2	4	6	8	10	m
1:200	0	4	8	12	16	20	m
1:250	0	5	10	15	20	25	m
1:500	0	10	20	30	40	50	m

DO NOT SCALE DRAWING

DATE: 11 MAY 05

ref. roll number	rev no	date	particulars	plan	sect	appd
	2	09/05/05	GENERAL REVISION			DT
	1	29/04/05	MISC. REVISION			DT

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS -
PIER 1 AND PIER 2 EXTENSION

ONTARIOPOWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

drawn		designed by	
chkd			dsgn date
date	yr/month/day 05/05-11	design approved	plot scale
			plot. code
scale	AS SHOWN	authorized	CAD file type
dwg no	MH - 6005		rev 00

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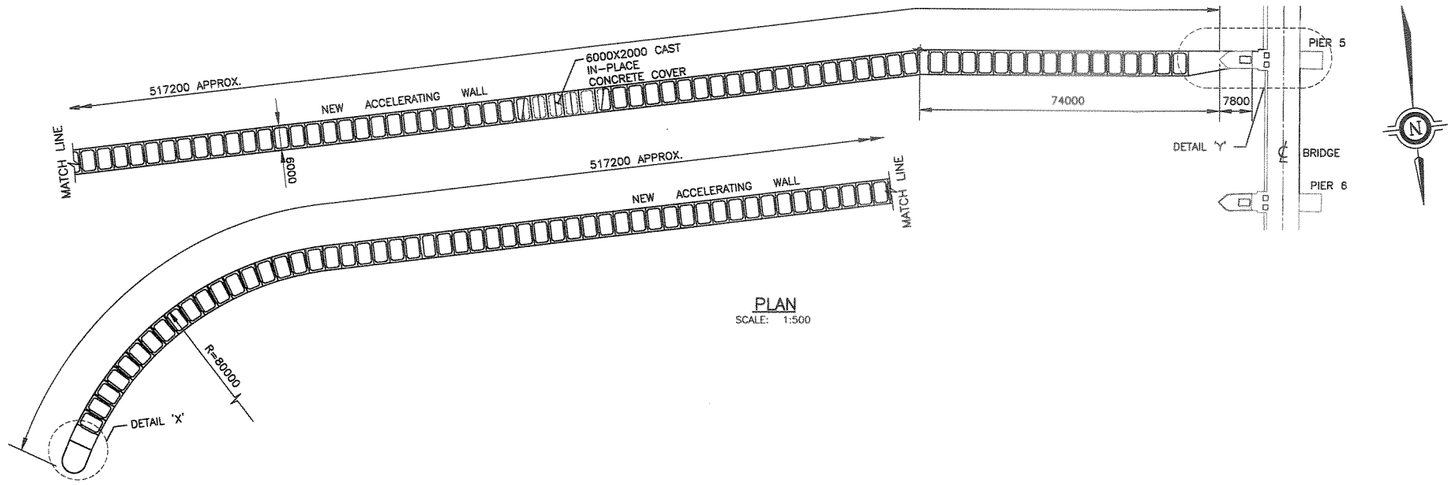
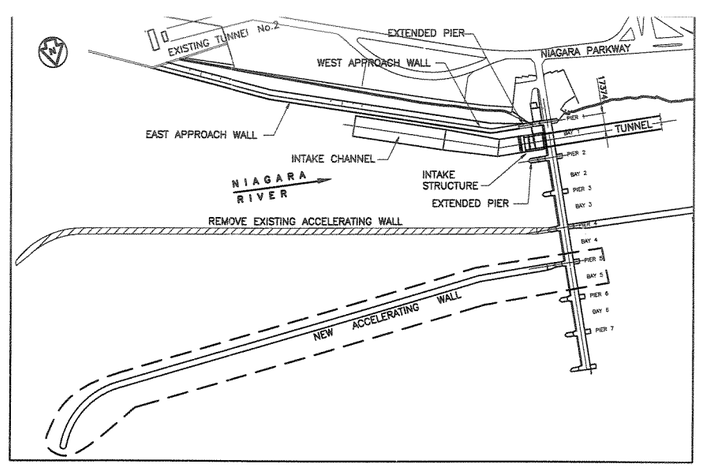
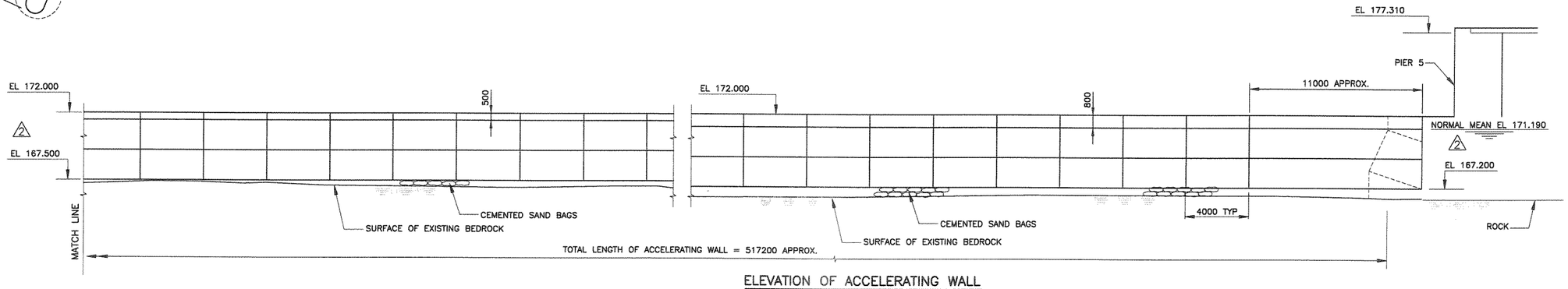
PLOT DATE: 2005/05/11 10:54:01 AM

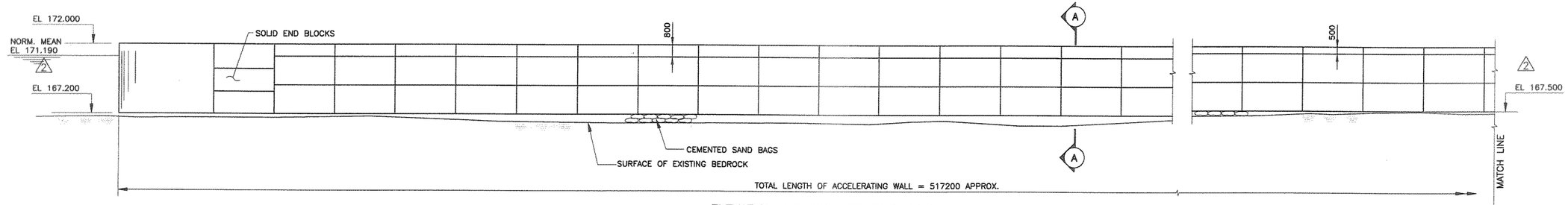


PLAN
SCALE: 1:500

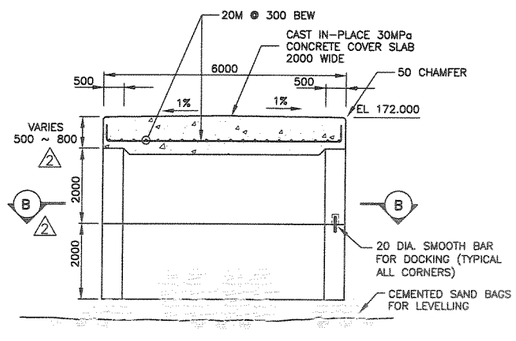




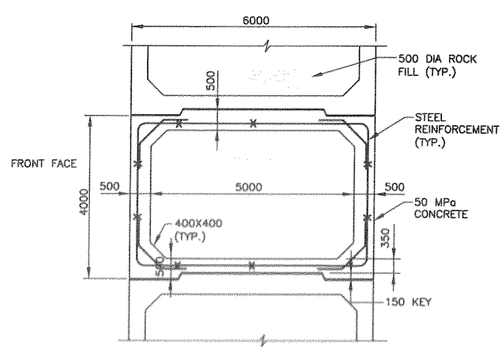
ELEVATION OF ACCELERATING WALL
SCALE 1:100



ELEVATION OF ACCELERATING WALL
SCALE 1:100

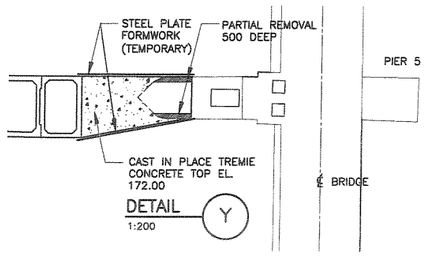


SECTION A–A
SCALE: 1:50

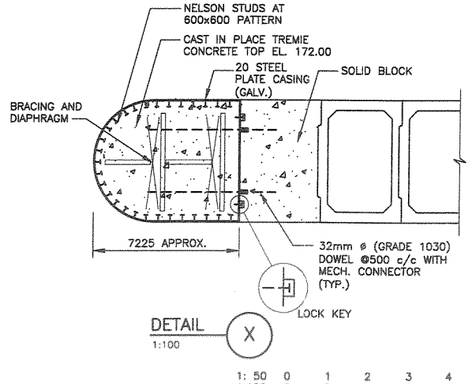


SECTION B–B
SCALE: 1:50

APPROX. WT. = 45 Tonnes/Unit



DETAIL Y
1:200



DETAIL X
1:100

1: 50	0	1	2	3	4	5 m
1:100	0	2	4	6	8	10 m
1:200	0	4	8	12	16	20 m
1:250	0	5	10	15	20	25 m
1:500	0	10	20	30	40	50 m

DO NOT SCALE DRAWING

DATE: 11 MAY 05

mf roll number	ver no	date	particulars	dsn chkd	appd
	2	05/05/05	GENERAL REVISION	DT	
	1	25/04/05	MISC. REVISION	DT	

NIAGARA TUNNEL FACILITY PROJECT

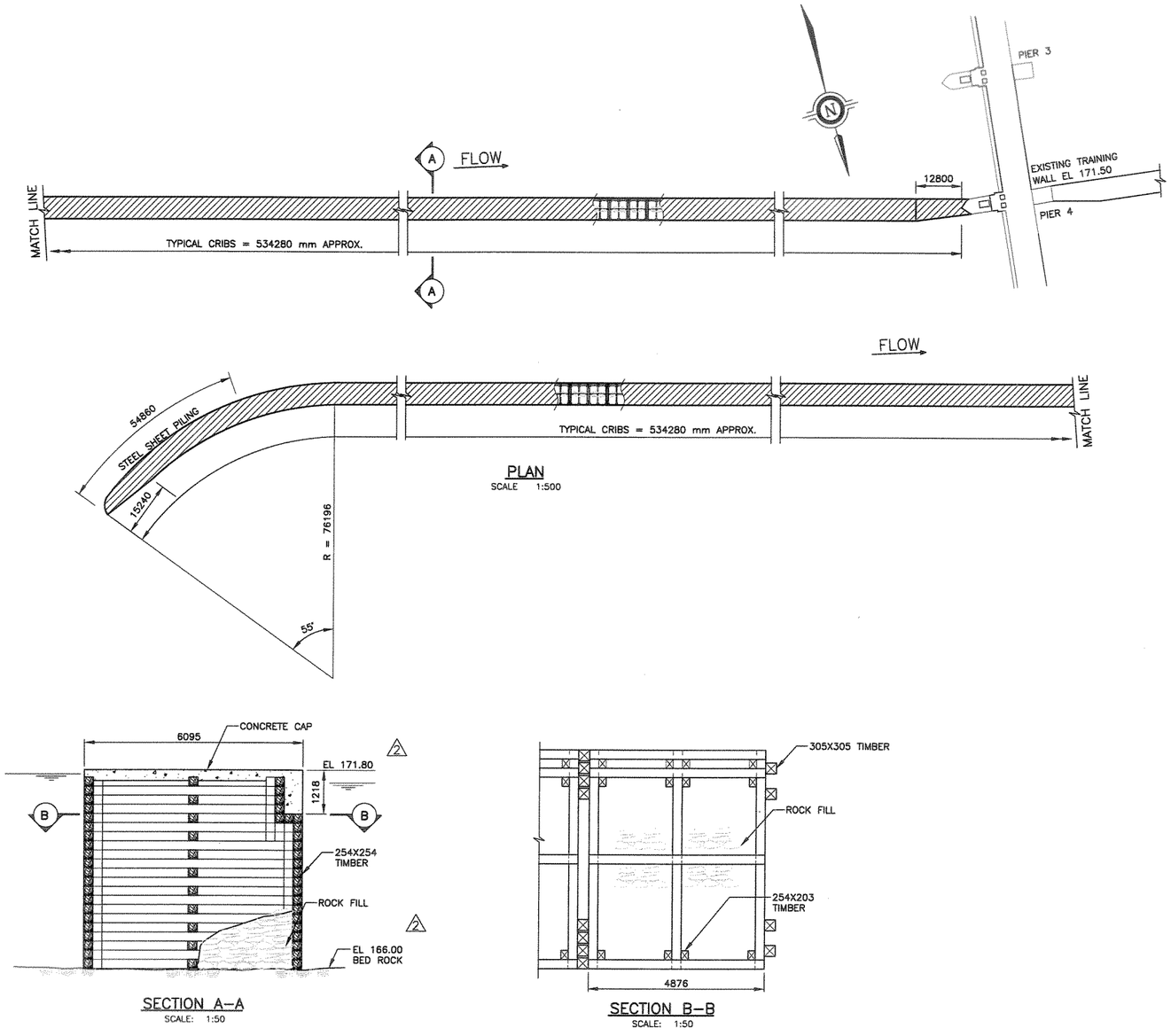
INTAKE WORKS -
NEW ACCELERATING WALL
AND PIER 5 MODIFICATION

ONTARIOPOWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

dsn	designed by		
chkd		size	
date yr/month/day 05/05-11	design approved		plot scale
scale AS SHOWN	authorized		plot. code
			CAD file type
dwg no	MH - 6006		rev 00

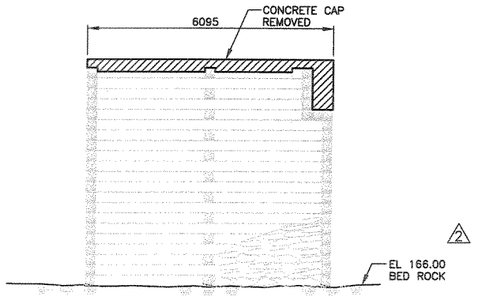
DRAWING NAME: R:\cm\1161\6000\Drawings\Struct\MH-6006 00.dwg (Layout1)
PLOT DATE: 2005/05/11 10:53:32 AM



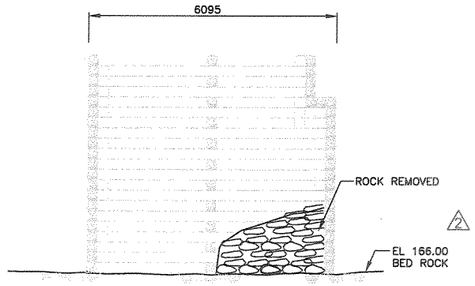
PLAN
SCALE 1:500

SECTION A–A
SCALE: 1:50

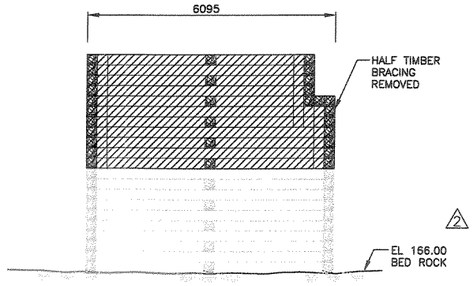
SECTION B–B
SCALE: 1:50



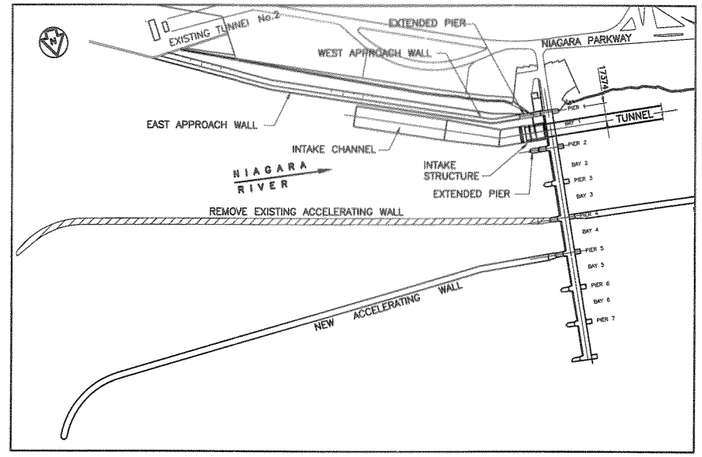
REMOVAL STAGE 1
SCALE: 1:50



REMOVAL STAGE 2
SCALE: 1:50



REMOVAL STAGE 3
SCALE: 1:50



GENERAL NOTES

1.0 THE CONTRACTOR SHALL BE RESPONSIBLE FOR MEETING ALL THE ENVIRONMENTAL REQUIREMENTS REGARDING IN–RIVER WORK AND DISPOSAL OF MATERIALS REMOVED FROM THE SITE.

2.0 CROSS–SECTIONS SHOWN IN THIS DRAWING ARE BASED ON TYPICAL CRIB FOR ILLUSTRATION PURPOSES ONLY. THE CONTRACTOR SHALL REFER TO THE SET OF REFERENCE DRAWINGS NO. NF28–F–6269 REV 4, NF28–F–6275 REV D, AND NF28–F–6276 REV D PROVIDED BY OPG FOR OTHER RELEVANT DESIGN DETAILS OF THE EXISTING ACCELERATING WALL.

3.0 THE CONTRACTOR HAS THE RESPONSIBILITY TO CONDUCT FIELD SURVEY AND INSPECTION OF THE EXISTING STRUCTURE TO VERIFY ALL DETAILS AND DIMENSIONS NECESSARY IN PLANNING AND EXECUTION OF THE REMOVAL WORK.

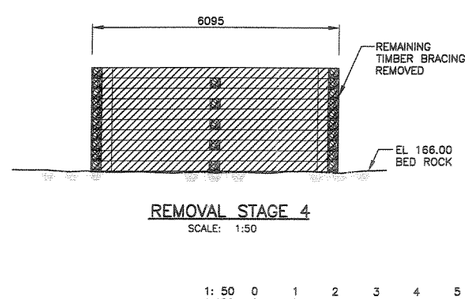
CONSTRUCTION NOTES

1.0 MEANS AND METHODS USED IN DEMOLITION OF THE EXISTING ACCELERATING WALL SHALL BE SUCH AS TO MINIMIZE IMPACT ON THE OPERATION OF THE INCW. ALL IN–RIVER ACTIVITIES SHALL BE CO–ORDINATED WITH ONTARIO POWER GENERATION.

2.0 DEMOLITION OF THE WALL SHALL BE UNDERTAKEN SECTION BY SECTION STARTING FROM THE FAR END WORKING TOWARDS THE INCW STRUCTURE. THE LENGTH OF EACH WALL SECTION SHALL BE DETERMINED BY THE CONTRACTOR WITH AGREEMENT OF THE ENGINEERING CONSULTANT. FOR EACH SECTION TO BE REMOVED, DEMOLITION SHALL BE DONE FROM THE TOP DOWN. AS SUCH, THE CONCRETE CAP WILL BE BROKEN UP AND REMOVED, FOLLOWED BY SAW CUTTING AND REMOVAL OF THE TOP HALF OF THE TIMBER CRIB FRAME, AND FINALLY THE BOTTOM HALF.

3.0 ALL STRUCTURAL MATERIALS OF THE EXISTING WALL SHALL BE REMOVED FROM THE NIAGARA RIVER. ROCK FILL MATERIALS OF GOOD QUALITIES MAY BE RE–USED FOR CONSTRUCTION OF THE NEW ACCELERATING WALL SUBJECT TO THE APPROVAL OF THE ENGINEERING CONSULTANT AS WELL AS ONTARIO POWER GENERATION.

DATE: 11 MAY 05



REMOVAL STAGE 4
SCALE: 1:50

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DO NOT SCALE DRAWING

mf roll number	ver no	date	particulars	dwn	appd
2	0	09/05/05	GENERAL REVISION	DT	
1	0	29/04/05	MISC. REVISION	DT	

NIAGARA TUNNEL FACILITY PROJECT

INTAKE WORKS -
EXISTING ACCELERATING WALL REMOVAL

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD

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chkd			plot scale
date yr/month/day 05/05-11	design approved		drwt. code
scale AS SHOWN	quantified		DAD file type
dwg no MH - 6007			rev 00

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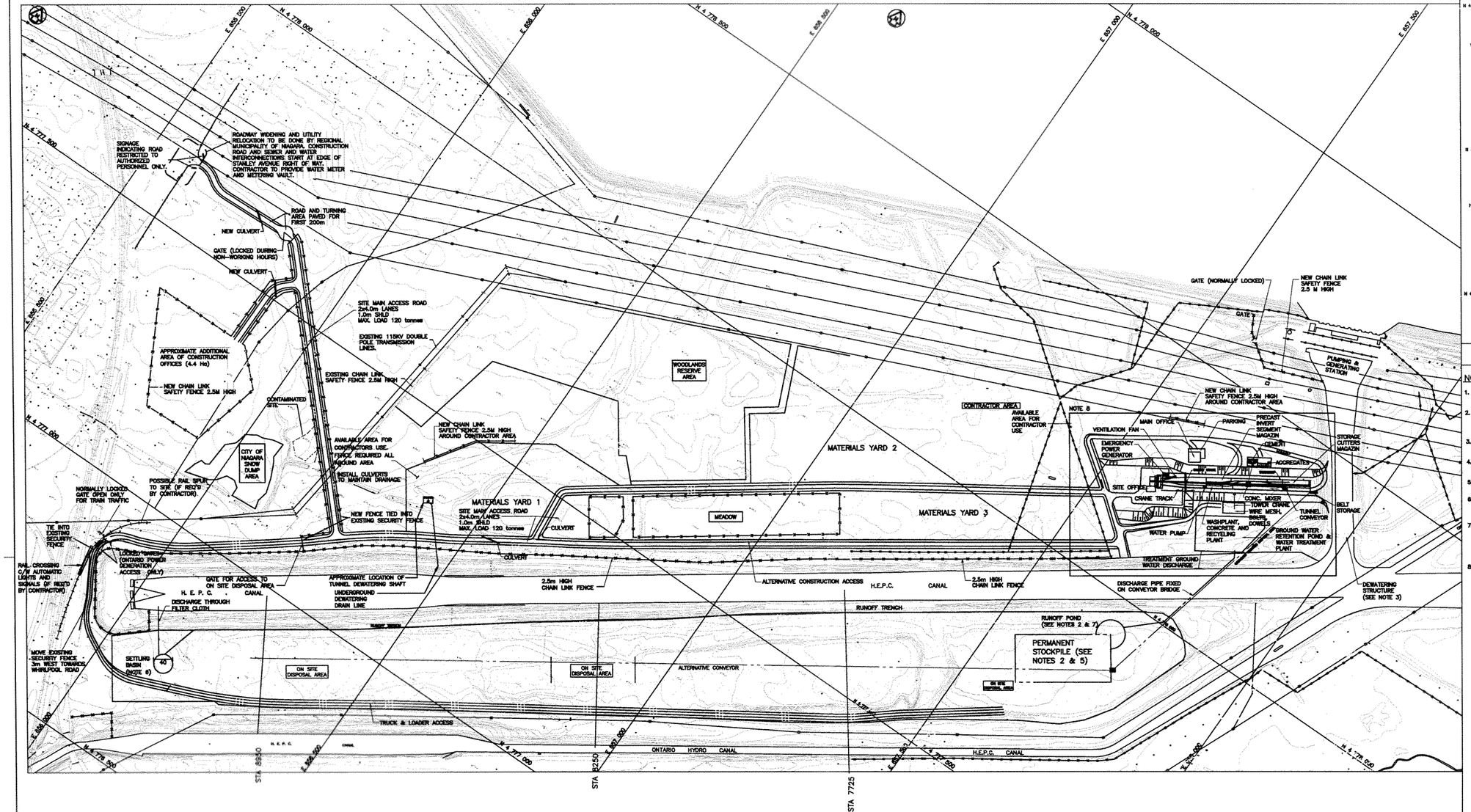

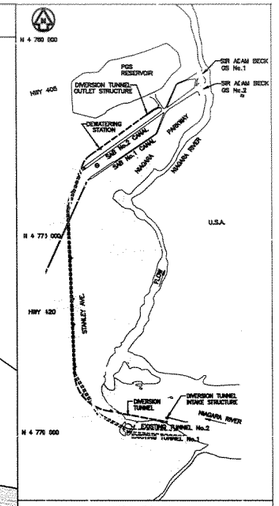

KEY PLAN
SCALE 1 : 65000

NOTES:

1. CONVEYOR CAPACITY 1200 t/hr CAPABLE OF WORKING 24 hr/day, 7 d/week.
2. PERMANENT SHALES CONTAINING BTEX STOCKPILE AND RUNOFF POND TO BE LINED IN ORDER TO AVOID GROUND CONTAMINATION.
3. STRUCTURE TO BE DEMOLISHED. EXISTING WATERMAIN ON THE STRUCTURE TO BE RELOCATED.
4. NO CLEARING AND CUTTING OF TREES PERMITTED BETWEEN MAY 1st TO JUNE 15th UNLESS BY OWNERS' PERMITS.
5. ROCHESTER, POWER GLEN & GRIMSBY FORMATION TO BE PLACED IN THE SEPARATE PILE.
6. CONTENTS OF SETTLING POND WILL BE TRANSFERED TO THE TREATMENT FACILITY IN MATERIALS YARD 2
7. CONTENTS OF THE RUNOFF POND WILL BE TRANSFERED DIRECTLY INTO THE TREATMENT FACILITY VIA PIPE. GROUND WATER FROM CONTAMINATED FORMATIONS WILL BE DIRECTED INTO THE RUNOFF POND, NOT INTO THE GROUND WATER RETENTION POND
8. SHOWED IN THE PLAN "SITE INSTALLATION TUNNELING"

LEGEND:

- AREA AVAILABLE FOR CONTRACTORS
- AREA NOT AVAILABLE FOR CONTRACTOR ACCESS
- DISPOSAL AREA
- PAVED CONSTRUCTION ROAD
- CHAIN LINK FENCE

EXCAVATED MATERIAL STOCKPILING PROCEDURES:
(BASED ON OPG'S MANAGEMENT OF EXCAVATED MATERIALS BY HATCH MOTT MacDONALD/ACRES INTERNATIONAL DATED DECEMBER 2004 AND ON OPG'S MANAGEMENT PLAN FOR BTEX BY HATCH MOTT MacDONALD DATED DECEMBER 2004)

*QUEENSTON SHALE TEMPORARILY STOCKPILED AT THE WEST END OF THE ON-SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

*SHALES CONTAINING BTEX (ROCHESTER,GRIMSBY & POWER GLEN FORMATION) PERMANENTLY STORED IN ON- SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

*LIMESTONES/DOLOMITES TEMPORARILY STORED FOR RE-USE.

*OTHER ROCKS - PERMANENTLY STOCKPILED IN ON-SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

1:3000 0 60 120 180 240 300 m

rvf rvd number	rev no	date	particulars	dsn / chkd	appd
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NIAGARA TUNNEL FACILITY PROJECT

CONSTRUCTION FACILITIES
OUTLET AREA

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — Morrison Hershfield

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chkd		
date yr/month/day 05/05-11	design approved	plot scale 1 : 1 M
scale AS SHOWN	authorized	plot. mode
dwg no MH - 6009		CAD file type DWG
		rev 01

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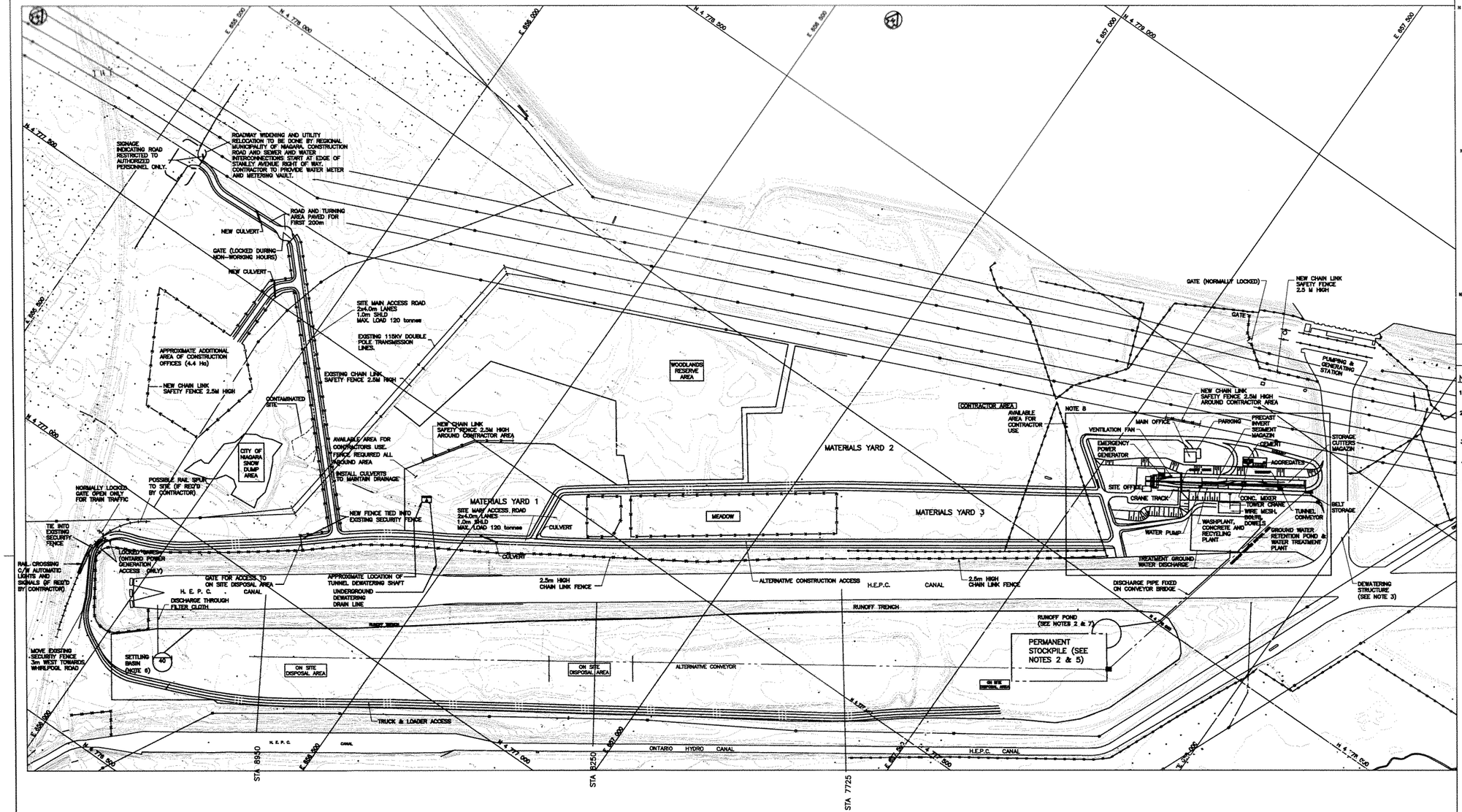

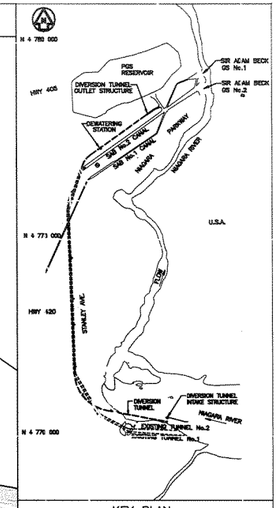

KEY PLAN
SCALE 1 : 80000

NOTES:

1. CONVEYOR CAPACITY 1200 t/hr CAPABLE OF WORKING 24 hr/day, 7 d/week.
2. PERMANENT SHALES CONTAINING BTEX STOCKPILE AND RUNOFF POND TO BE LINED IN ORDER TO AVOID GROUND CONTAMINATION.
3. STRUCTURE TO BE DEMOLISHED. EXISTING WATERMAIN ON THE STRUCTURE TO BE RELOCATED.
4. NO CLEARING AND CUTTING OF TREES PERMITTED BETWEEN MAY 1st TO JUNE 15th UNLESS BY OWNERS' PERMITS.
5. ROCHESTER, POWER GLEN & GRIMSBY FORMATION TO BE PLACED IN THE SEPARATE PILE.
6. CONTENTS OF SETTLING POND WILL BE TRANSFERED TO THE TREATMENT FACILITY IN MATERIALS YARD 2
7. CONTENTS OF THE RUNOFF POND WILL BE TRANSFERED DIRECTLY INTO THE TREATMENT FACILITY VIA PIPE. GROUND WATER FROM CONTAMINATED FORMATIONS WILL BE DIRECTED INTO THE RUNOFF POND, NOT INTO THE GROUND WATER RETENTION POND
8. SHOWED IN THE PLAN "SITE INSTALLATION TUNNELING"

LEGEND:

- AREA AVAILABLE FOR CONTRACTORS
- AREA NOT AVAILABLE FOR CONTRACTOR ACCESS
- DISPOSAL AREA
- PAVED CONSTRUCTION ROAD
- CHAIN LINK FENCE

EXCAVATED MATERIAL STOCKPILING PROCEDURES:
(BASED ON OPG'S MANAGEMENT OF EXCAVATED MATERIALS BY HATCH MOTT MacDONALD/ACRES INTERNATIONAL DATED DECEMBER 2004 AND ON OPG'S MANAGEMENT PLAN FOR BTEX BY HATCH MOTT MacDONALD DATED DECEMBER 2004)

*QUEENSTON SHALE TEMPORARILY STOCKPILED AT THE WEST END OF THE ON-SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

*SHALES CONTAINING BTEX (ROCHESTER,GRIMSBY & POWER GLEN FORMATION) PERMANENTLY STORED IN ON- SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

*LIMESTONES/DOLOMITES TEMPORARILY STORED FOR RE-USE.

*OTHER ROCKS - PERMANENTLY STOCKPILED IN ON-SITE DISPOSAL AREA, SEPARATED FROM OTHER ROCK.

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	1	06/12	GENERAL REVISION		

NIAGARA TUNNEL FACILITY PROJECT

CONSTRUCTION FACILITIES
OUTLET AREA

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — Morrison Hershfield

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scale AS SHOWN	author/cad		dwg. scale
dwg no MH - 6009			CAD file type DWG ver 01

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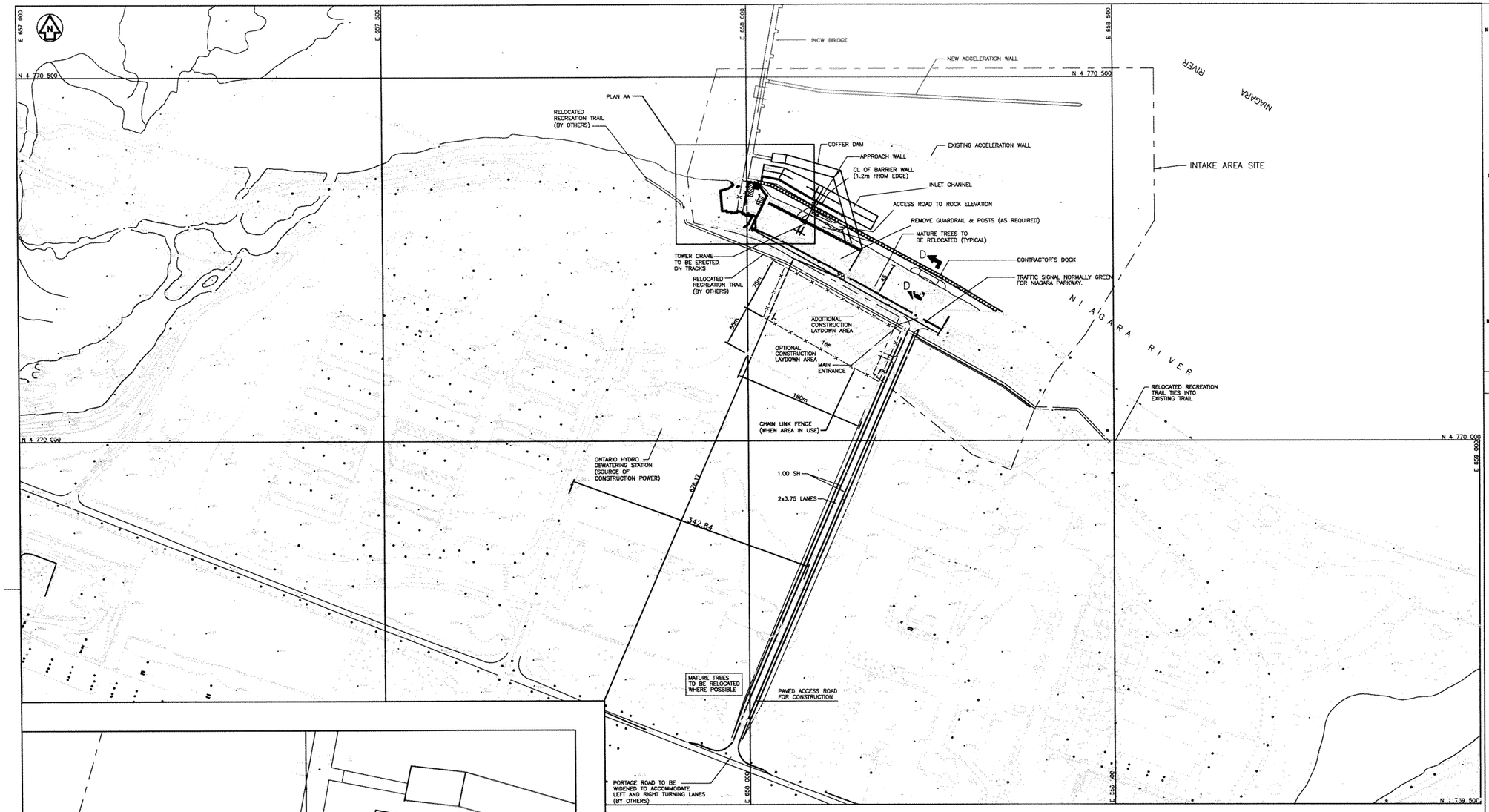

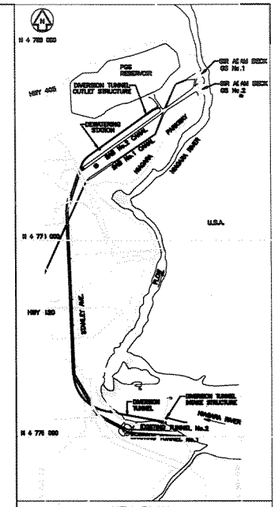

KEY PLAN
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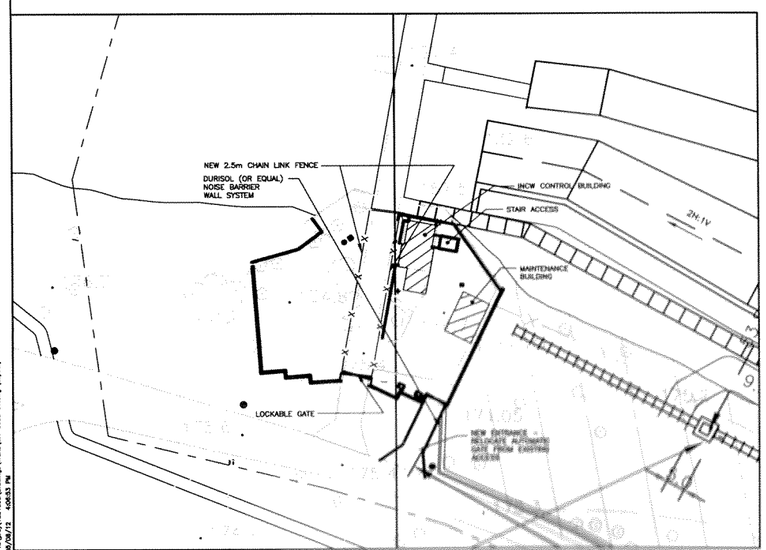
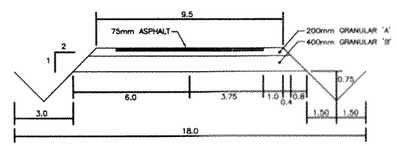
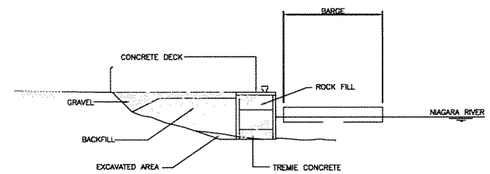


PLAN A–A AT INCW CONTROL BUILDING
SCALE 1:200



INLET ACCESS ROAD CROSS SECTION
HORIZONTAL SCALE 1:100
VERTICAL SCALE 1:50



SECTION D–D
SCALE 1:200

1:200 0 5 10 15 20 m
1:2000 0 50 100 150 200 m

NOTES:

1. STOCKPILING AREA TO CONTAIN AN IMPERVIOUS LINER FOR POSSIBLE CONTAMINATION IN EXCAVATED MATERIALS

mf roll number	ver no	date	particulars	dsn chkd	appd
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NIAGARA TUNNEL FACILITY PROJECT

CONSTRUCTION FACILITIES
INTAKE AREA

ONTARIO POWER GENERATION — Electricity Production – Hydroelectric Technical Services

STRABAG — MORRISON HERSHFIELD MH

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chkd			
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scale AS SHOWN	authorized	CAD file type DWG	
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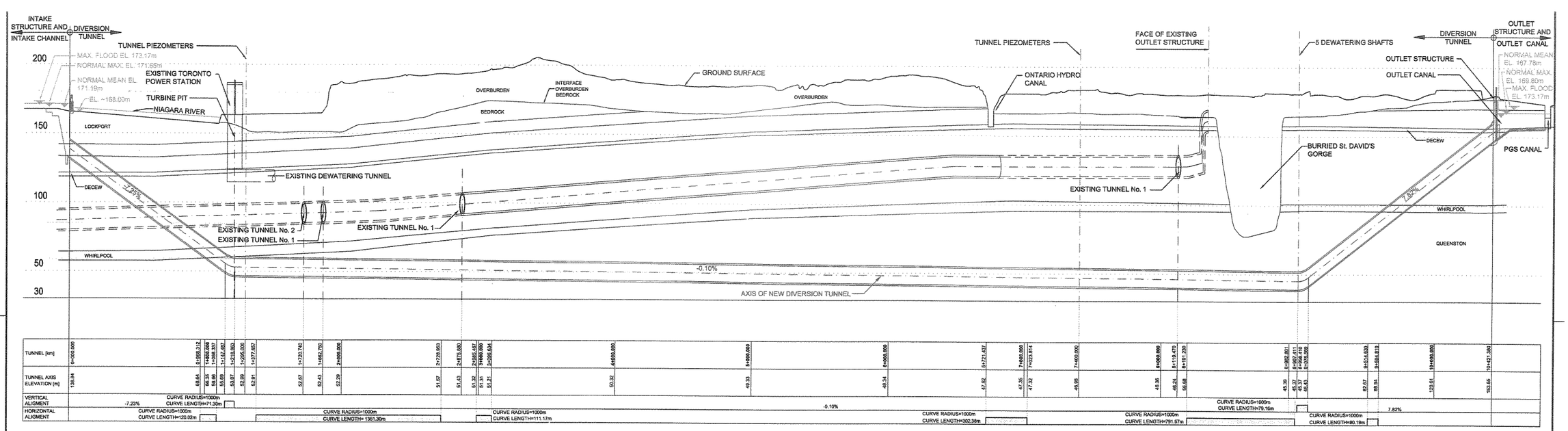

LONGITUDINAL SECTION
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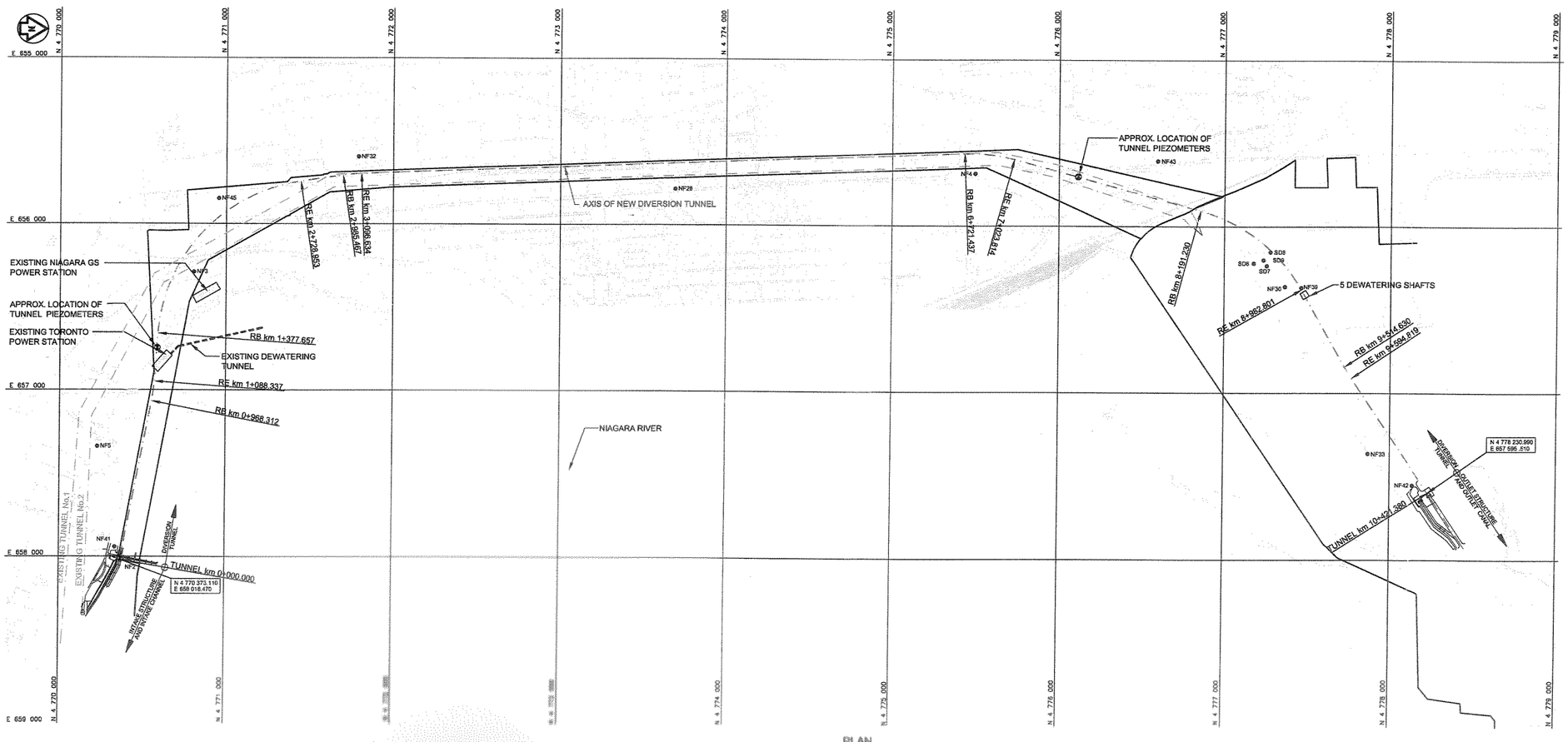

PLAN
SCALE 1: 10000

LEGEND:

km...KILOMETER
RB...BEGIN OF CURVE
RE...END OF CURVE
NF, SD...GEOTECHNICAL BOREHOLES

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	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
PLAN AND LONGITUDINAL SECTION

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — LYP CONSULTING ENGINEERS

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chkd			
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scale: 1:10000/1:1000	authorized	plot date: CAD file type: DWG	

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© OPG 2005 21821-Niagara-Tunnel\Phase4\Legislative\PD-01-1001-S.dwg

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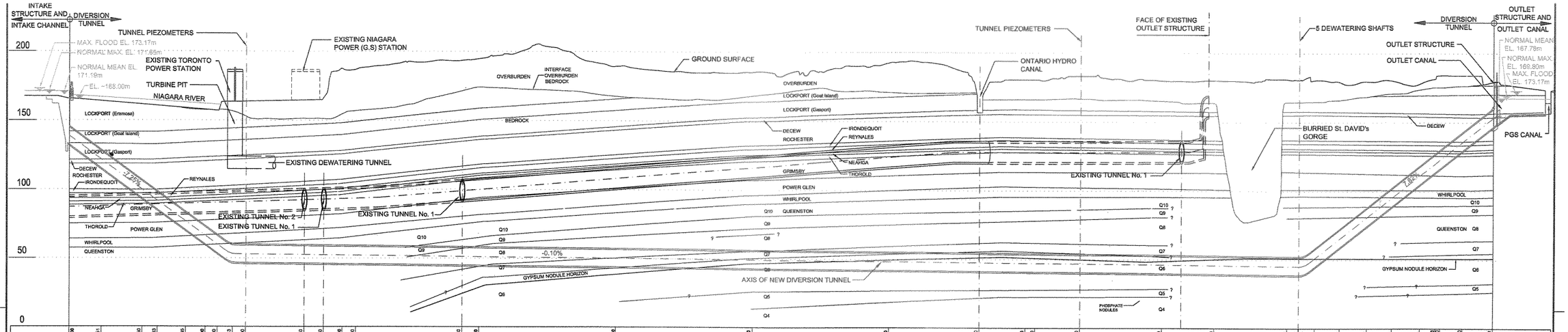
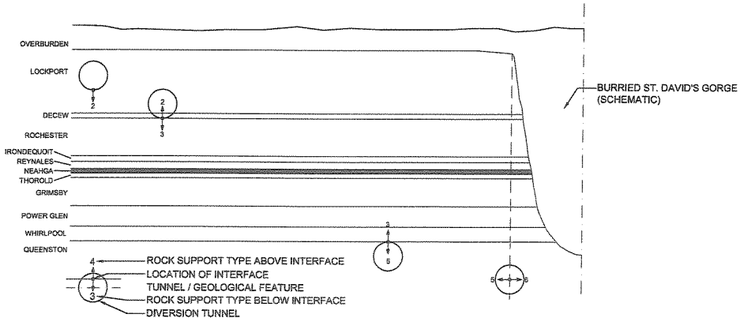
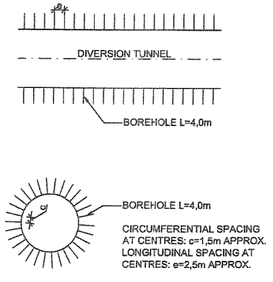


TUNNEL [km]	0+000.000	0+237.051	0+437.550	0+650.393	0+857.335	1+000.000	1+068.580	1+198.443	1+295.000	1+720.740	1+852.760	2+000.000	2+100.000	2+475.980	3+000.000	4+000.000	4+800.000	5+452.890	5+600.000	6+000.000	6+520.000	7+000.000	7+400.000	8+352.159	8+915.388	8+958.359	9+000.000	9+115.668	9+300.000	9+500.000	9+692.328	9+885.653	10+000.000	10+139.000	10+421.380	TUNNEL [km]
SURFACE ELEVATION [m]	184.46					187.62	187.64	181.48				187.49																							177.00	SURFACE ELEVATION [m]
BEDROCK ELEVATION [m]	138.626	138.90				187.62		182.86				184.69				187.72	189.48	185.56	185.41	171.18	192.48	185.23	180.82	165.73	183.20	165.25	179.88	164.67	180.64	164.67	180.65	175.40	182.68	177.00	183.55	BEDROCK ELEVATION [m]
TUNNEL AXIS ELEVATION [m]						66.35		62.99				53.29				51.31	174.77	174.12	49.33	48.34	174.77	47.35	169.23	48.95	169.25	48.36	169.25	45.37	164.67	45.37	164.67	120.81	175.40	177.00	120.81	TUNNEL AXIS ELEVATION [m]
GROUNDWATER TABLE ELEVATION [m]	160-175m															155-165m								120-130m				140-150m						160-170m		GROUNDWATER TABLE ELEVATION [m]
INTERNAL RADIUS [m]	6.24 - 6.39															6.14 - 6.29																6.24 - 6.39			INTERNAL RADIUS [m]
FINAL LINING THICKNESS [m]	0.60															0.70																0.60			FINAL LINING THICKNESS [m]
INTERNAL WATERPRESSURE [MPa]	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30							1.40													1.30	1.20	1.10	1.00	0.90	0.80	0.70	0.60	0.50	0.40	INTERNAL WATERPRESSURE [MPa]
LONG TERM GROUTING PRESSURE [MPa]	0.15	0.20	0.25	0.32	0.38	0.45	0.52	0.58	0.65							0.77													0.65	0.58	0.52	0.45	0.38	0.32	0.25	0.20	0.15	0.10	LONG TERM GROUTING PRESSURE [MPa]
SHORT TERM GROUTING PRESSURE [MPa]	1.45	1.50	1.55	1.63	1.72	1.80	1.88	1.97	2.05							2.20													2.05	1.97	1.88	1.80	1.72	1.63	1.55	1.50	1.45	1.40	SHORT TERM GROUTING PRESSURE [MPa]
STRATIGRAPHY DOMINANT FORMATION	LOCKPORT DEWEW	ROCHESTER		IRONDEQUOIT REYNALES NEAHGA	THOROLD GRIMSBY	POWER GLEN	WHIRLPOOL	QUEENSTON Q10 - Q8								QUEENSTON Q8 - Q7								QUEENSTON BELOW ST. DAVID'S GORGE		QUEENSTON Q6 - Q5		QUEENSTON Q8 - Q10			WHIRLPOOL, THOROLD POWERGLEN, GRIMSBY	NEAHGA REYNESQUIOT	ROCH-ESTER	LOCK-PORT DEWEW	STRATIGRAPHY
GEOTECHNICAL DESCRIPTION	SEQUENCE OF DOLOSTONE, LIMESTONE,SHALE AND SANDSTONE, MODERATELY TO SLIGHTLY FRACTURED, CHERT NODULES COMMON IN UPPER SECTION								SILTY MUDSTONES AND MUDDY SILTSTONES, SLIGHTLY WEATHERED, MODERATELY FRACTURED							MUDDY SILTSTONES,FRESH, SLIGHTLY FRACTURED GYPSUM NODULES							MUDDY SILTSTONES,WEATHERED INTENSELY FRACTURED GYPSUM NODULES				MUDSTONES TO MUDDY SILTSTONES; MOD. FRACT			SEQUENCE OF DOLOSTONE, LIMESTONE,SHALE AND SANDSTONE, MODERATELY TO SLIGHTLY FRACTURED				GEOTECHNICAL DESCRIPTION
PERMEABILITY [m/s]	3.6x10^{-6} - 5.9x10^{-6} (5x10^{-6})	1 x 10^{-6} - 9 x 10^{-7} (1.4 x 10^{-7})		1 x 10^{-6} - 3 x 10^{-7} (7.9 x 10^{-7})		1 x 10^{-6} - 8 x 10^{-7} (1.7 x 10^{-7})			1 x 10^{-9} - 2 x 10^{-6} (3.6 x 10^{-7})							1 x 10^{-9} - 2 x 10^{-7} (3.6 x 10^{-8})							1 x 10^{-8} - 8 x 10^{-7} (5.5 x 10^{-8})	1 x 10^{-6} - 2.2 x 10^{-7} (3.8 x 10^{-7})			1 x 10^{-6} - 2 x 10^{-6} (3.6 x 10^{-7})		1 x 10^{-6} - 8 x 10^{-7} (2.8 x 10^{-7})	1 x 10^{-6} - 4 x 10^{-7} (7.2 x 10^{-7})	1 x 10^{-6} - 1 x 10^{-7} (5.5x10^{-8})	1 x 10^{-6} - 9 x 10^{-7} (1.4 x 10^{-7})	PERMEABILITY [m/s]
SEEPAGE [l/s PER 100m]	0 - 92 (12)	0 - 1.6 (0.2)		0 - 1.1 (0.1)		0 - 2.2 (0.4)			0 - 5.1 (0.9)							0 - 0.5 (0.1)								0 - 1.4 (0.1)	0 - 0.5 (0.1)		0 - 4.5 (0.7)			0 - 1.2 (0.4)	0 - 0.6 (0.1)	0 - 0.1 (0.1)	0 - 1.9 (0.1)	SEEPAGE [l/s PER 100m]
PH - VALUE	7.4 ± 0.3								6.6 ± 0.3							7.7 ± 0.5								6.2 ± 0.6									7.0 ± 0.6	PH - VALUE
CONDUCTIVITY [µS/cm]	25973 ± 21739								75980 ± 22423							5600 ± 1680								75540 ± 38413									44830 ± 36313	CONDUCTIVITY [µS/cm]
CHLORIDE [mg/l]	30408 ± 21486								66250 ± 24185							1120 ± 536								68550 ± 39843									35028 ± 25785	CHLORIDE [mg/l]
SULPHATE [mg/l]	1416 ± 99								1155 ± 184							6 ± 2								1134 ± 282									316 ± 438	SULPHATE [mg/l]
ABRASIVITY	MODERATE/ LOW	MODERATE			HIGH				MODERATE																									MODERATE	ABRASIVITY
GEOTECHNICAL PARAMETERS: COMPRESSIVE STRENGTH [MPa]	87 - 183 (126)	12.1 - 65.5 (42)		69-140.6 (101)	72.5 - 242.2 (146)		11.9 - 33.9 (24)	138.5 - 284.4 (189)	7.5 - 117.5 (33)							7.5 - 117.5 (46)								7.5 - 117.5 (33)	7.5 - 117.5 (46)		7.5 - 117.5 (33)			11.9 - 33.9 (24)	73.5-242.2 (146)	42-140.8 (101)	12.1 - 65.5 (42)	COMPRESSIVE STRENGTH [MPa]
GEOTECHNICAL PARAMETERS: MODULUS OF DEFORMATION [GPa]	17 - 31 (24)	9 - 24 (15)		16 - 32 (24)	12 - 24 (18)		5 - 13 (9)	32-42 (42)	4 - 16 (10)							5 - 27 (16)								1 - 7 (4)	5 - 27 (16)		4 - 16 (10)			5 - 13 (9)	13 - 23 (18)	16-32 (24)	5 - 24 (15)	MODULUS OF DEFORMATION [GPa]
GEOTECHNICAL PARAMETERS: PRIMARY STRESSES VERTICAL [MPa]	0.5 - 2.3 (1.4)								2.3 - 3.9 (3.1)							3.3 - 3.4 (3.3)								0.5 - 3.4 (2.0)									PRIMARY STRESSES VERTICAL [MPa]
GEOTECHNICAL PARAMETERS: PRIMARY STRESSES HORIZONTAL [MPa]	17 (RADIAL), 11 (AXIAL)								19 (RADIAL), 17 (AXIAL)							22 (RADIAL), 16 (AXIAL)								15 (RADIAL), 23 (AXIAL)									PRIMARY STRESSES HORIZONTAL [MPa]
GEOTECHNICAL PARAMETERS: ANGLE OF FRICTION [°]	31 - 37 (34)	30 - 34 (32)		31 - 37 (34)	36 - 40 (38)		26 - 32 (30)	41 - 46 (43)	28 - 32 (30)							31 - 35 (33)								22 - 26 (24)	31 - 35 (33)		26 - 32 (30)			28 - 32 (30)	36 - 40 (38)	31 - 37 (34)	30 - 34 (32)	ANGLE OF FRICTION [°]
GEOTECHNICAL PARAMETERS: COHESION [KPa]	4.8 - 10.9 (7.9)	0.9 - 4.8 (2.9)		2.3-10.5 (5.3)	4.8 - 14.8 (9.9)		9.1 - 1.9 (1.3)	9 - 25 (18)	0.8 - 2.8 (1.8)							0.8 - 4.8 (2.8)								0.3 - 2.3 (1.3)	1.8 - 4.8 (2.9)		0.8 - 2.8 (1.8)			0.7 - 1.9 (1.3)	4.9-14.5 (9.3)	2.3-10.3 (6.3)	0.5 - 4.8 (2.9)	COHESION [KPa]
DISTRIBUTION OF ROCK SUPPORT TYPES	1 10% 2 30% 3 60%	L=178.41m (TRUE LENGTH = 178.09m)							L=1020.59m (TRUE LENGTH = 1022.62m)							L=1783.72m (TRUE LENGTH = 1788.73m)								L=534.13m (TRUE LENGTH = 534.13m)		L=376.60m (TRUE LENGTH = 377.53m)				L=829.59m (TRUE LENGTH = 832.05m)			1 2 3 4 5 6	DISTRIBUTION OF ROCK SUPPORT TYPES
GEOTECHNICAL MONITORING SECTIONS	CM	CM	CM	CM	CM	CM	PIT	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	CM	GEOTECHNICAL MONITORING SECTIONS
POSSIBILITY OF GAS	LOW	HIGH							MEDIUM																									HIGH	POSSIBILITY OF GAS
CRITICAL SECTIONS	NIAGARA RIVER ABOVE					TUNNEL CROSSINGS		DEFORMABLE BEDDING PLANE Q8/Q9																ST. DAVID'S GORGE						DEFORMABLE BEDDING PLANE Q8/Q9					CRITICAL SECTIONS
CAVITY GROUTING	20% OF LENGTH OF SECTION L=378.69m (TRUE LENGTH = 379.68m)																																		CAVITY GROUTING

GEOTECHNICAL LONGITUDINAL SECTION
SCALE 1:1000



PREDICTION OF ROCK SUPPORT TYPES
INTERFACES BETWEEN PREDOMINANT SUPPORT TYPES
NOT TO SCALE



CAVITY GROUTING
NOT TO SCALE

LEGEND:

CM...CONVERGENCE MONITORING SECTION

PI ..PIEZOMETER MONITORING SECTION

PIT...TUNNEL PIEZOMETER

EX ...EXTENSOMETER MONITORING SECTION

EL ...ELEVATION

1:1000 0 20 40 60 80 100 m

1:10000 0 200 400 600 800 1000 m

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
GEOTECHNICAL LONGITUDINAL SECTION

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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chkd			
date	yr/mon/day	design approved	plot scale 1:1 M
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scale		author/over	CAD file type
	1:10000/1:1000		DWG
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	PD-01-1002		00

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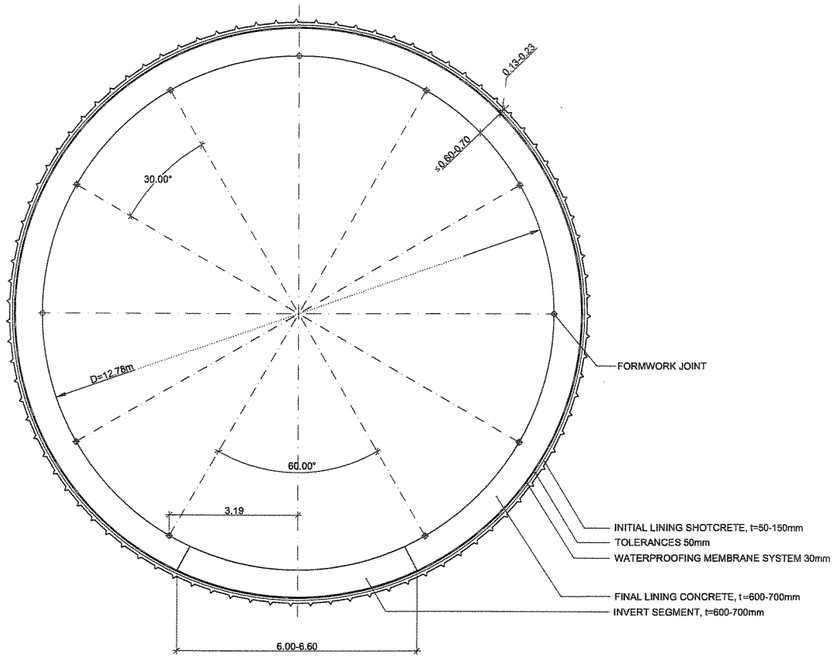
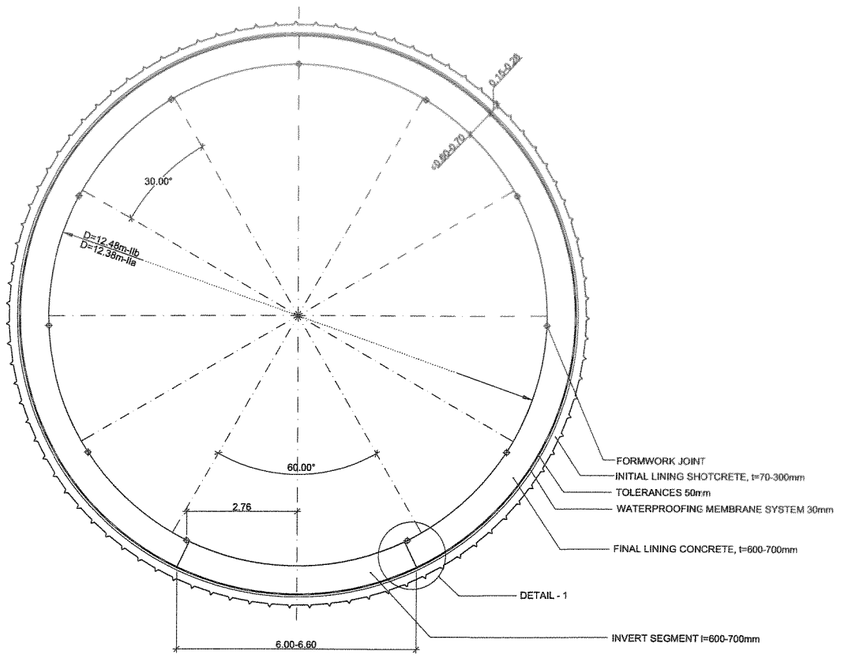
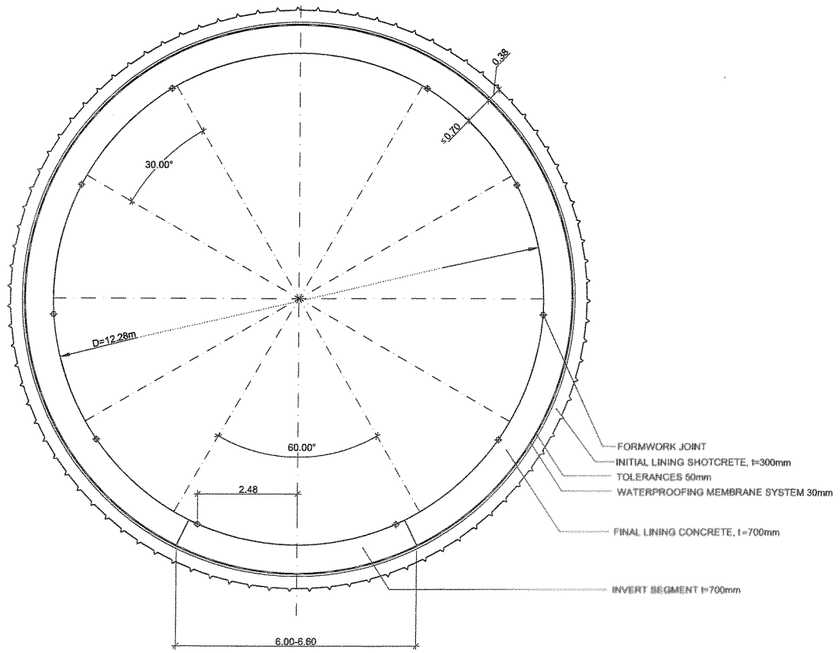
millimetres 0 10 50 100 200 300



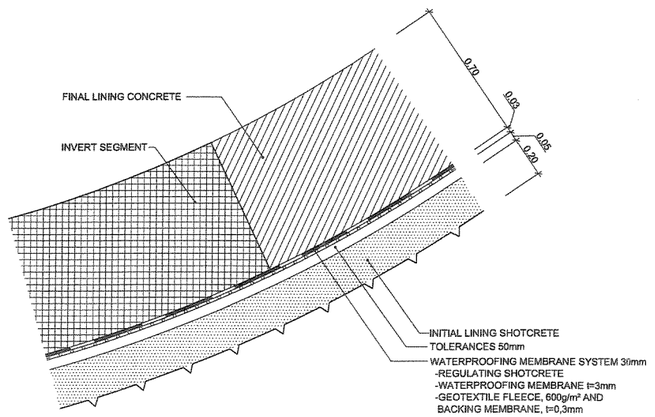
TYPICAL CROSS SECTION - I, D_{TBM}=14.44m
SCALE 1:50



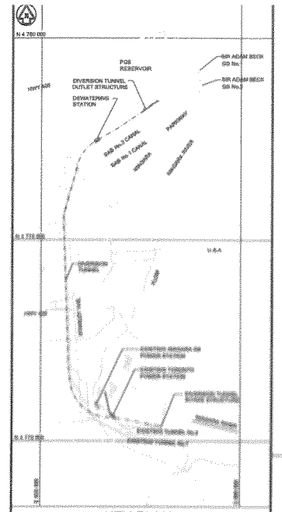
TYPICAL CROSS SECTION - IIa, D_{TBM}=14.44m, $t \leq 0.70+0.15m$
TYPICAL CROSS SECTION - IIb, D_{TBM}=14.44m, $t \leq 0.70+0.20m$
SCALE 1:50



TYPICAL CROSS SECTION - III, D_{TBM}=14.44m
SCALE 1:50



DETAIL - 1
SCALE: 1:10



KEY PLAN
SCALE 1 : 50000

NOTES:

1. FINAL LINING CONCRETE FORMWORK TO BE ADJUSTED TO VARIABLE INTERNAL DIAMETER AT FORMWORK JOINTS
2. SIZE OF INVERT SEGMENT TO BE CONFIRMED BY THE REQUIREMENTS FOR MATERIAL TRANSPORT AND MUCKING
3. TEMPORARY DRAINAGE ARRANGEMENT TO BE DETAILED ON SITE
4. TYPICAL CROSS SECTION-LINING THICKNESS COMBINATIONS

FINAL LINING	t=0,6m	t=0,7m
INITIAL LINING		
t=0,05m	I	I
t=0,07m	I	IIa
t=0,10m	I	IIa
t=0,15m	I	IIa
t=0,20m	IIa	IIb
t=0,30m	IIb	III

ref no/ number	ver no	date	particulars	chkd	apprd
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
TYPICAL CROSS SECTIONS
AND DETAIL

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HATCH CONSULTING ENGINEERS

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chkd			
date yr/mo/dy/day	design approved	plot scale	1:1 M
05/04/29		plot date	
scale 1:50 / 1:10	authorized	CAD file type	DWG
dwg no PD-01-1004			ver 00

1:50 0 1 2 3 4 5 m
1:10 0 0.2 0.4 0.6 0.8 1 m

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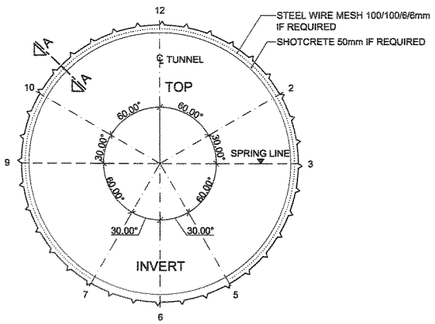
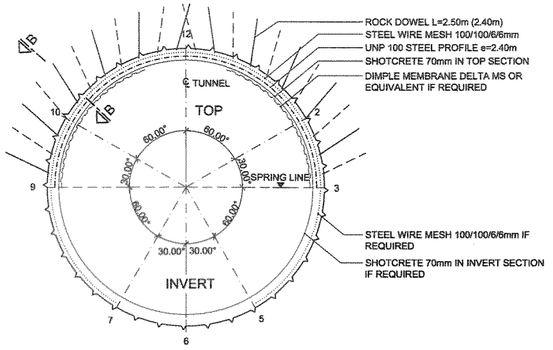
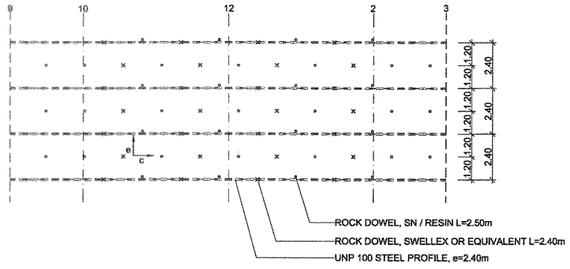


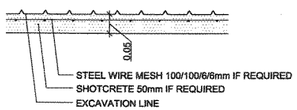
ROCK SUPPORT TYPE 1
CROSS SECTION, SCALE 1:100



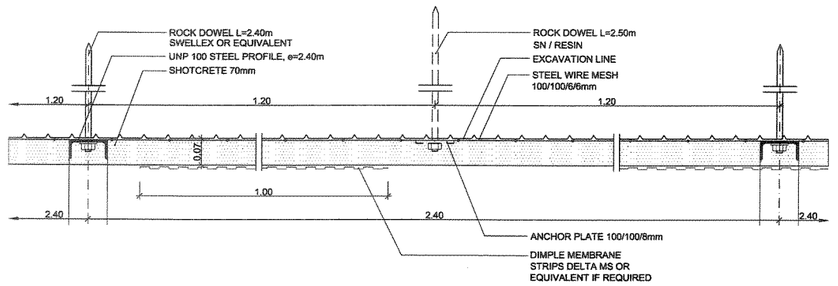
ROCK SUPPORT TYPE 2
CROSS SECTION, SCALE 1:100



DEVELOPED VIEW OF TOP SECTION
SCALE 1:100



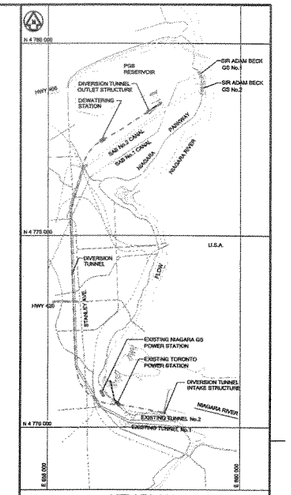
DETAIL SECTION A-A
SCALE 1:5



DETAIL SECTION B-B
SCALE M1:5

EXCAVATION AND SUPPORT TYPES 1 AND 2

ROCK MASS CHARACTERISTICS	ROCK MASS STRATIGRAPHY (DOMINANT)	ROCK SUPPORT TYPES	CLASSIFICATION CRITERIA ROCK MASS BEHAVIOUR PRESENCE OF WATER	RADIAL DEF.	EFFECT ON ADVANCE OF TBM	SUPPORT MEASURES SUPPORT MEASURES	SUPPORT MEASURES TOP 12 TO 2 (10)	DISTANCE TO EXC. FACE	QUANTITY PER M	SUPPORT MEASURES TOP 2 (10) TO 3 (9)	DISTANCE TO EXC. FACE	QUANTITY PER M	SUPPORT MEASURES INVERT 3 (9) TO 5 (7)	DISTANCE TO EXC. FACE	QUANTITY PER M	SUPPORT MEASURES INVERT 5 (7) TO 6	DISTANCE TO EXC. FACE	QUANTITY PER M	TOTAL QUANTITY	UNIT
STABLE ROCK	LOCKPORT DE CEW	1	NO GEOLOGICAL OVERBREAK SIGMA 1 > 100 MPa	< 5 mm 200 m BEHIND TBM CUTTER HEAD	CONTINUOUS ADVANCE		-	-	-	-	-	-	-	-	-	-	-	-		
		1A	DRY OR NEGLIGIBLE INFLOW				-	-	-	-	-	-	-	-	-	-	-	-		
		1B	ROCK SENSITIVE TO WATER		CONTINUOUS ADVANCE AND SUPPORT INSTALLATION	1. STEEL WIRE MESH 100/100/6/6 MM 2. SHOTCRETE	1 LAYER, EXTRADOS 50 mm	< 40 m < 40 m	15,12 15,12	1 LAYER EXTRADOS 50 mm	< 40 m < 40 m	7,56 7,56	1 LAYER EXTRADOS 50 mm	< 40 m < 40 m	15,12 15,12	50 mm	< 40 m	7,56	37,80 45,36	m2 m2
LOOSENING OF ROCK IN CROWN OR LOCALIZED AREA	LOCKPORT DE CEW WHIRLPOOL	2	WEDGES OF ROCK < 0,2 x 0,2 x 0,2 m APPROX.	< 5 mm 200 m BEHIND TBM CUTTER HEAD																
		2A	DRY OR NEGLIGIBLE WATER		CONTINUOUS ADVANCE INTERRUPTED BY SUPPORT INSTALLATION	1. STEEL WIRE MESH 100/100/6/6 MM 2. STEEL PROFILES U NP 100 3. ROCK DOWELS SWELLEX OR EQ., L = 2.4 m 4. SHOTCRETE 5. ROCK DOWELS SN / RESIN, L = 2.5 m	1 LAYER, EXTRADOS e = 2.4 m c/e 4.0/1.2 70 mm c/e 4.0/1.2	< 7 m < 7 m < 7 m < 40 m < 40 m	15,12 6,30 3,33 15,12 3,33	1 LAYER, EXTRADOS e = 2.4 m - 70 mm c/e 4.0/1.2	< 40 m < 40 m - < 40 m < 40 m	7,56 3,15 - 7,56 2,50	- - - - -	- - - - -	- - - - -	- - - - -	- - - - -	22,68 9,45 3,33 22,68 5,83	m2 m pcs m2 pcs
		2B	SUBSTANTIAL INFLOW			6. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	e = 2.4 m	< 40 m	1,67	e = 2,4 m	< 40 m	1,67	-	-	-	-	-	-	3,33	m2
		2C	ROCK SENSITIVE TO WATER			1. STEEL WIRE MESH 100/100/6/6 MM 2. STEEL PROFILES U NP 100 3. ROCK DOWELS SWELLEX OR EQ., L = 2.4 m 4. SHOTCRETE 5. ROCK DOWELS SN / RESIN, L = 2.5 m 6. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	1 LAYER, EXTRADOS e = 2.4 m c/e 4.0/1.2 70 mm c/e 4.0/1.2 e = 2.4 m	< 7 m < 7 m < 7 m < 40 m < 40 m < 40 m	15,12 6,30 3,33 15,12 3,33 1,67	1 LAYER, EXTRADOS e = 2.4 m - 70 mm c/e 4.0/1.2 e = 2.4 m	< 40 m < 40 m - < 40 m < 40 m < 40 m	7,56 3,15 - 7,56 2,50 1,67	1 LAYER EXTRADOS - < 40 m - 70 mm - < 40 m - - -	< 40 m - - 15,12 - -	- - - 70 mm - -	- - - < 40 m - -	- - - 7,56 - -	37,80 9,45 3,33 45,36 5,83 3,33	m2 m pcs m2 pcs m2



KEY PLAN
SCALE 1 : 50000

NOTES:

1. LOOSE ROCK TO BE REMOVED
2. LOCAL OVERBREAK TO BE FILLED WITH SHOTCRETE
3. POSITION OF ROCK DOWELS TO BE ADJUSTED TO REACH OF INSTALLATION EQUIPMENT.
4. STEEL WIRE MESH TO BE FIXED IN SHORT HOLES WITH ANCHORS (NOT SHOWN)
5. POSITION 2, 5, 7 AND 10 TO BE ADJUSTED TO ACTUAL GRIPPER POSITION OF TBM
6. QUANTITIES OF SUPPORT MEASURES ARE BASED ON LENGTH OF EXCAVATION LINE
7. SUPPORT MEASURES INCLUDED IN "CROSS SECTION" ARE DRAWN NOT TO SCALE
8.

STEEL PROFILE		UNP 100	UNIT
WEIGHT		10.6	kg/m
2nd MOMENT OF AREA y-y		206	cm⁴
y h z b y	h	50.0	mm
	b	100.0	mm

1:100 0 2 4 6 8 10 m
1:5 0 0,1 0,2 0,3 0,4 0,5 m

ref. no.	ver no.	date	particulars	chkd	appd
	02	05/08/12	ROCK MASS CHARACTERISTICS		
	01	05/06/23	ANCHOR PLATE		
	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
ROCK SUPPORT TYPES 1 AND 2

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services
STRABAG — HLP CONSULTING ENGINEERS

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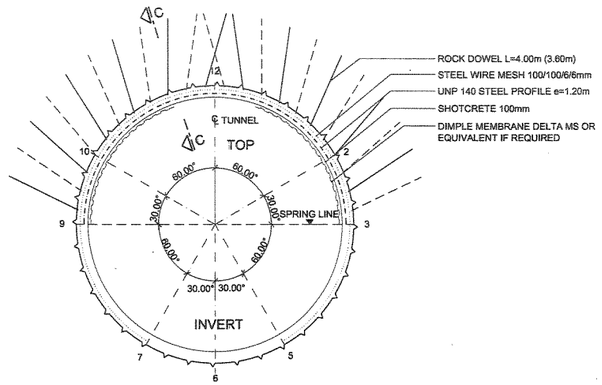
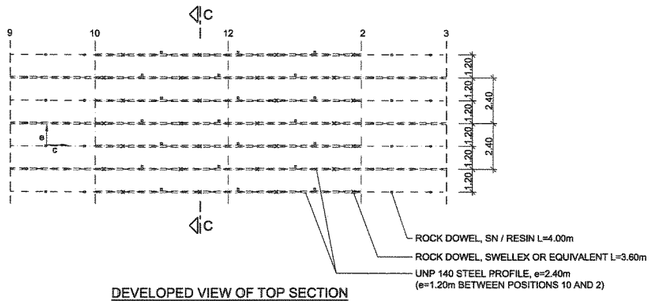
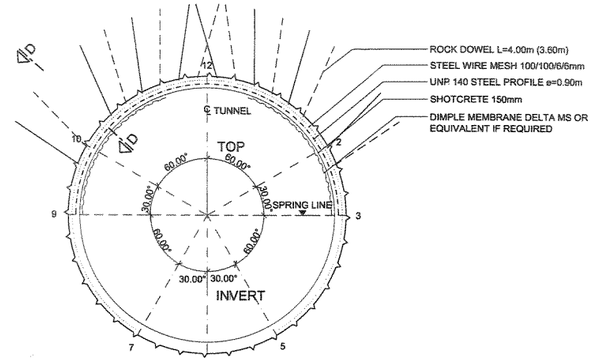


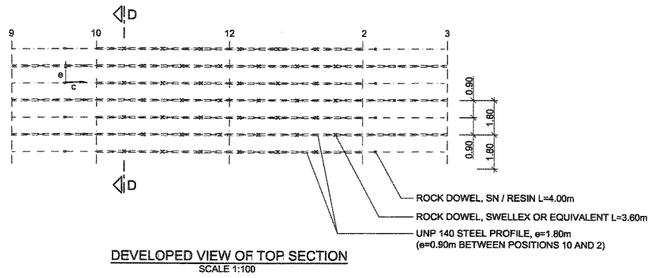
ROCK SUPPORT TYPE 3
CROSS SECTION, SCALE 1:100



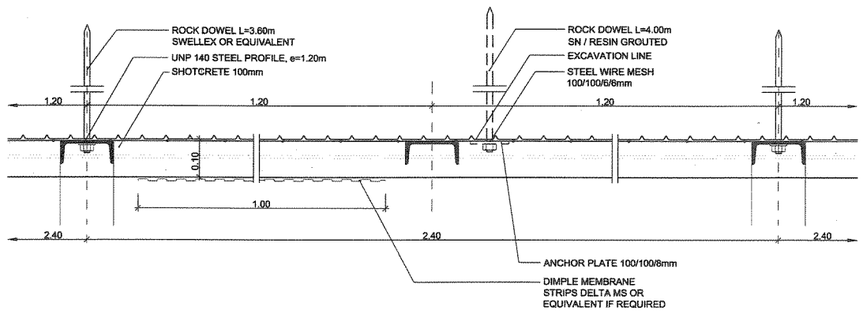
DEVELOPED VIEW OF TOP SECTION
SCALE 1:100



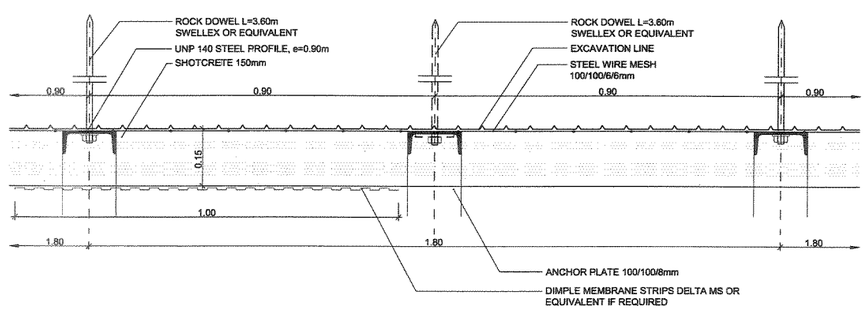
ROCK SUPPORT TYPE 4
CROSS SECTION, SCALE 1:100



DEVELOPED VIEW OF TOP SECTION
SCALE 1:100



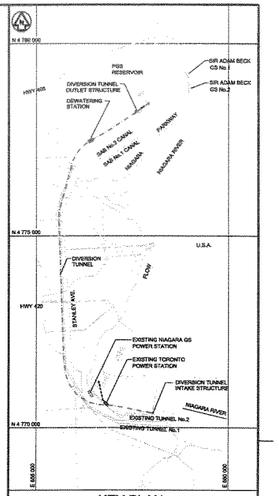
DETAIL SECTION C-C
SCALE 1:5



DETAIL SECTION D-D
SCALE 1:5

EXCAVATION AND SUPPORT TYPES 3 AND 4

ROCK MASS CHARACTERISTICS	ROCK MASS STRATIGRAPHY (DOMINANT)	ROCK SUPPORT TYPES	CLASSIFICATION CRITERIA ROCK MASS BEHAVIOUR PRESENCE OF WATER	RADIAL DEF.	EFFECT ON ADVANCE OF TBM	SUPPORT MEASURES	SUPPORT MEASURES TOP 12 TO 2 (10)	DISTANCE TO EXC. FACE	QUANTITY PER M	TOP 2 (10) TO 3 (9)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 3 (9) TO 5 (7)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 5 (7) TO 6	DISTANCE TO EXC. FACE	QUANTITY PER M	TOTAL QUANTITY	UNIT
UNSTABLE OR CLOSELY BROKEN ROCK	ROCHESTER REYNALES	3	WEDGES OF ROCK < 0,5 x 0,5 x 0,5 m APPROX.	< 10 mm 200 m																
FREQUENT OVERBREAK DUE TO DISCONTINUITIES	NEAHGA TOROLD GRIMSBY POWERGLEN WHIRLPOOL QUEENSTON	3A	DRY OR LIMITED WATER	BEHIND TBM CUTTER HEAD	CONTINUOUS ADVANCE INTERRUPTED BY SUPPORT INSTALLATION	1. STEEL WIRE MESH 100/100/6/6 MM	1 LAYER, EXTRADOS	< 7 m	15,12	1 LAYER, EXTRADOS	< 40 m	7,56	1 LAYER, EXTRADOS	< 40 m	15,12	-	-	-	37,80	m2
						2. STEEL PROFILES U NP 140	e = 1.2 m	< 7 m	12,60	e = 2.4 m	< 40 m	3,15	-	-	-	-	-	-	15,75	m
						3. ROCK DOWELS SWELLEX OR EQ., L = 3.6 m	c/e 4.0/1.2	< 7 m	3,33	-	-	-	-	-	-	-	-	-	3,33	pcs
						4. SHOTCRETE	100 mm	< 40 m	15,12	100 mm	< 40 m	7,56	100 mm	< 40 m	15,12	100 mm	< 40 m	7,56	45,36	m2
						5. ROCK DOWELS SN / RESIN, L = 4.0 m	c/e 4.0/1.2	< 40 m	2,50	c/e 4.0/1.2	< 40 m	3,33	-	-	-	-	-	-	5,83	pcs
		3B	SUBSTANTIAL INFLOW			6. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	e = 2.4 m	< 40 m	1,67	e = 2.4 m	< 40 m	1,67	-	-	-	-	-	-	3,33	m2
UNSTABLE OR CLOSELY BROKEN ROCK CONTINUOUS OVERBREAK DUE TO ANY OF: -DISCONTINUITIES -SIDEWALL SPALLING -INVERT HEAVE	LOCKPORT ROCHESTER REYNALES NEAHGA TOROLD GRIMSBY POWERGLEN WHIRLPOOL QUEENSTON	4	WEDGES OF ROCK < 1,0 x 1,0 x 1,0 m APPROX.	< 20 mm 200 m																
		4A	DRY OR UNLIMITED WATER	BEHIND TBM CUTTER HEAD	CONTINUOUS ADVANCE INTERRUPTED BY SUPPORT INSTALLATION	1. STEEL WIRE MESH 100/100/6/6 MM	1 LAYER, EXTRADOS	< 7 m	15,12	1 LAYER, EXTRADOS	< 40 m	7,56	1 LAYER, EXTRADOS	< 40 m	15,12	-	-	-	37,80	m2
						2. STEEL PROFILES U NP 140	e = 0.9 m	< 7 m	16,80	e = 1.8 m	< 40 m	4,20	-	-	-	-	-	-	21,00	m
						3. ROCK DOWELS SWELLEX OR EQ., L = 3.6 m	c/e 2.0/0.9	< 7 m	6,67	-	-	-	-	-	-	-	-	-	6,67	pcs
						4. SHOTCRETE	150 mm	< 40 m	15,12	150 mm	< 40 m	7,56	150 mm	< 40 m	15,12	150 mm	< 40 m	7,56	45,36	m2
						5. ROCK DOWELS SN / RESIN, L = 4.0 m	-	-	-	c/e 4.0/0.9	< 40 m	4,44	-	-	-	-	-	-	4,44	pcs
		4B	SUBSTANTIAL INFLOW			6. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	e = 2.4 m	< 40 m	1,67	e = 1.8 m	< 40 m	1,67	-	-	-	-	-	-	3,33	m2



KEY PLAN
SCALE 1 : 50000

NOTES:

1. LOOSE ROCK TO BE REMOVED
2. LOCAL OVERBREAK TO BE FILLED WITH SHOTCRETE
3. POSITION OF ROCK DOWELS TO BE ADJUSTED TO REACH OF INSTALLATION EQUIPMENT.
4. STEEL WIRE MESH TO BE FIXED IN SHORT HOLES WITH ANCHORS (NOT SHOWN)
5. POSITION 2, 5, 7 AND 10 TO BE ADJUSTED TO ACTUAL GRIPPER POSITION OF TBM
6. QUANTITIES OF SUPPORT MEASURES ARE BASED ON LENGTH OF EXCAVATION LINE
7. SUPPORT MEASURES INCLUDED IN "CROSS SECTION" ARE DRAWN NOT TO SCALE
8.

STEEL PROFILE		UNP 140	UNIT
WEIGHT		16.0	kg/m
2nd MOMENT OF AREA y-y		605	cm⁴
y t z b	h	60.0	mm
	b	140.0	mm

1:100 0 2 4 6 8 10 m
1:5 0 0.1 0.2 0.3 0.4 0.5m

rel	ver no	date	particulars	des	appd
	02	05/05/12	ROCK MASS CHARACTERISTICS		
	01	05/06/23	ANCHOR PLATE		
	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
ROCK SUPPORT TYPES 3 AND 4

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HLP CONSULTING ENGINEERS

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chkd			
date yr/month/day 05/04/29	design approved	plot scale 1:1 M	
scale 1:100/1:5	authorised	plot date 1:100	
		CAD file type DWG	
dwg no PD-01-1006		rev 02	

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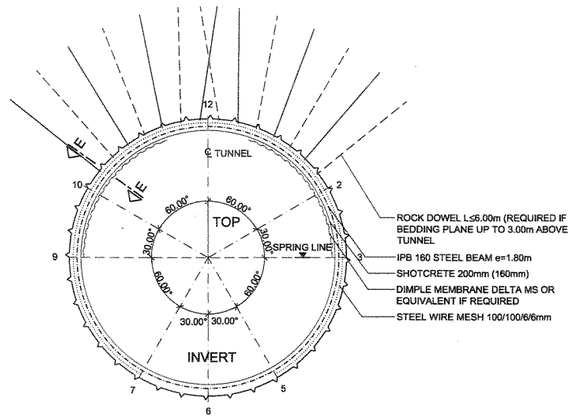
A0 (841 x 1189)

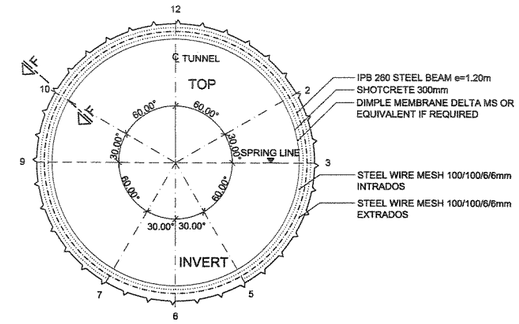


ROCK SUPPORT TYPE 5
CROSS SECTION, SCALE 1:100

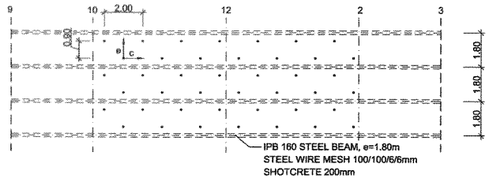
ROCK SUPPORT TYPE 5:
BEDDING PLANE >3,0m ABOVE TUNNEL
SHOTCRETE THICKNESS 200mm
NO ROCK DOWELS

BEDDING PLANE 1,5m-3,0m ABOVE TUNNEL
SHOTCRETE THICKNESS 160mm
ROCK DOWELS: L=6,0m

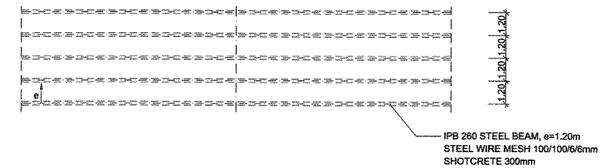
BEDDING PLANE 0m-1,5m ABOVE TUNNEL
SHOTCRETE THICKNESS 160mm
ROCK DOWELS: L=4,0m



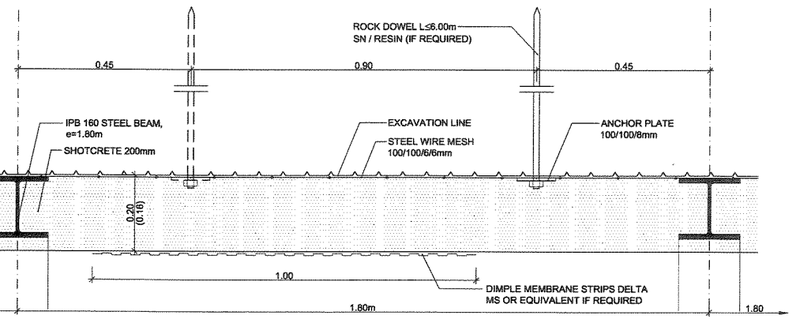
ROCK SUPPORT TYPE 6
CROSS SECTION, SCALE 1:100



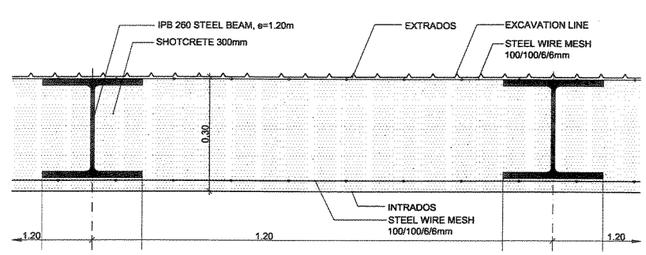
DEVELOPED VIEW OF TOP SECTION
SCALE 1:100



DEVELOPED VIEW OF TOP SECTION
SCALE 1:100



DETAIL SECTION E-E
SCALE 1:5

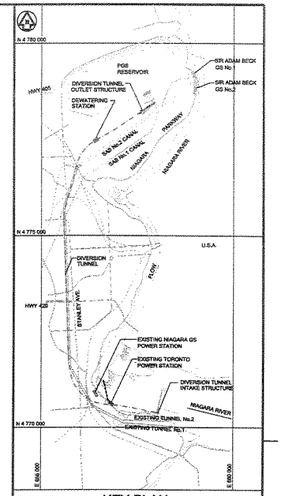


DETAIL SECTION F-F
SCALE 1:5

EXCAVATION AND SUPPORT TYPES 5 AND 6

ROCK MASS CHARACTERISTICS	ROCK MASS STRATIGRAPHY (DOMINANT)	ROCK SUPPORT TYPES	CLASSIFICATION CRITERIA ROCK MASS BEHAVIOUR PRESENCE OF WATER	RADIAL DEF.	EFFECT ON ADVANCE OF TBM
CONTINUOUS OVERBREAK DUE TO ANY OF: - SIDEWALL SPALLING - INVERT HEAVE - SLABBING SQUEEZING ROCK CONDITIONS, ROCK PRESSURE GENERALLY EXCEEDING ROCK MASS STRENGTH, CROWN IS WITHIN 3M OF BEDDING PLANE	QUEENSTON	5	WEDGES OF ROCK < 15,0 x 3,0 x 3,0 m APPROX.	< 50 mm 200 m BEHIND TBM CUTTER HEAD	CONTINUOUS ADVANCE GOVERNED BY SUPPORT INSTALLATION
		5A	DRY OR LIMITED WATER		
		5B	SUBSTANTIAL INFLOW		
CONTINUOUS OVERBREAK DUE TO ANY OF: - SIDEWALL SPALLING - INVERT HEAVE - SLABBING SQUEEZING ROCK CONDITIONS, ROCK PRESSURE GENERALLY EXCEEDING ROCK MASS STRENGTH, CLOSELY BROKEN SHEAR AND AND THRUST ZONES, CROWN IS WITHIN 3M OF BEDDING PLANE, ALL OTHER COND. REQUIRING GREATER SUPPORT THAN UNDER COND. 4Q AND 5	QUEENSTON	6	WEDGES OF ROCK < 20,0 x 10,0 x 4,0 m APPROX.	< 50 mm 200 m BEHIND TBM CUTTER HEAD	CONTINUOUS ADVANCE GOVERNED BY SUPPORT INSTALLATION

SUPPORT MEASURES	DISTANCE TO EXC. FACE	QUANTITY PER M	TOP 2 (10) TO 3 (9)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 3 (9) TO 5 (7)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 5 (7) TO 6	DISTANCE TO EXC. FACE	QUANTITY PER M	TOTAL QUANTITY	UNIT
1. STEEL WIRE MESH 100/100/6/6 MM	< 7 m	15,12	1 LAYER, EXTRADOS	< 7 m	7,56	1 LAYER, EXTRADOS	< 7 m	15,12				37,8	m2
2. STEEL BEAM IPB 160	< 7 m	8,40	e = 1.8 m	< 7 m	4,20	e = 1.8 m	< 7 m	8,40	e = 1.8 m	< 7 m	4,20	25,20	m
3. ROCK DOWELS SN/RESIN L 6.00M	< 7 m	7,78										7.78	pcs
4. SHOTCRETE	< 40 m	15,12	200 mm	< 40 m	7,56	200 mm	< 40 m	15,12	200 mm	< 40 m	7,56	45,36	m2
5. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	< 40 m	1,67	e = 2.4 m	< 40 m	1,67	-	-	-	-	-	-	3,33	m2
1. STEEL WIRE MESH 100/100/6/6 MM	< 7 m	15,12	1 LAYER, EXTRADOS	< 7 m	7,56	1 LAYER, EXTRADOS	< 7 m	15,12	-	-	-	37,80	m2
2. STEEL BEAM IPB 260	< 7 m	12,60	e = 1.2 m	< 7 m	6,30	e = 1.2 m	< 7 m	12,60	e = 1.2 m	< 7 m	6,30	37,80	m
3. STEEL WIRE MESH 100/100/6/6 MM	< 40 m	15,12	1 LAYER, INTRADOS	< 40 m	7,56	1 LAYER, INTRADOS	< 40 m	15,12	1 LAYER, INTRADOS	< 40 m	7,56	45,36	m2
4. SHOTCRETE	< 7 + < 40 m	15,12	100 + 200 mm	< 7 + < 40 m	7,56	100 + 200 mm	< 7 + < 40 m	15,12	100 + 200 mm	< 7 + < 40 m	7,56	45,36	m2



KEY PLAN
SCALE 1 : 50000

NOTES:

1. LOOSE ROCK TO BE REMOVED
2. LOCAL OVERBREAK TO BE FILLED WITH SHOTCRETE
3. POSITION OF ROCK DOWELS TO BE ADJUSTED TO REACH OF INSTALLATION EQUIPMENT.
4. STEEL WIRE MESH TO BE FIXED IN SHORT HOLES WITH ANCHORS (NOT SHOWN)
5. POSITION 2, 5, 7 AND 10 TO BE ADJUSTED TO ACTUAL GRIPPER POSITION OF TBM
6. QUANTITIES OF SUPPORT MEASURES ARE BASED ON LENGTH OF EXCAVATION LINE
7. SUPPORT MEASURES INCLUDED IN "CROSS SECTION" ARE DRAWN NOT TO SCALE

8 STEEL PROFILE		IPB 160	IPB 260	UNIT
WEIGHT		42.6	93.0	kg/m
2nd MOMENT OF AREA y-y		2490	14920	cm⁴
	h	160.0	260.0	mm
	b	160.0	260.0	mm

1:100 0 2 4 6 8 10 m
1:5 0 0.1 0.2 0.3 0.4 0.5 m

mf no/ number	ver no	date	particulars	prin'd	appd
	02	05/09/12	ROCK MASS CHARACTERISTICS		
	01	05/05/21	DOWELS TYPE 5		
	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
ROCK SUPPORT TYPES 5 AND 6

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — FLF CONSULTING ENGINEERS

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date yr/mon/day 05/04/29	design approved	print scale 1:1 M	
scale 1:100/1:5	authorized	CAD file type DWG	
dwg no PD-01-1007			ver 02

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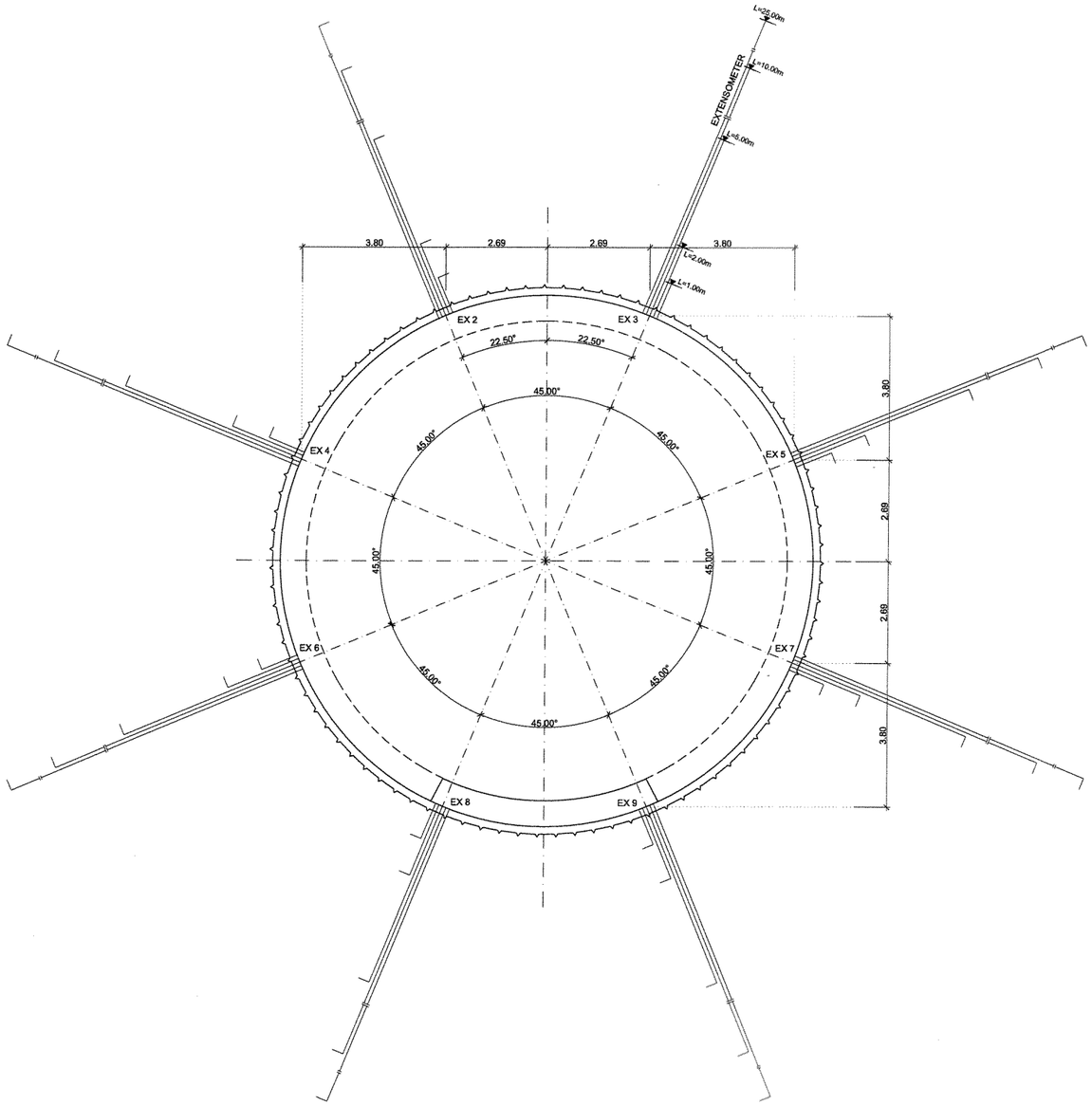
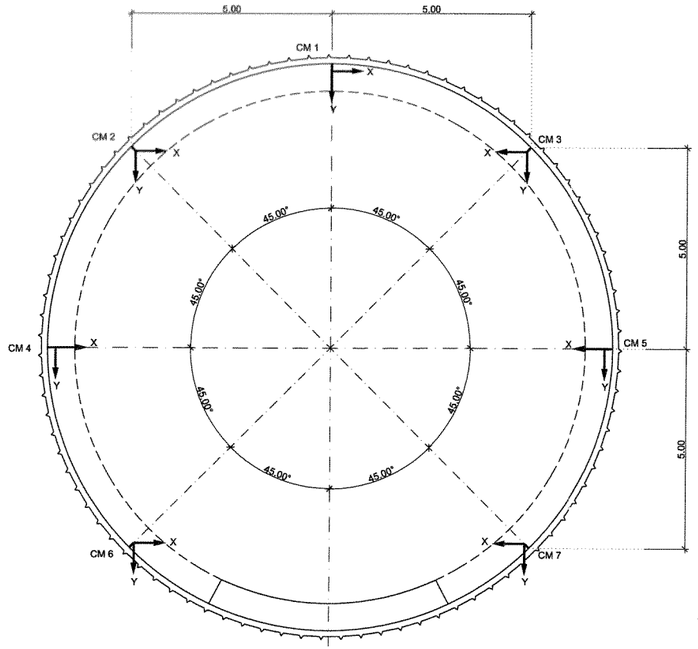
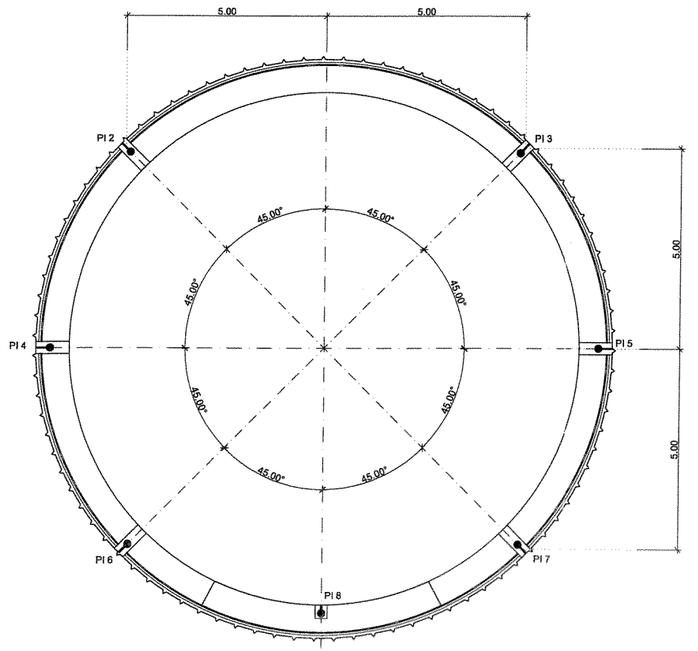
EXTENSOMETER MONITORING SECTION (EX)

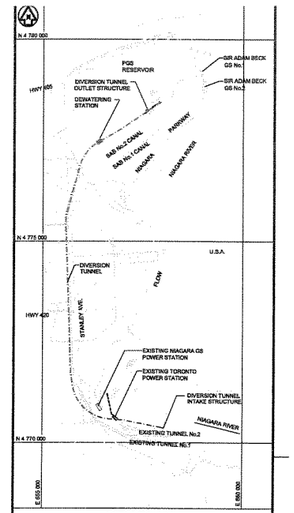


CONVERGENCE MONITORING SECTION (CM)



PIEZOMETER MONITORING SECTION (PI)





KEY PLAN
SCALE 1 : 50000

NOTES:

1. EXTENSOMETERS AND PIEZOMETERS TO BE PERMANENTELY LINKED TO DATA LOGGER AT THE GROUND SURFACE
2. FOR DETAILS OF PIEZOMETERS REFER TO DRG. PD-01-1021
3. FOR LOCATION OF MONITORING CROSS SECTIONS REFER TO DRG. PD-01-1002

ref no/ number	ver no	date	particulars	chkd	appd
	01				
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
GEOTECHNICAL MEASUREMENTS

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

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chkd			
date: yr/mo/dd/day: 05/04/29	design approved	plot scale	1:1 M
scale: 1:50	authorized	plot, code	
		CAD file type: DWG	
dwg no: PD-01-1008			ver 00

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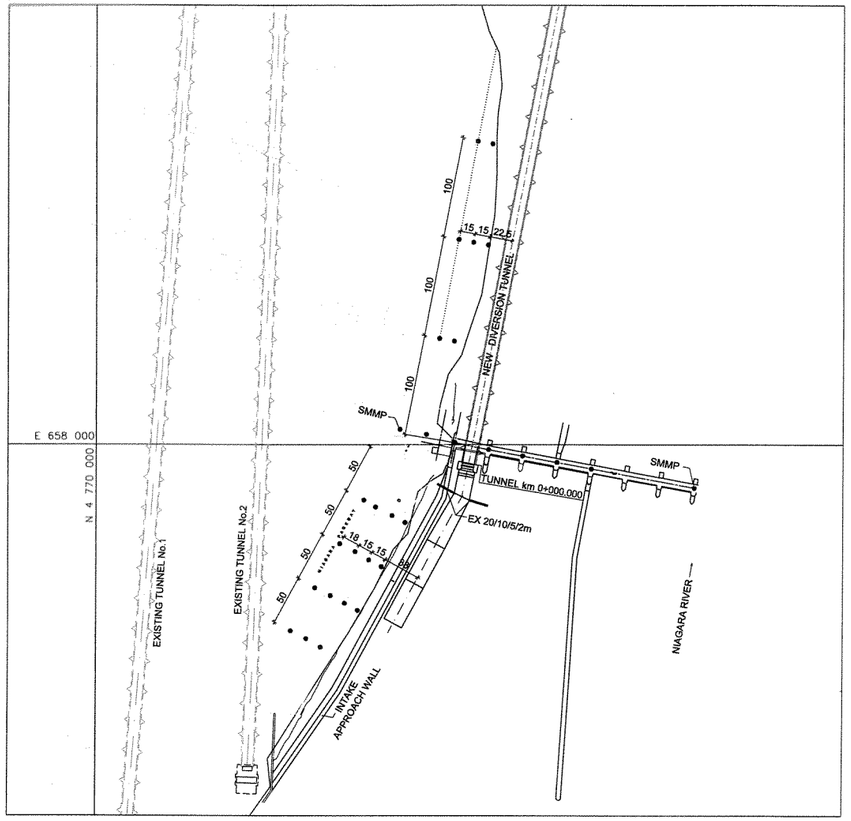
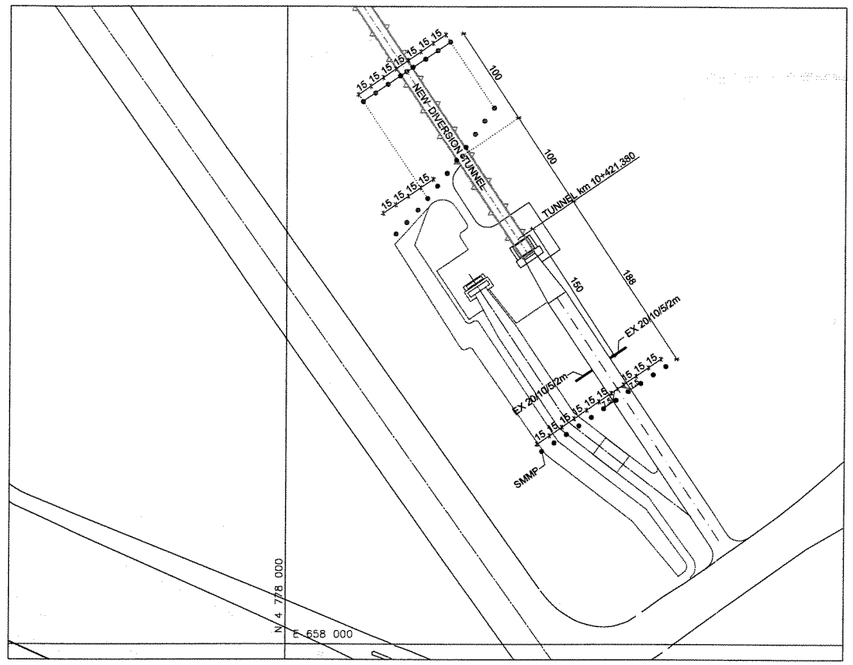
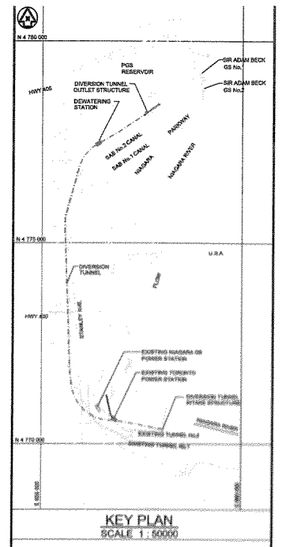


PLAN - INTAKE AREA
SCALE 1 : 2000



PLAN - OUTLET AREA
SCALE 1 : 2000



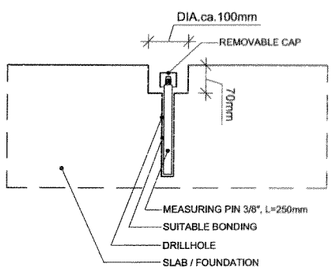
KEY PLAN
SCALE 1 : 50000

LEGEND:

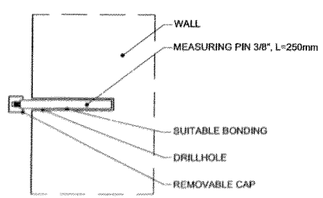
- ● ... MEASURING POINTS ON GROUND LEVEL
- ▼ ... MEASURING POINTS AT WALLS
- EX ... EXTENSOMETER

NOTES:

DIMENSIONS IN PLANS ARE IN METRES
UNLESS SHOWN OTHERWISE



MEASURING POINTS ON GROUND LEVEL



MEASURING POINTS AT WALLS

SURFACE MOVEMENT MONITORING POINT (SMMP)
SCALE 1 : 5

nif ref number	ver no	date	particulars	chkd	appd
	01				
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
GEOTECHNICAL MEASUREMENTS
SURFACE AND SUBSURFACE

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — LEA CONSULTING ENGINEERS

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05/04/29		plot. date	
scale 1:5, 1:2000	authorized	CAD file type	DWG
dwg no PD-01-1009			ver 00

1:2000 0 50 100 150 200 m

1:5 0 100 200 300 400 500 mm

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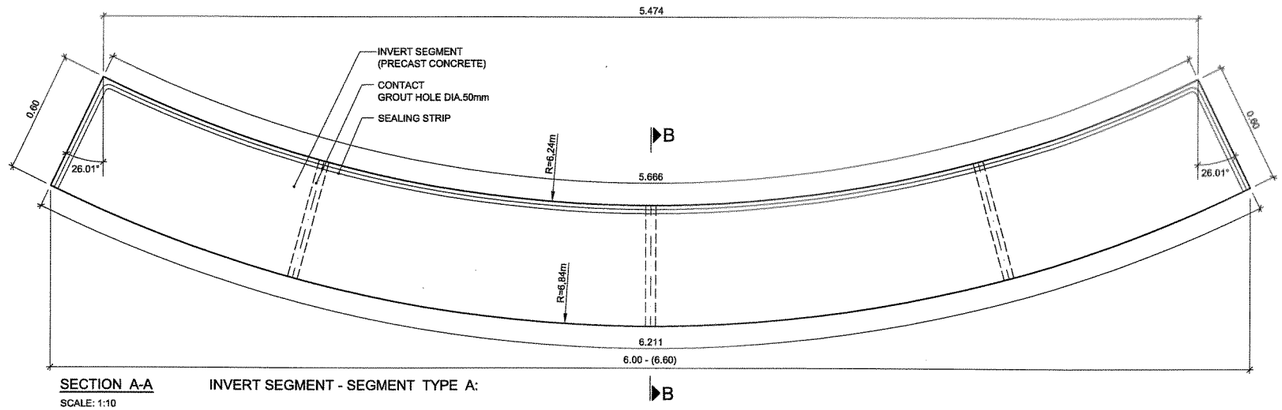
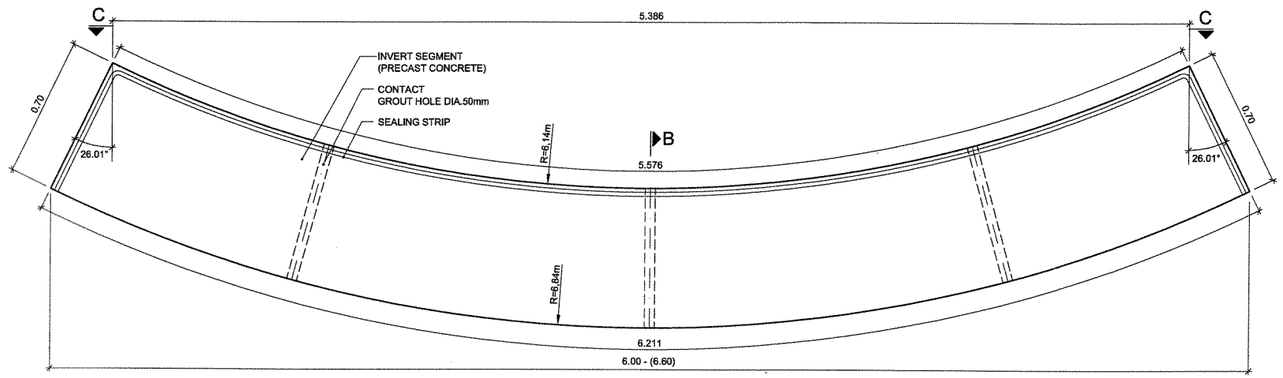


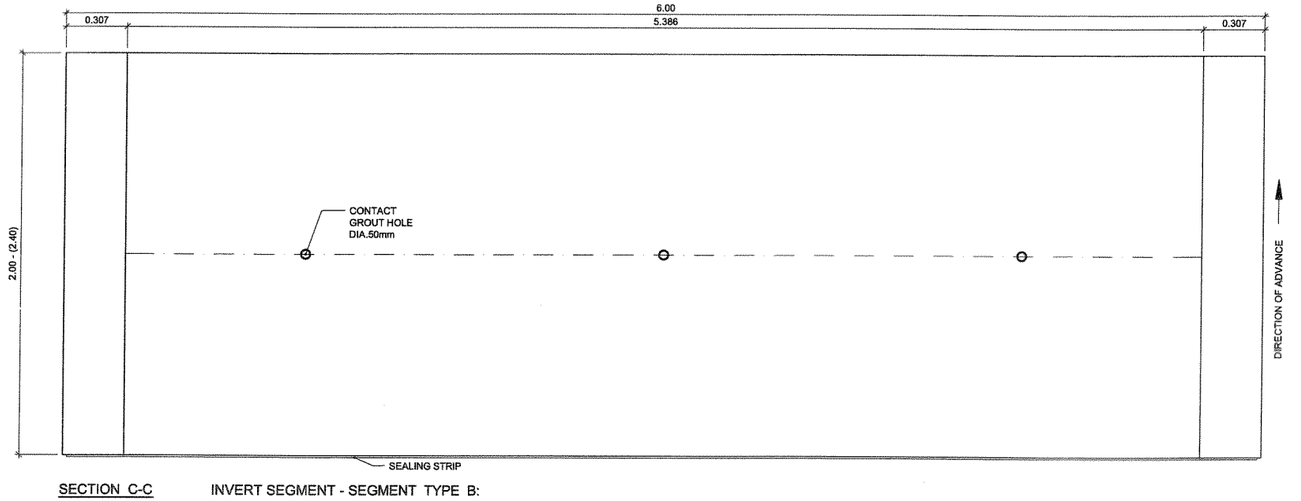
SECTION A-A
SCALE: 1:10

INVERT SEGMENT - SEGMENT TYPE A:



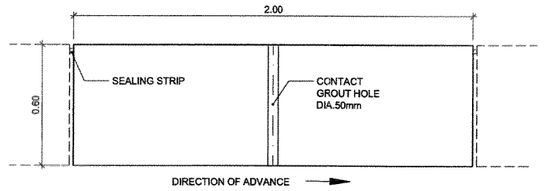
SECTION A-A
SCALE: 1:10

INVERT SEGMENT - SEGMENT TYPE B:



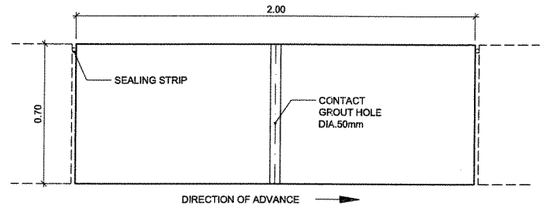
SECTION C-C
SCALE: 1:10

INVERT SEGMENT - SEGMENT TYPE B:



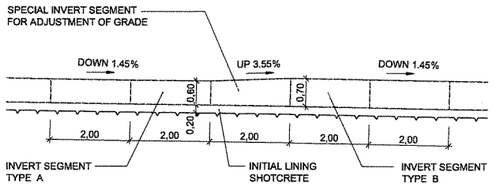
SECTION B-B
SCALE: 1:10

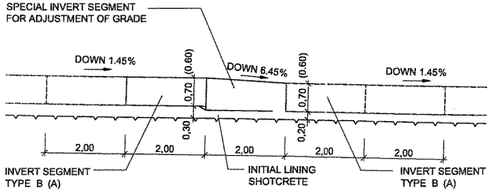
SEGMENT TYPE A:



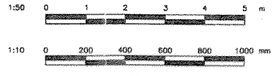
SECTION B-B
SCALE: 1:10

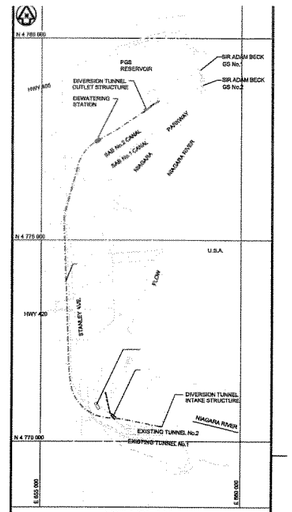
SEGMENT TYPE B:





LINING THICKNESS CHANGE (INVERT):
SCALE: 1:50





KEY PLAN
SCALE 1 : 50000

NOTES:

1. MAX. CHANGE OF LINING THICKNESS AT TRANSITIONS IS 100mm.
2. MIN. LENGTH OF TRANSITIONS AT CHANGES OF INTERNAL DIAMETER IS 2.0m

mf roll number	rev no	date	particulars	chkd	appd
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
INVERT SEGMENT
SECTIONS AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

drawn	designed by		
chkd			
date ymm/dd/yy: 05/04/29	design approved	plot date / plot scale: 1:1 M	
scale: 1:10, 50	authorized	dwg. code / CAD file type: DWG	
dwg no: PD-01-1010			rev: 00

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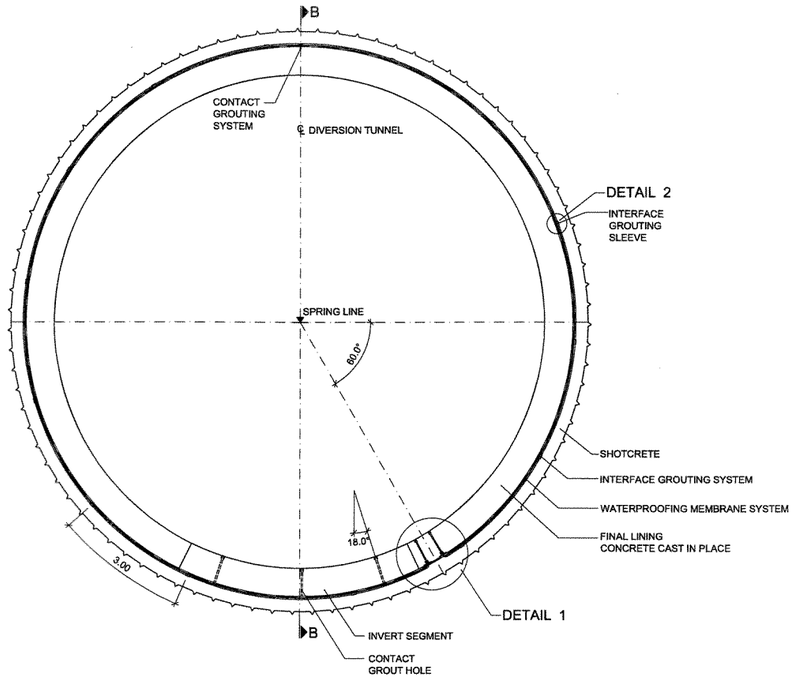
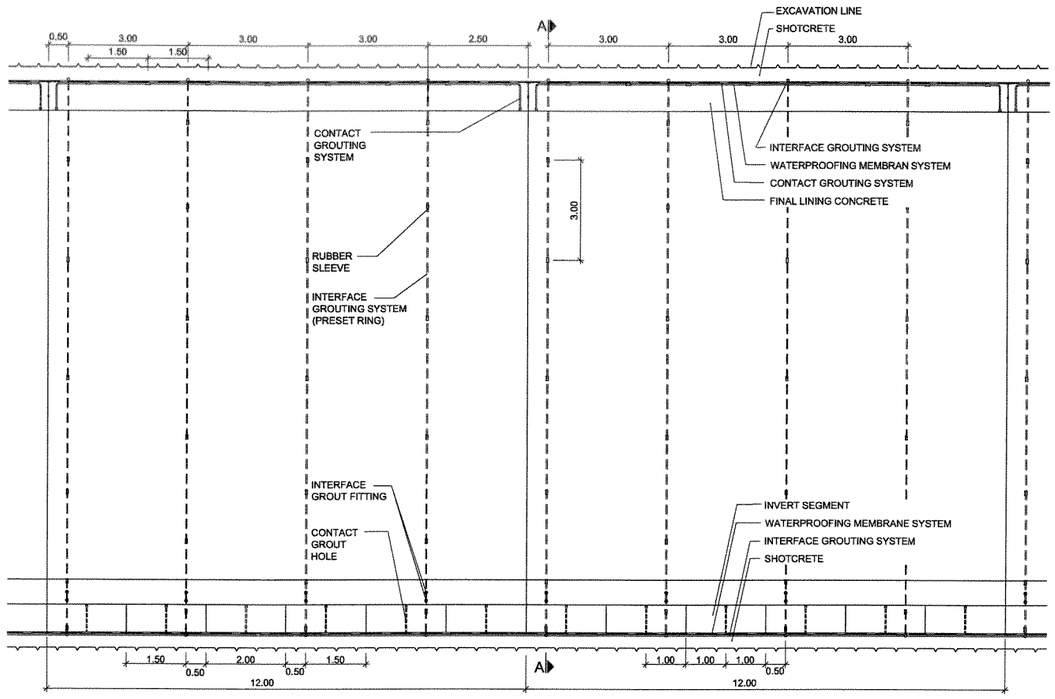
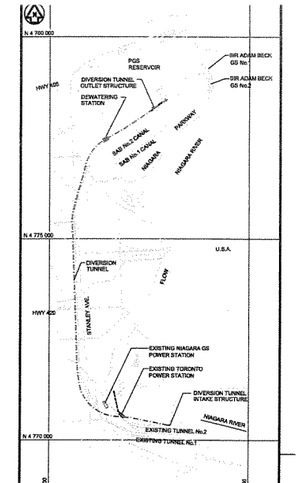


CROSS SECTION A-A
SCALE: 1:50



LONGITUDINAL SECTION B-B
SCALE: 1:50



KEY PLAN
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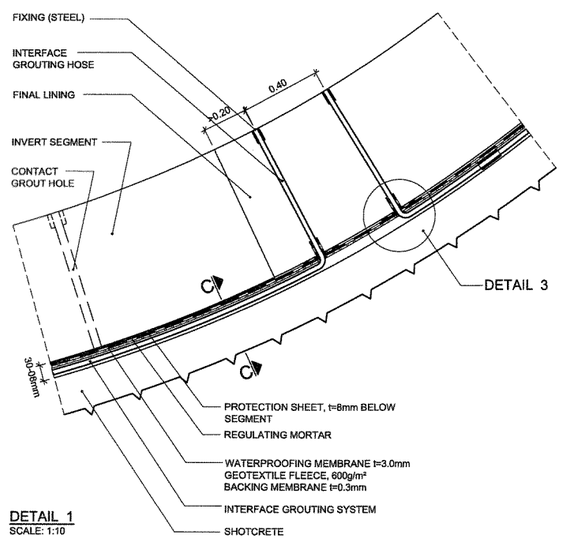
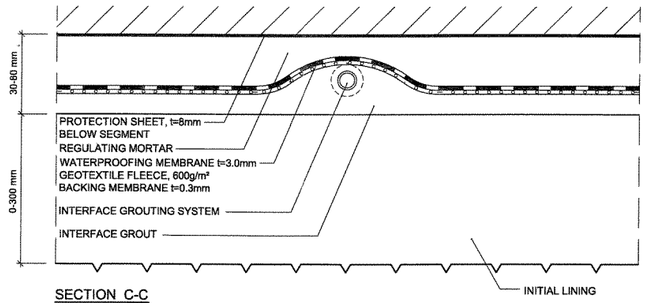
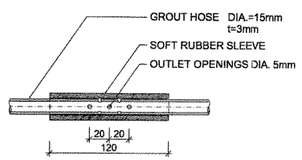


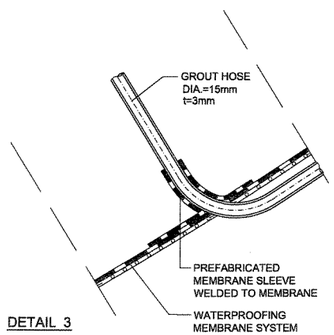
DETAIL 1
SCALE: 1:10



SECTION C-C
SCALE: 1:2



DETAIL 2 INTERFACE GROUTING SYSTEM
GROUT HOSE WITH OUTLET VALVE
SCALE: 1:2



DETAIL 3
SCALE: 1:2

1:50 0 1 2 3 4 5 m
1:10 0 200 400 600 800 1000 mm
1:2 0 50 100 150 200 mm

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
INTERFACE GROUTING
SECTION AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HLP CONSULTING ENGINEERS

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chkd			
date	xmlno/dd/yy 05/04/29	design approved	print scale 1:1 M
scale	1:50, 1:10, 1:2	authorized	CAD file type DWG
dwg no	PD-01-1019		ver 00

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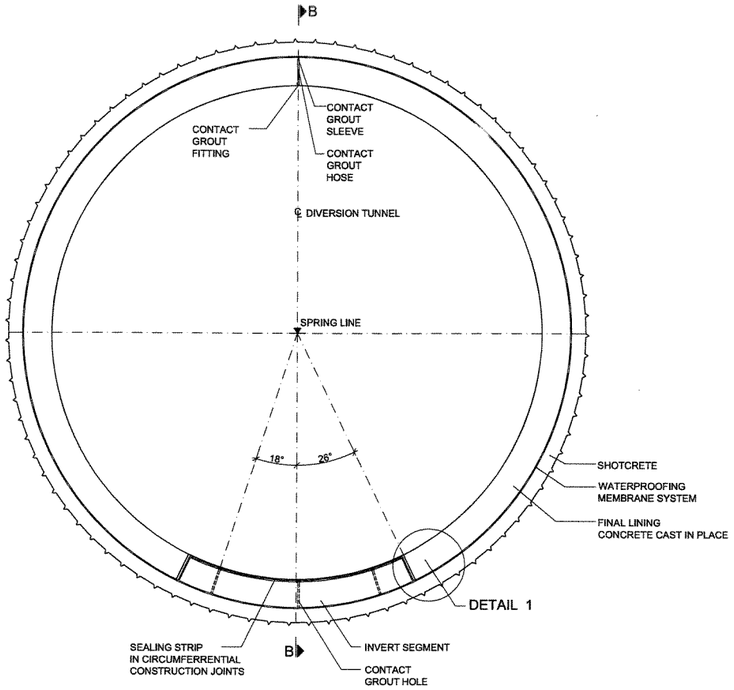
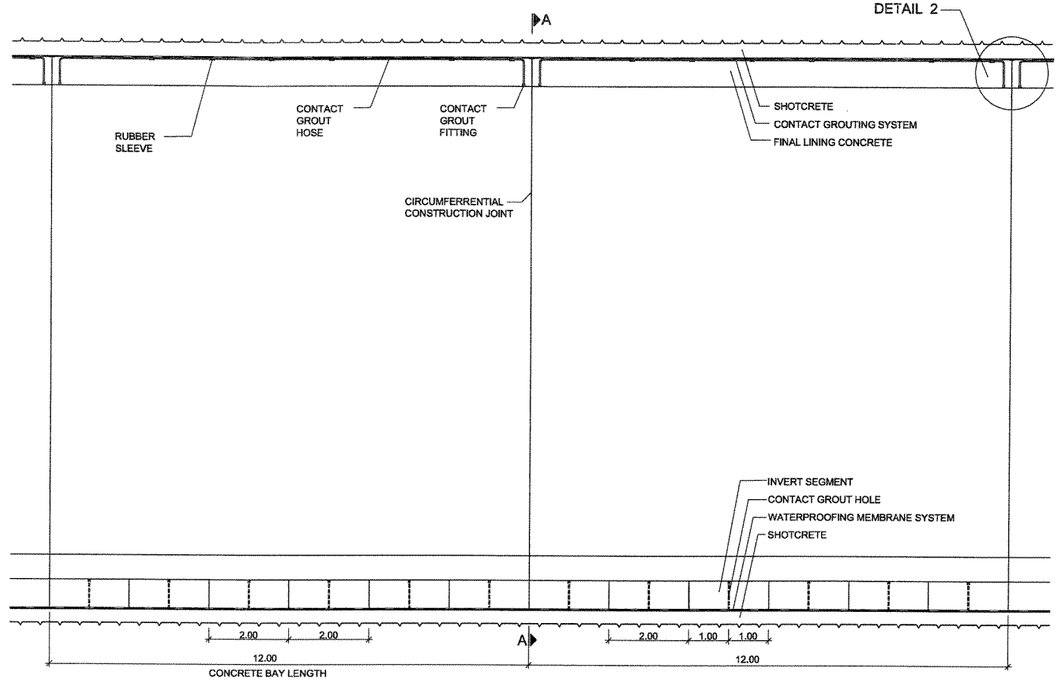
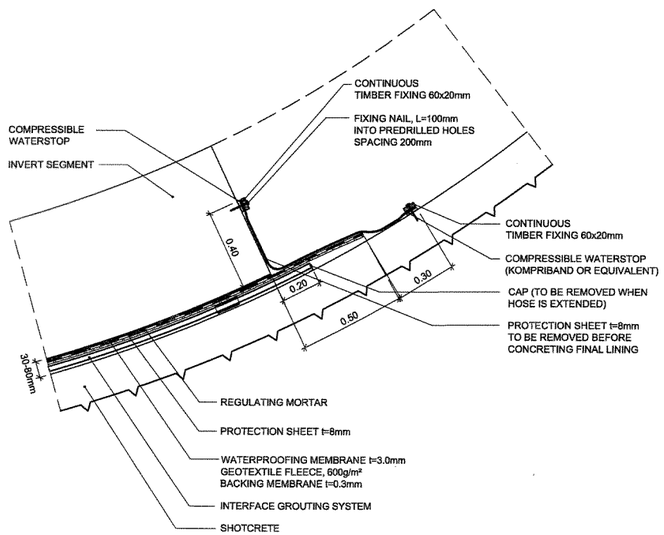
A0 (641 x 1189)



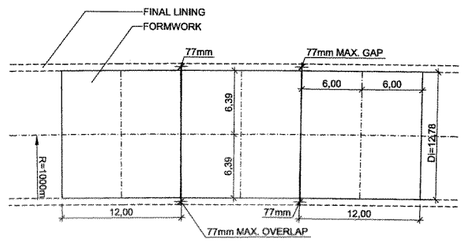
CROSS SECTION A-A
SCALE: 1:50



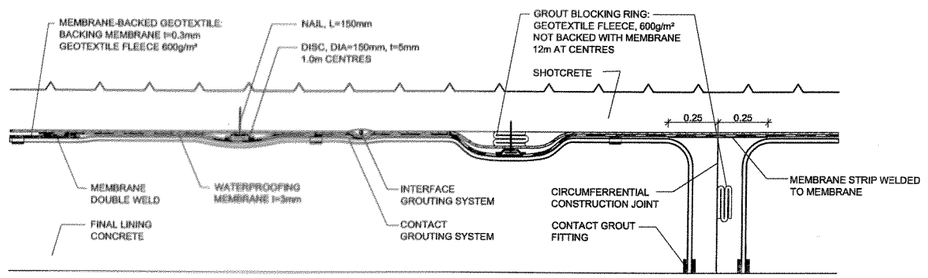
LONGITUDINAL SECTION B-B
SCALE: 1:50



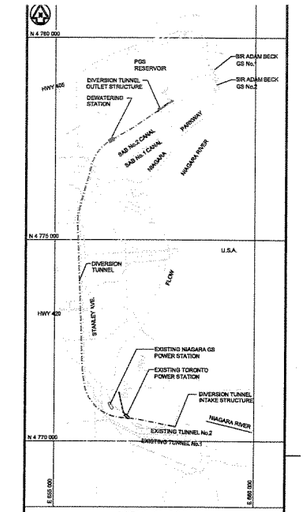
DETAIL 1
SCALE: 1:10
WATERPROOFING MEMBRANE PROTECTION



12m LONG FORMWORK AT HORIZONTAL / VERTICAL CURVE
SCALE: 1:200



DETAIL 2
NOT TO SCALE
FIXING OF WATERPROOFING MEMBRANE SYSTEM AND CONTACT GROUTING SYSTEM



KEY PLAN
SCALE 1 : 50000

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
FINAL LINING SECTIONS
AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HLP CONSULTING ENGINEERS

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date: yr/mo/dy/hr: 05/04/29	design approved	plot scale: 1:1 M	
scale: 1:10, 1:50, 1:200	authorized	dirct. cords	
		CAD file type: DWG	
dwg no: PD-01-1020			ver: 00

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1:50 0 1 2 3 4 5 m
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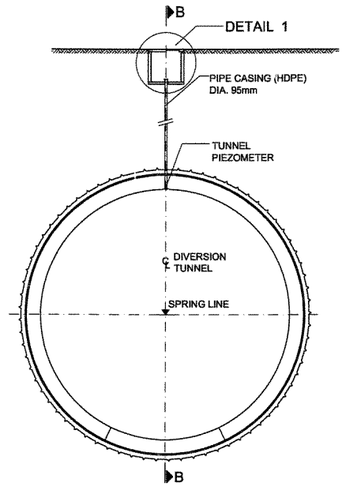
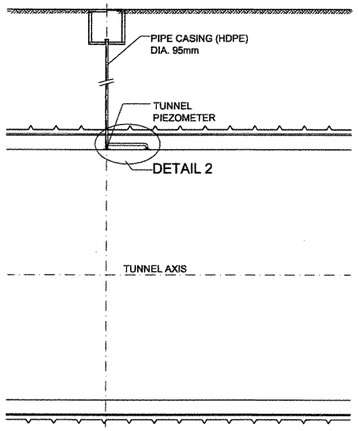
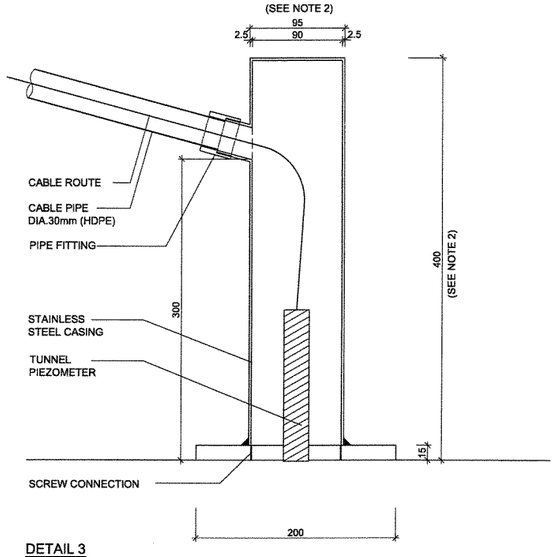
A0 (841 x 1189)



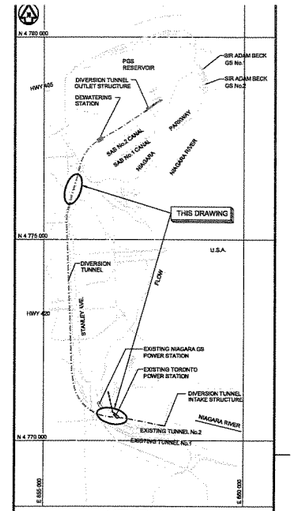
CROSS SECTION A-A
SCALE 1:100



LONGITUDINAL SECTION B-B
SCALE 1:100



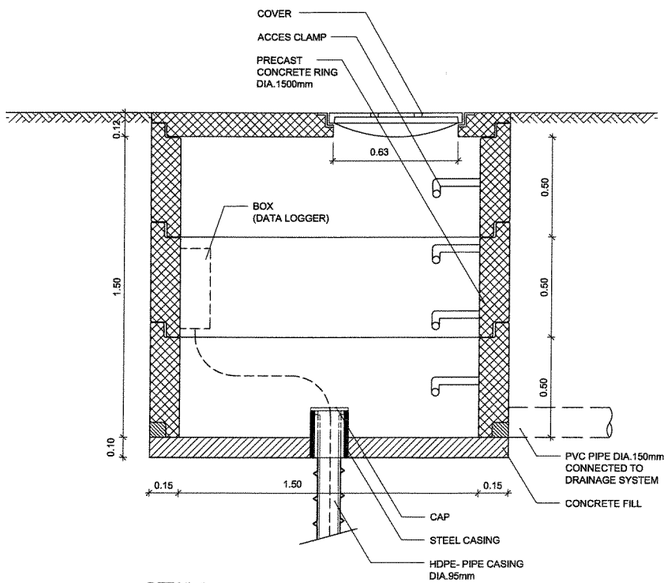
DETAIL 3
SCALE: 1:2



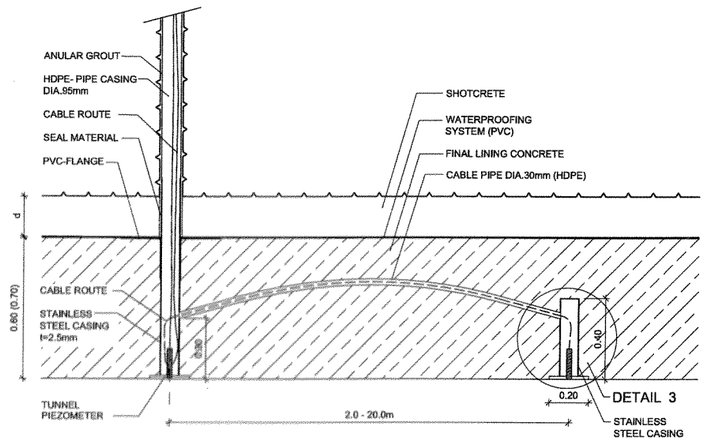
KEY PLAN
SCALE 1 : 50000

NOTES:

1. POSSIBLE OFFSET OF DRILLHOLE 2m WITH RESPECT TO DRILLING ACCURACY
2. DIMENSIONS OF STAINLESS STEEL CASING TO BE ADJUSTED ACCORDING TO THE PIEZOMETER MANUFACTURER'S RECOMMENDATION TO ALLOW MAINTENANCE OF THE INSTRUMENTS
3. TUNNEL PIEZOMETERS TO BE INSTALLED AT STATION 1+295.000m AND STATION 7+400.000m APPROXIMATELY.



DETAIL 1
SCALE 1:10



DETAIL 2
SCALE 1:10

1:100 0 2 4 6 8 10 m
1:10 0 200 400 600 800 1000 mm
1:2 0 50 100 150 200 mm

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
TUNNEL PIEZOMETERS
SECTIONS AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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date yr/mo/dd/day 05/04/29	design approved	plot scale	1:1 M
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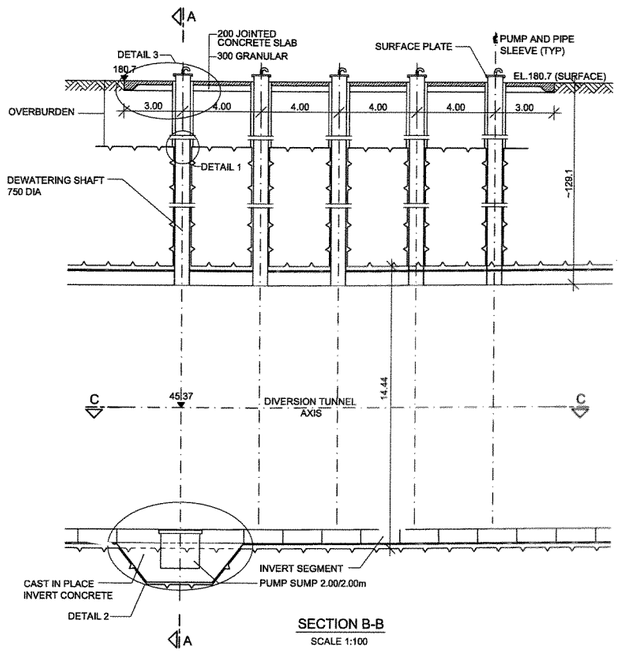
A0 (641 x 1189)



SECTION B-B
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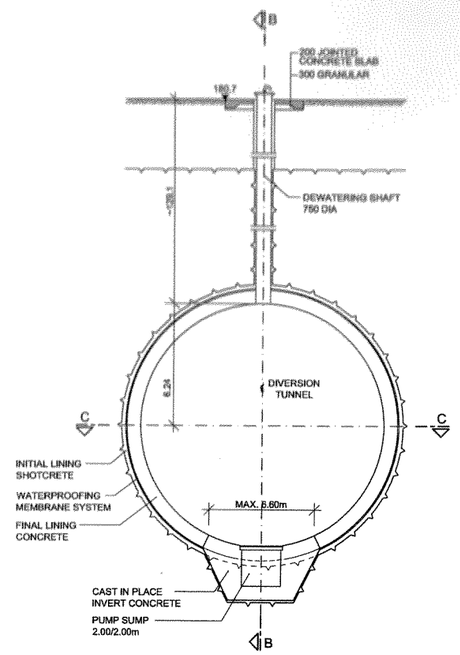
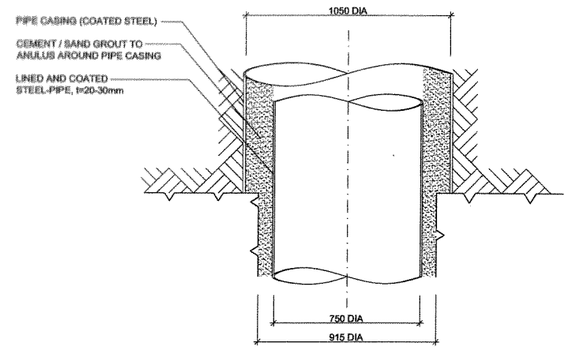
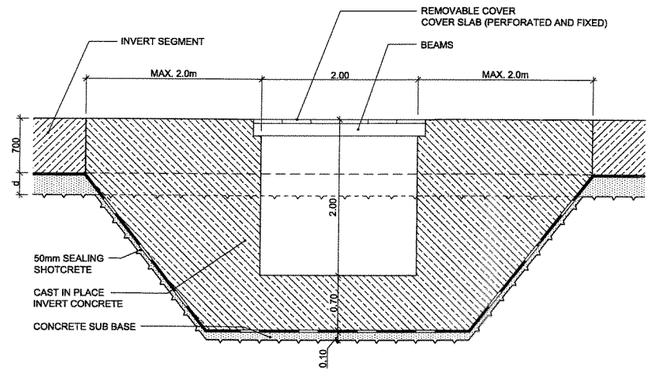


SECTION A-A
SCALE 1:100



DETAIL 1
SCALE 1:10



DETAIL 2
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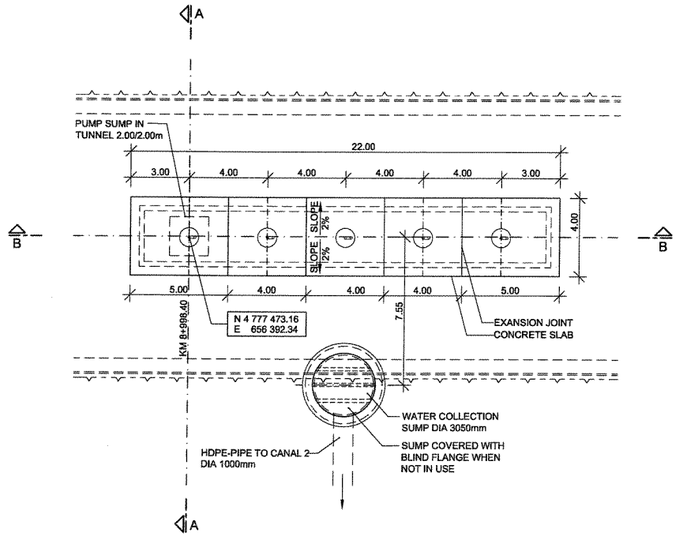
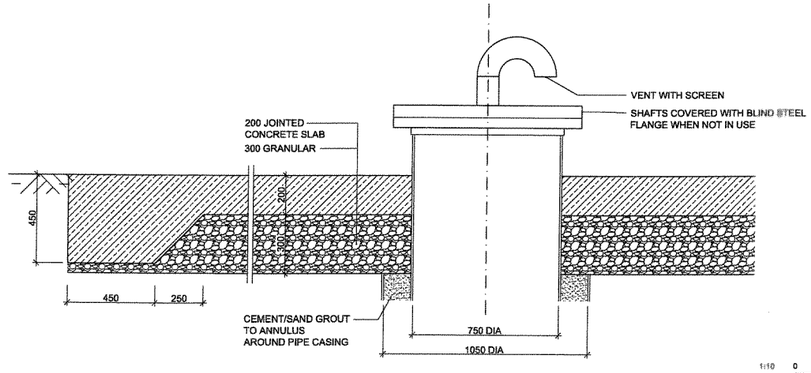


SURFACE PLAN
SCALE 1:100



DETAIL 3
SCALE 1:10

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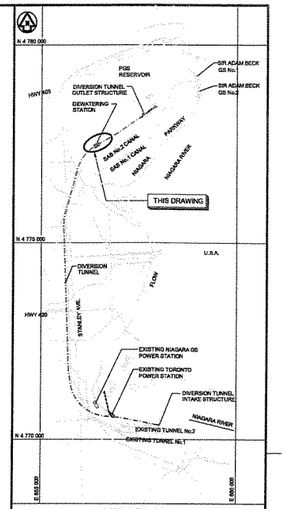
1:25 0 0.5 1.0 1.5 2.0 2.5 m
1:100 0 2 4 6 8 10 m



KEY PLAN
SCALE 1 : 50000

NOTES:

1. STEEL PIPE DIA.=750mm COATED WITH PE AND LINED WITH FUSION BONDED EPOXY

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
DEWATERING SYSTEM PLAN, SECTIONS AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

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scale 1:10, 1:25, 1:100	authorized	CAD file type DWG	
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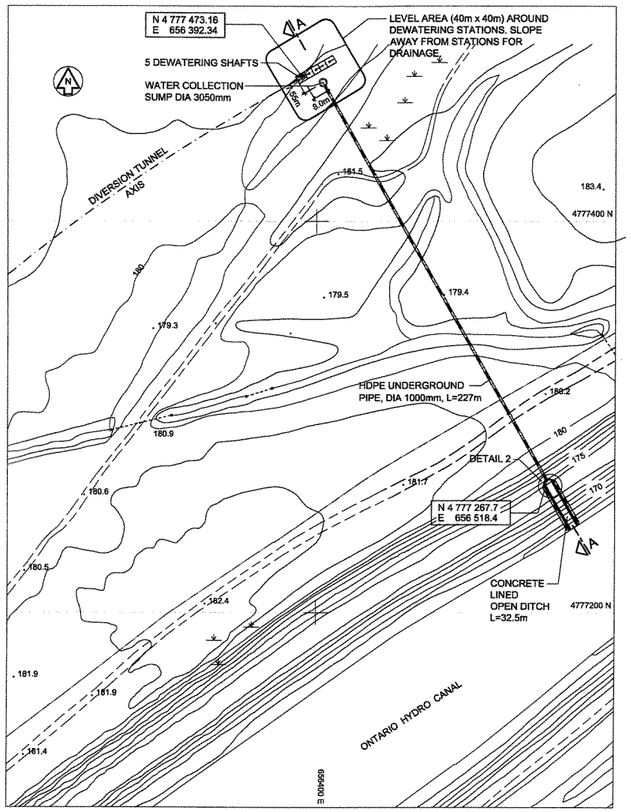
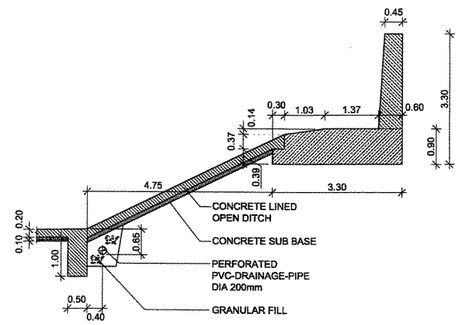
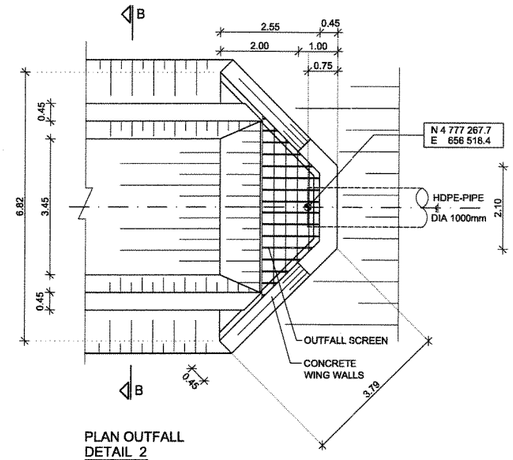


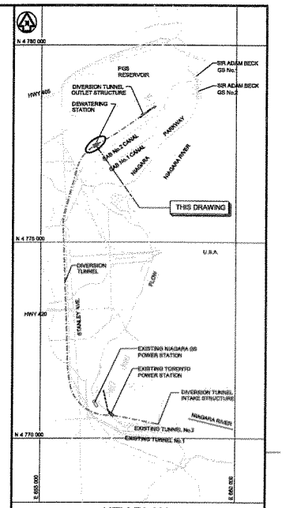
PLAN
SCALE 1:1000



DETAIL 1
SCALE 1:50



PLAN OUTFALL
DETAIL 2
SCALE 1:50



KEY PLAN
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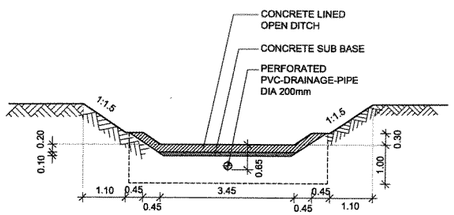
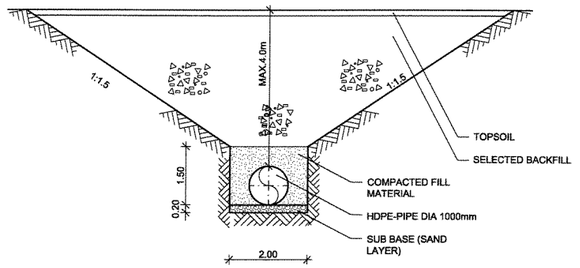
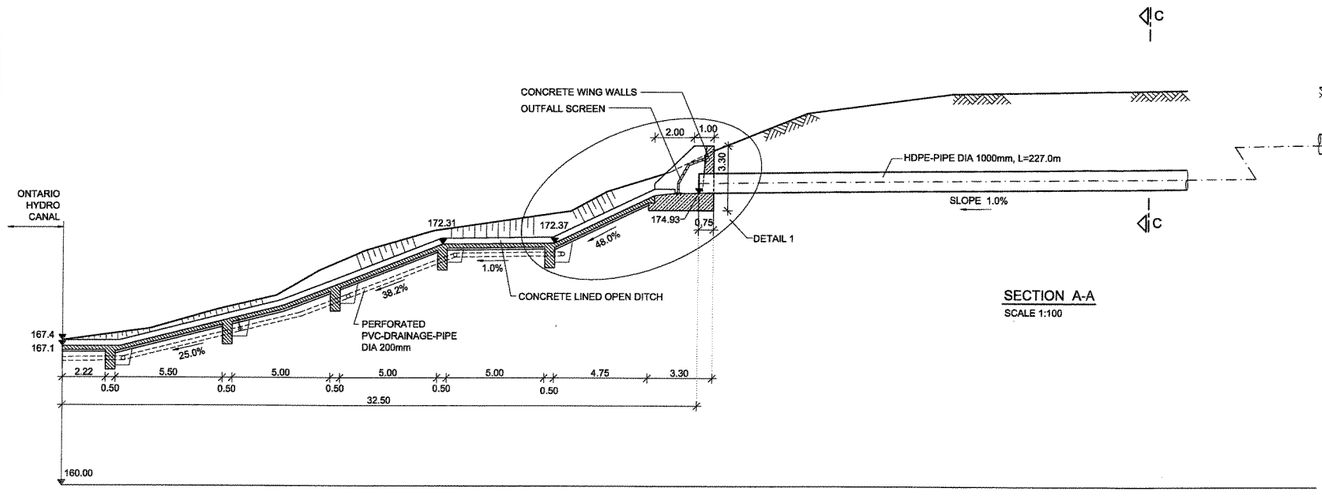


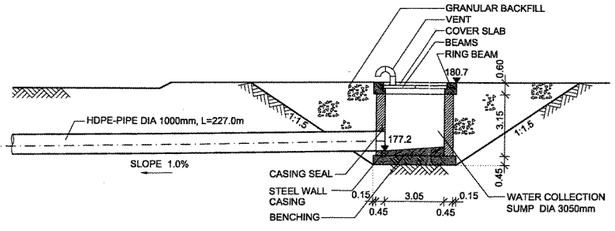
SECTION B-B
SCALE 1:50



SECTION C-C
SCALE 1:50



SECTION A-A
SCALE 1:100



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1:1000 0 20 40 60 80 100 m

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
DEWATERING OUTFALL AND PIPE
PLAN, SECTIONS AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

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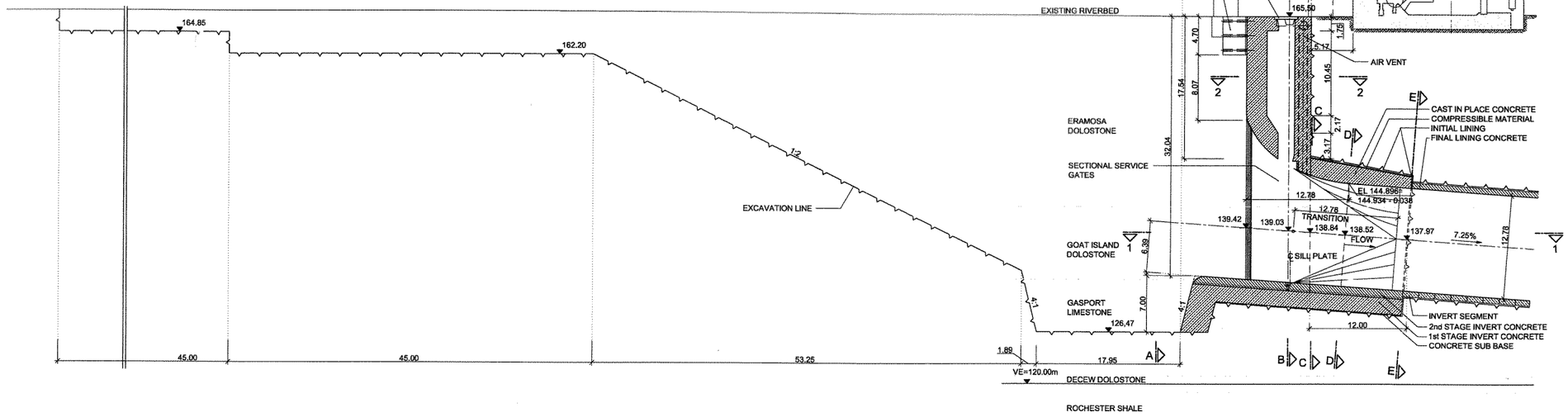
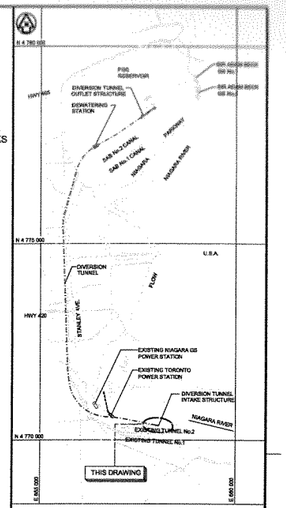
LONGITUDINAL SECTION
SCALE 1 : 200





KEY PLAN
SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L= 3.60m, e/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm

2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT

3. SECTIONS A-A, B-B, C-C, D-D, E-E ON DRAWING PD-02-1016

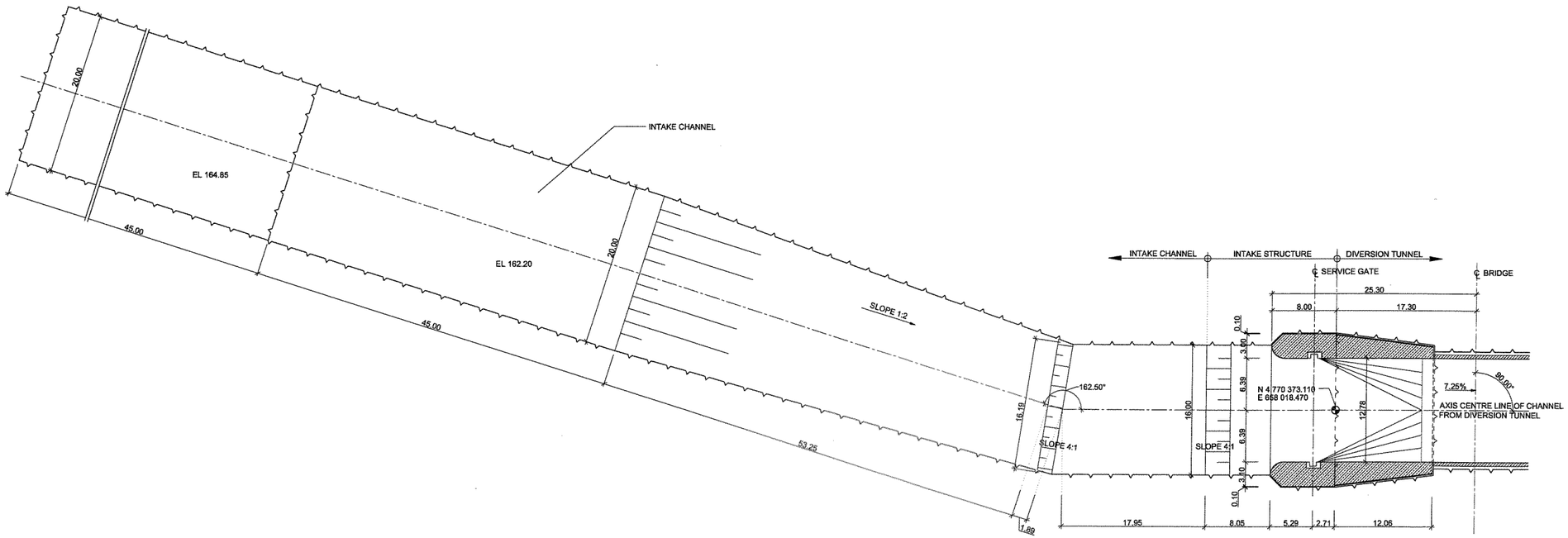
LEGEND:

FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

BH ... BOREHOLE

PLAN 1 - 1
SCALE 1 : 200



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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
PLAN AND LONGITUDINAL SECTION

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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date 05/04/29	design approved	plot scale 1:1 M	
scale 1:200	authorized	CAD file type DWG	
dwg no PD-02-1015			ver 00

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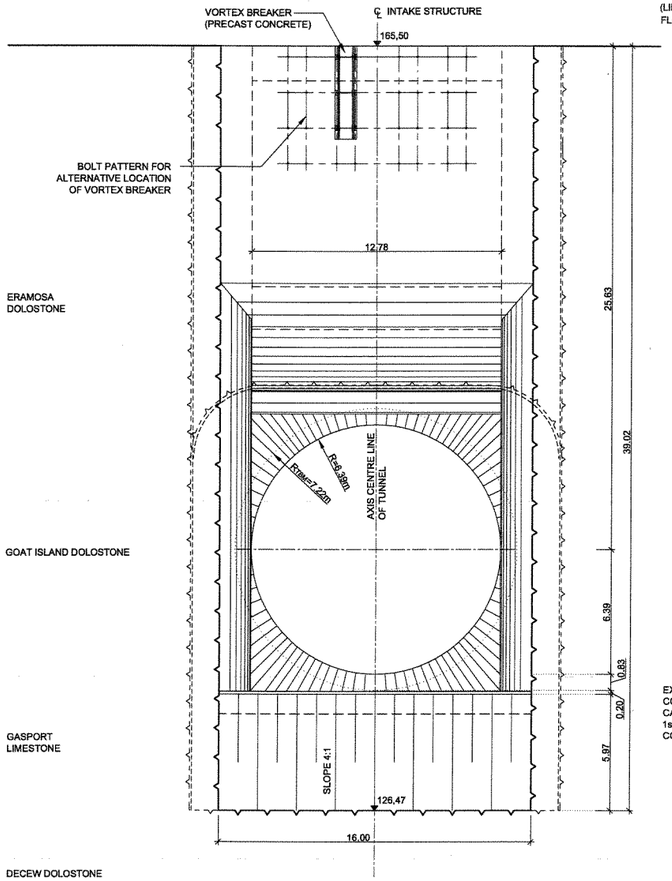

SECTION A - A

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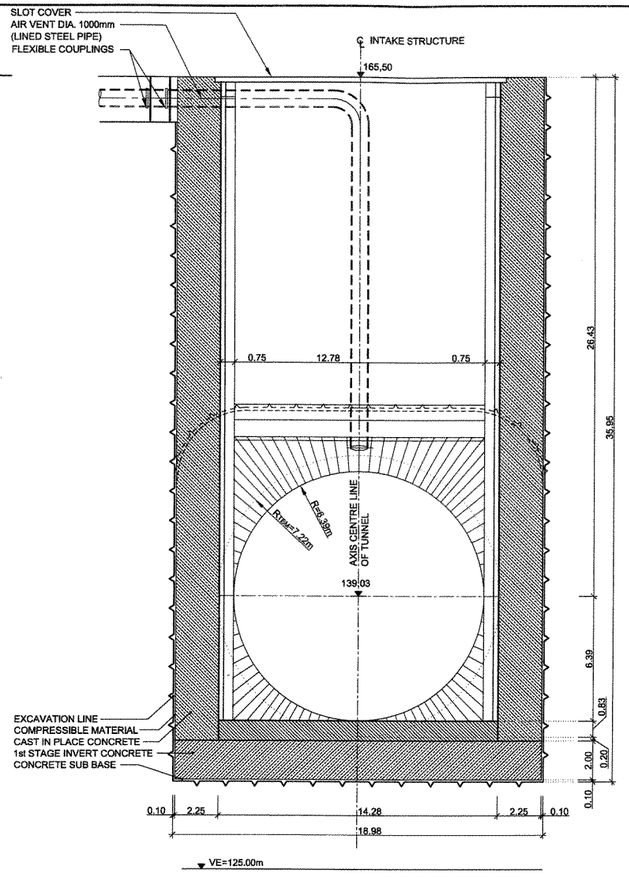
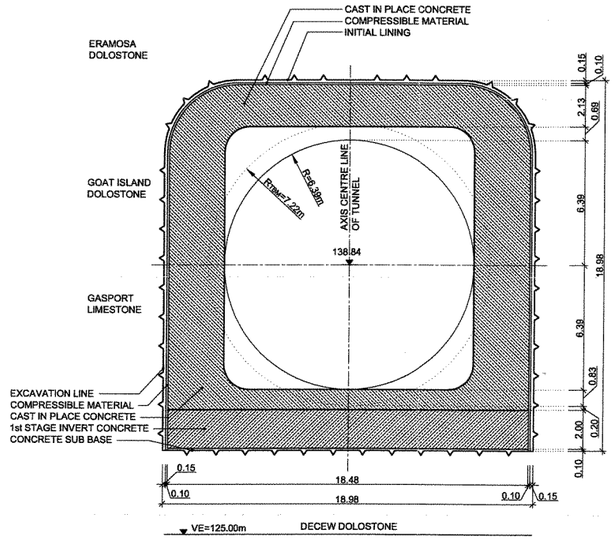


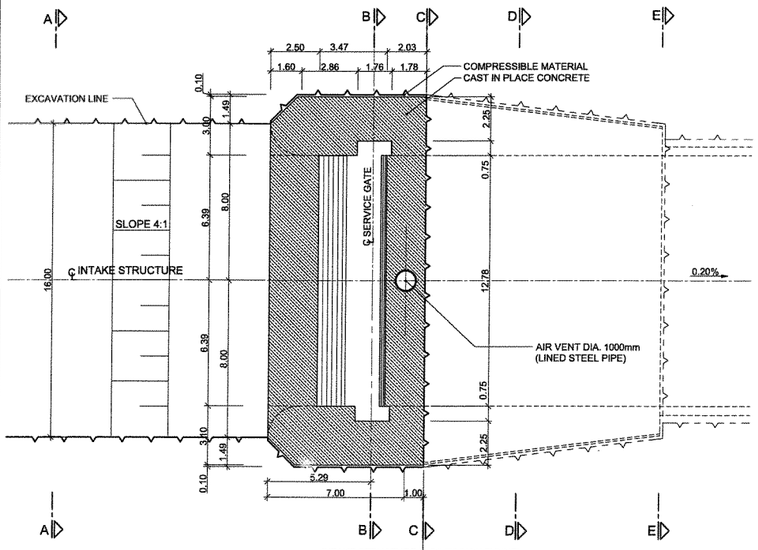
SECTION B - B

SCALE 1 : 100



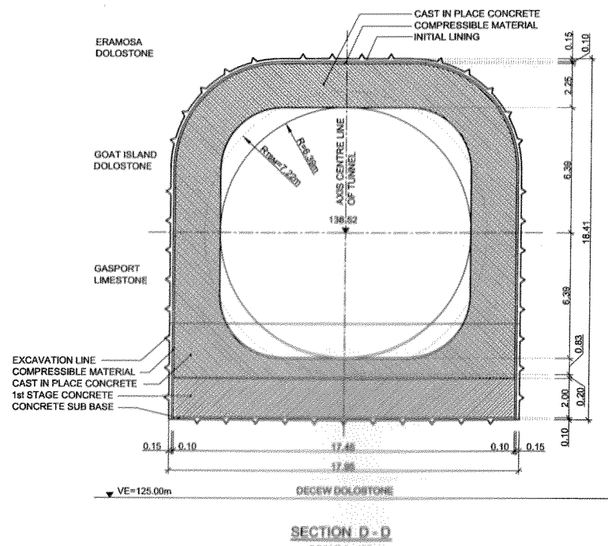
SECTION C - C

SCALE 1 : 100



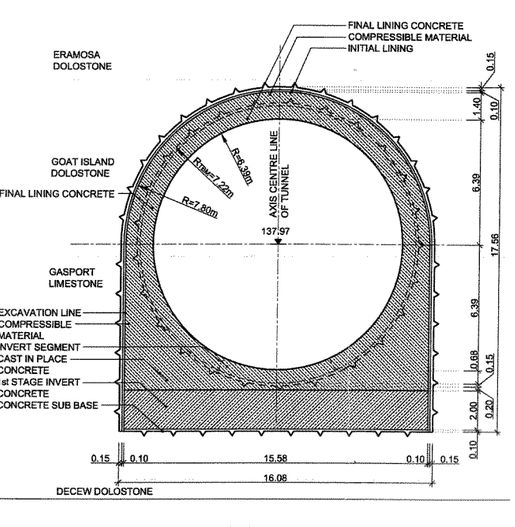
PLAN 2 - 2

SCALE 1 : 100



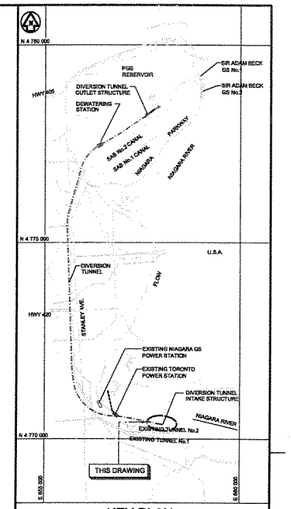
SECTION D - D

SCALE 1 : 100



SECTION E - E

SCALE 1 : 100



KEY PLAN

SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, e/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT
3. AIR VENT STEEL PIPE LINED WITH FUSION BONDED EPOXY.

1:100 0 2,5 5 7,5 10 m

ref. ref. number	ver. no.	date	particulars	per. chkd	appd
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
CROSS SECTIONS

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ELF CONSULTING ENGINEERS

drawn	designed by		
chkd			
date yr/mo/day 05/04/29	design approved	date	plot scale 1:1 M
scale 1:100	distributed		dwg file type DWG
dwg no. PD-02-1016			ver 00

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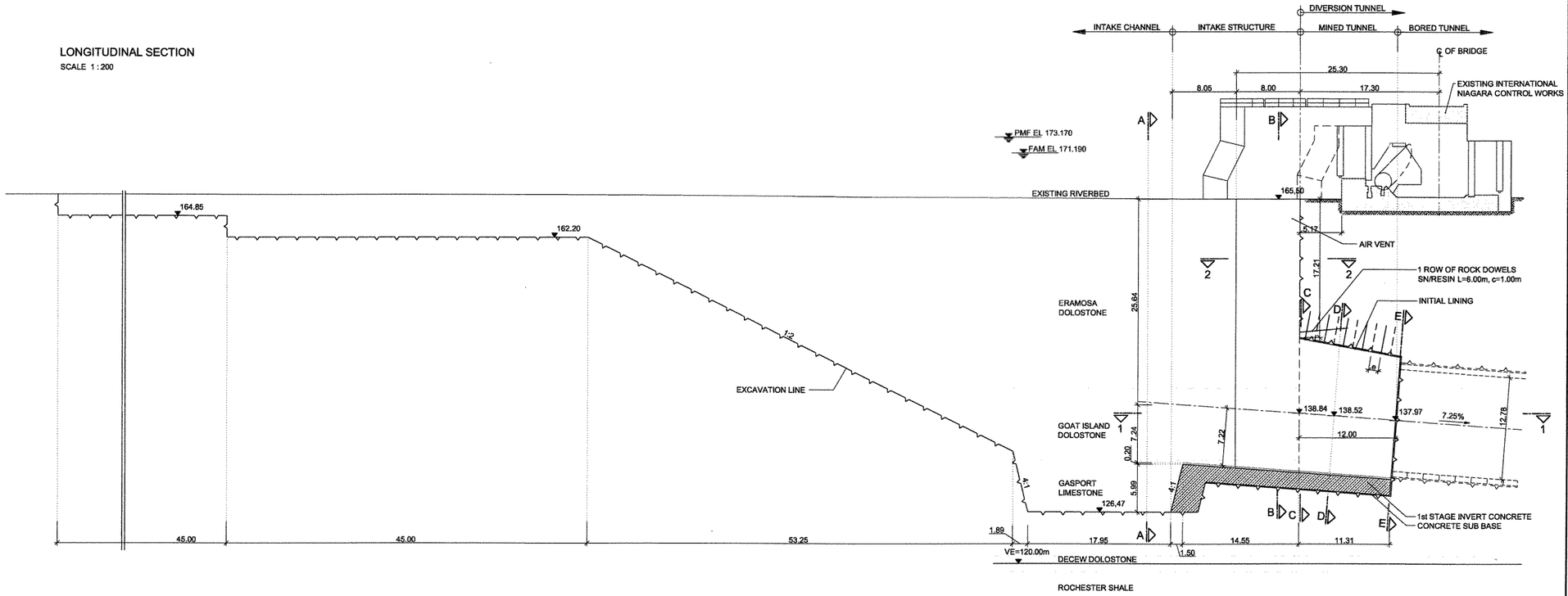
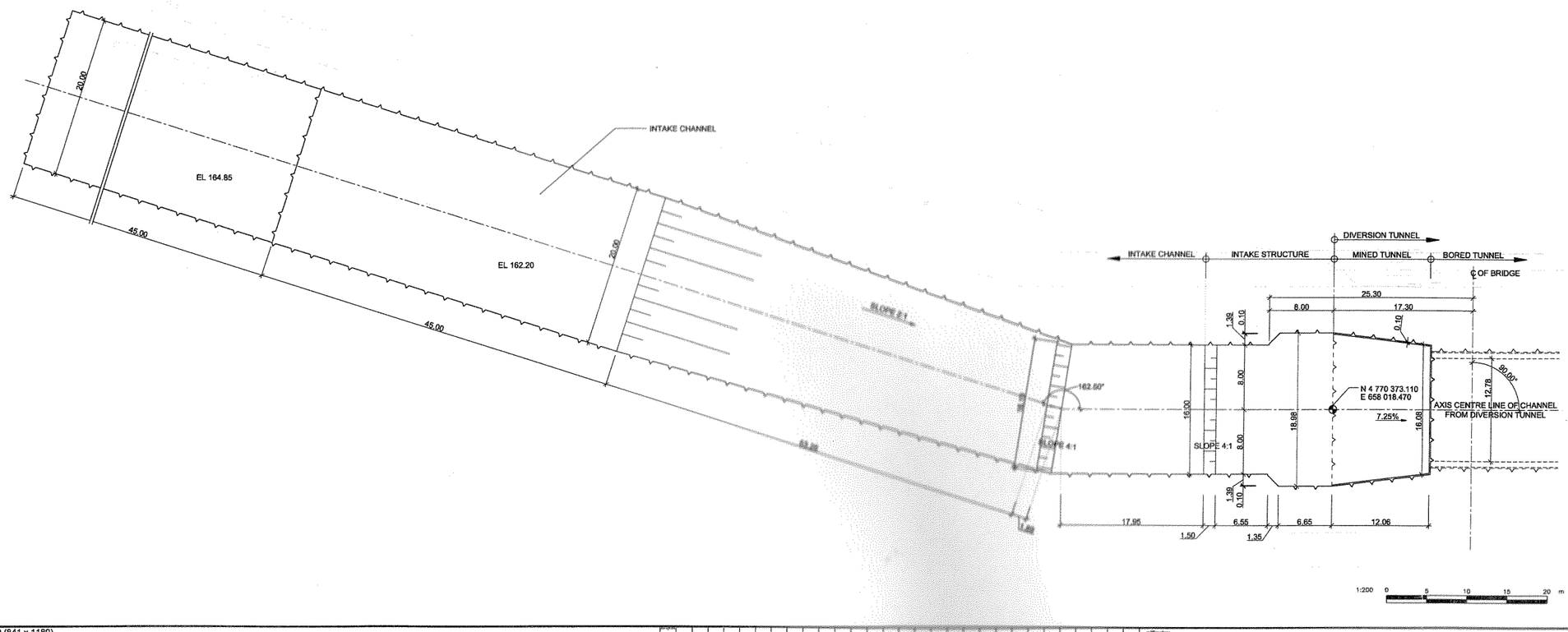
A0 (841 x 1189)

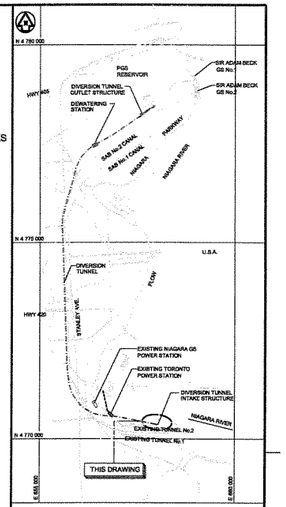
millimetres 0 10 50 100 200 250 300

LONGITUDINAL SECTION
SCALE 1 : 200



PLAN 1 - 1
SCALE 1 : 200





KEY PLAN
SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, e/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT
3. SECTIONS A-A, B-B, C-C, D-D, E-E ON DRAWING PD-02-1018

LEGEND:

FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

BH ... BOREHOLE

rel ref number	ver no	date	particulars	plan chkd	appd
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	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
TBM RECEPTION
PLAN AND LONGIDUDINAL SECTION

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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chkd		cad ope	
date yr/mo/dy 05/04/29	design approved	plot scale 1:1 M	
scale 1:200	authorized	CAD file type DWG	
dwg no PD-02-1017		rev 00	

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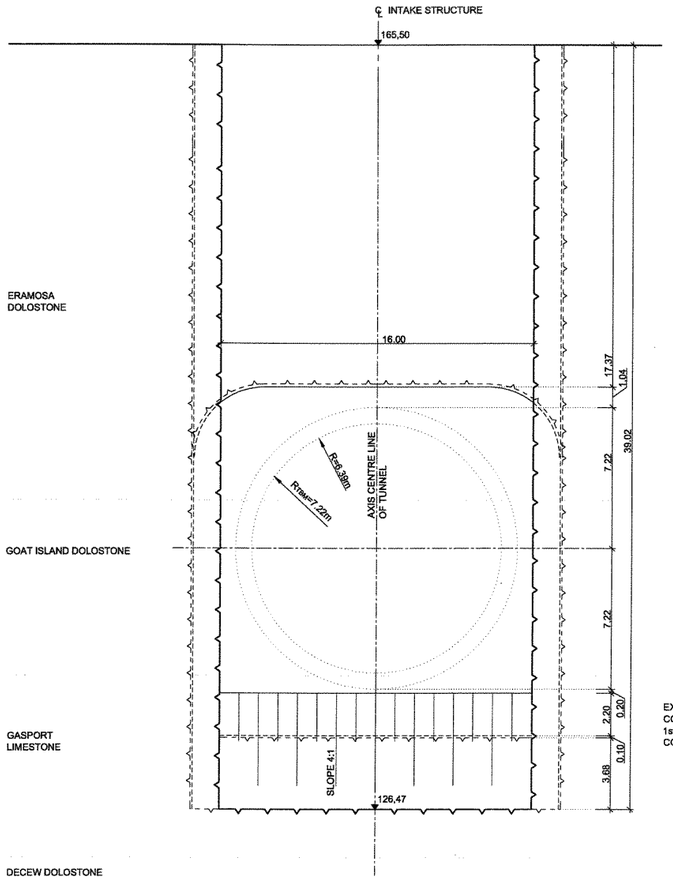
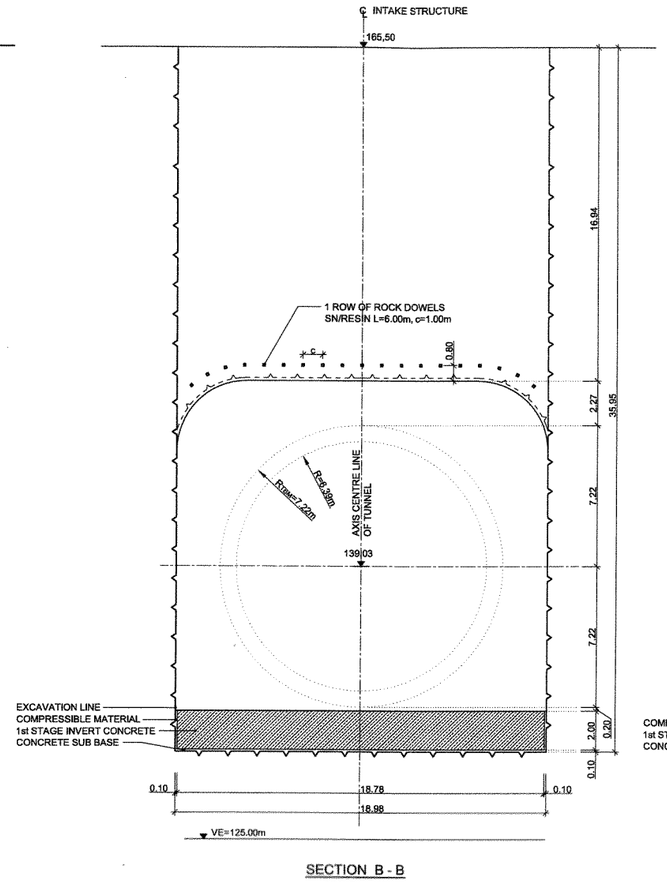
A0 (841 x 1189)

EE



SECTION A - A

SCALE 1 : 100



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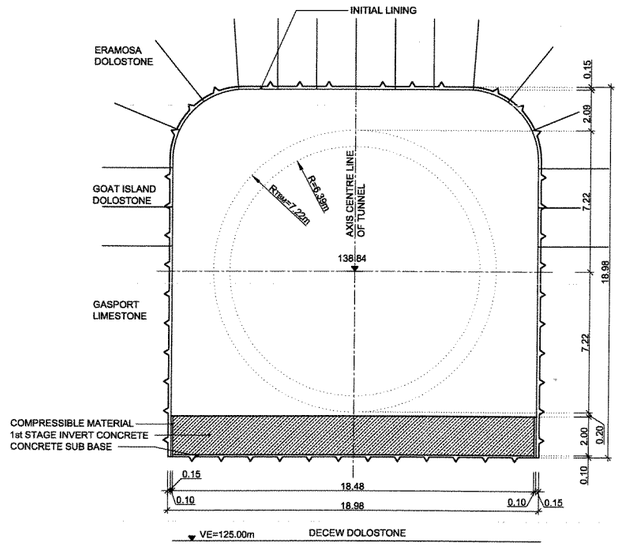

SECTION C - C

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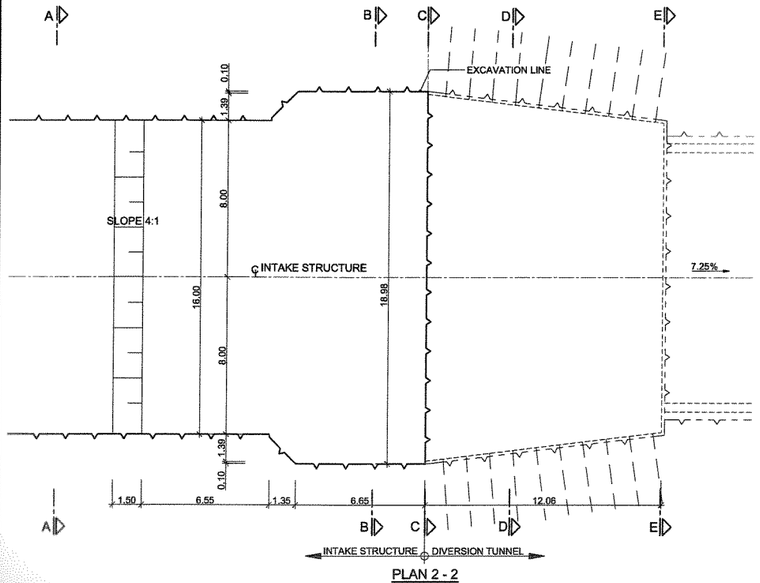
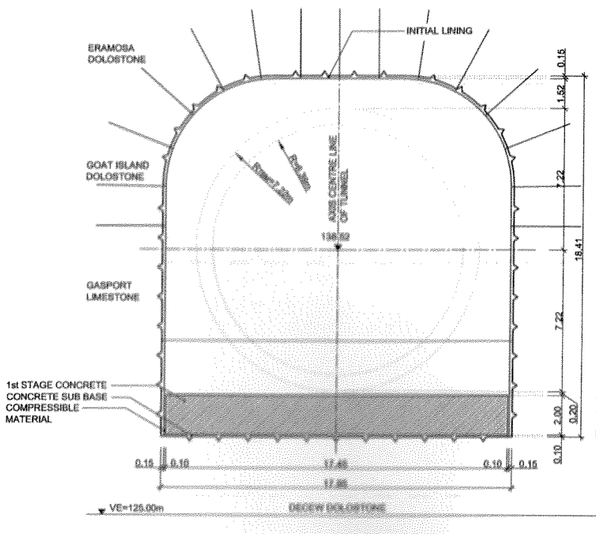


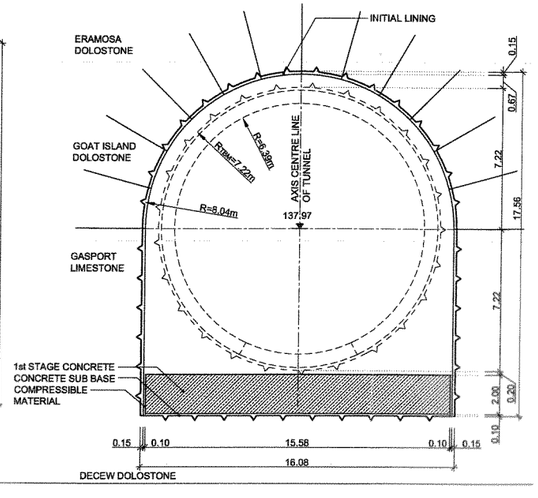
PLAN 2 - 2

SCALE 1 : 100



SECTION D - D

SCALE 1 : 100



SECTION E - E

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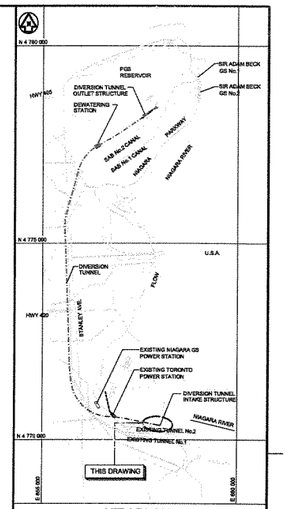

KEY PLAN

SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, e/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT
3. ADVANCE LENGTH OF ONE ROUND OF EXCAVATION AND SUPPORT INSTALLATION IN MINED TUNNEL SECTION TO BE RESTRICTED TO MAX. 1.50m

1:100 0 2,5 5 7,5 10 m

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
TBM RECEPTION
SECTIONS

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HATCH CONSULTING ENGINEERS

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scale	approved	file no. sub	
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dwg no. PD-02-1016 — rev 00

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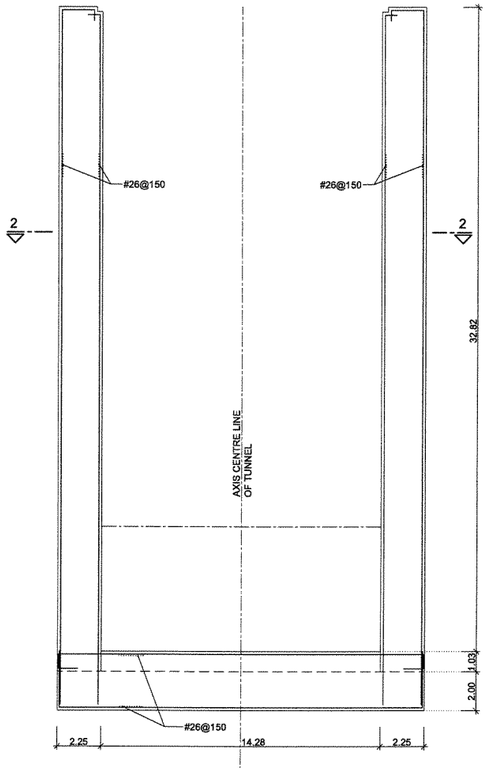
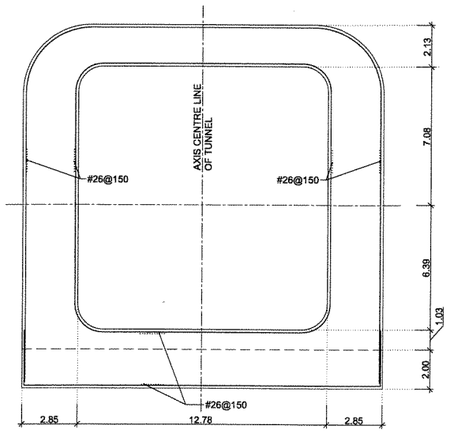


SECTION B - B
SCALE 1 : 100



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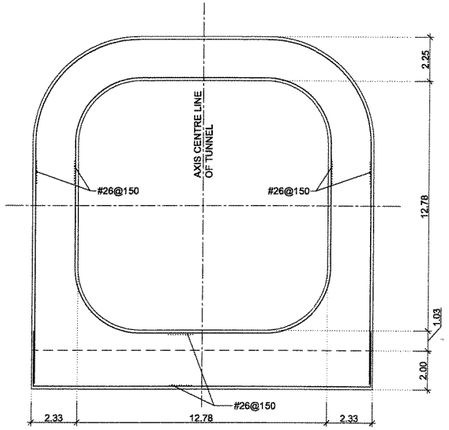

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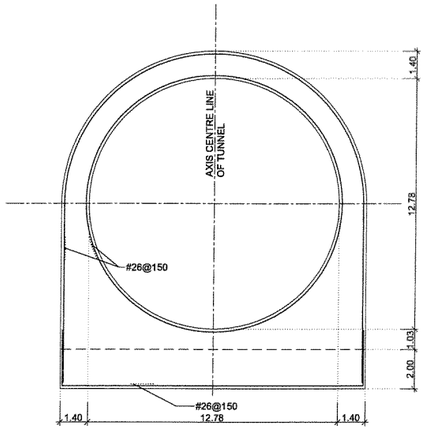

SECTION E - E
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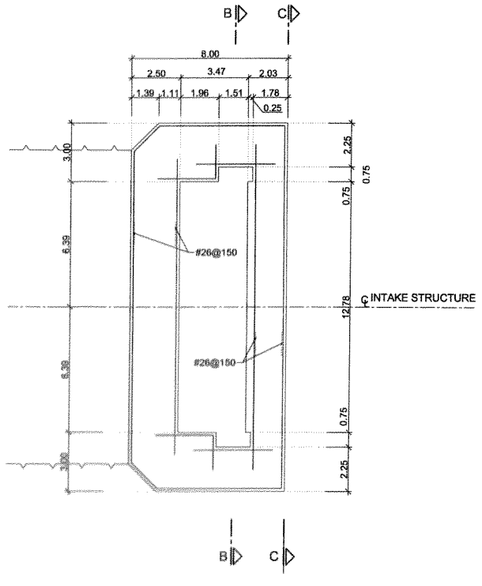
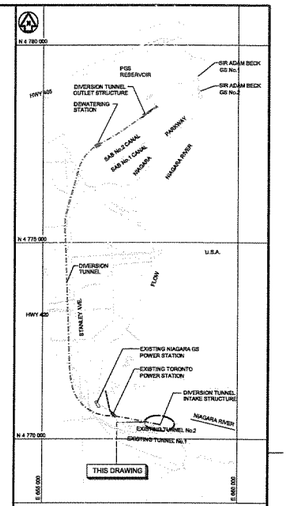


PLAN 2 - 2
SCALE 1 : 100



KEY PLAN
SCALE 1 : 50000

NOTES:

1. ARRANGEMENT OF BAR SIZE, SPACING AND LOCATION IS ONLY INDICATIVE
2. FOR AMOUNT OF STEEL 90kg/m³ ARE ASSUMED ON AVERAGE. INCLUDING MAX. 5 kg/m³ OF AUXILIARY REINFORCEMENT (I.E. CHAIRS AND SPACERS)
3. BAR SIZE AND SPACING OF REBAR MAY BE ADJUSTED SUBJECT TO THE RESULT OF DETAILED STRUCTURAL ANALYSIS.

1:100 0 2.5 5 7.5 10 m

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
REINFORCEMENT
CROSS SECTIONS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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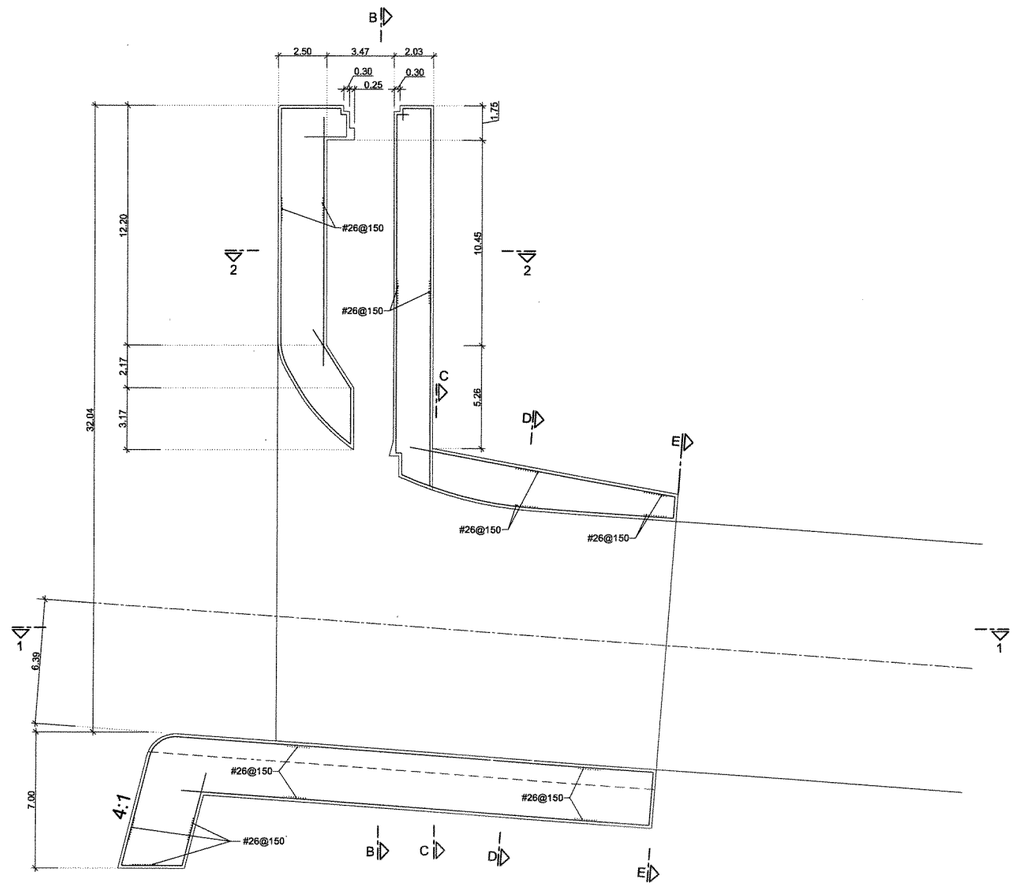
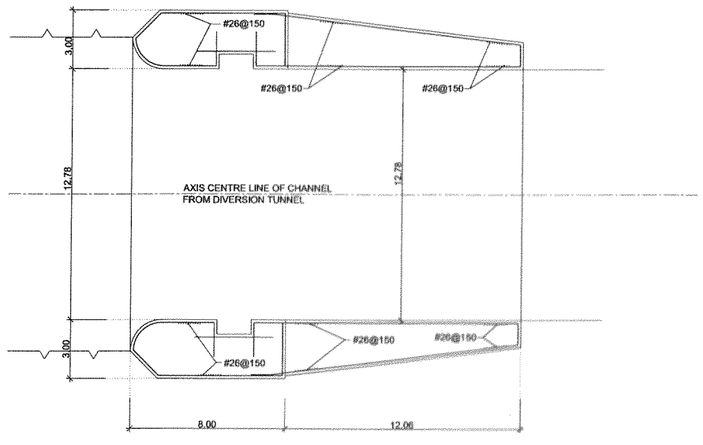
A0 (841 x 1189)

0 10 20 100 200 250 300 millimetres

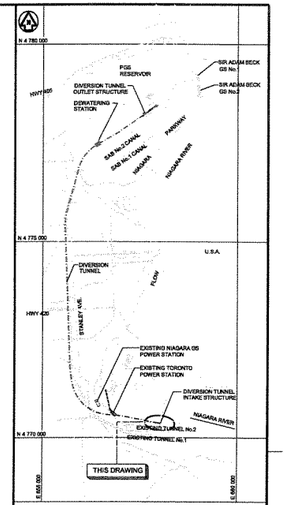


LONGITUDINAL SECTION
SCALE 1 : 100



PLAN 1 - 1

1:200 0 5 10 15 20 m



KEY PLAN
SCALE 1 : 50000

NOTES:

1. ARRANGEMENT OF BAR SIZE, SPACING AND LOCATION IS ONLY INDICATIVE
2. FOR AMOUNT OF STEEL 90kg/m³ ARE ASSUMED ON AVERAGE, INCLUDING MAX. 5 kg/m³ OF AUXILIARY REINFORCEMENT (I.E. CHAIRS AND SPACERS)
3. BAR SIZE AND SPACING OF REBAR MAY BE ADJUSTED SUBJECT TO THE RESULT OF DETAILED STRUCTURAL ANALYSIS.

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
INTAKE STRUCTURE
REINFORCEMENT
PLAN AND LONGITUDINAL SECTION

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HLF CONSULTING ENGINEERS

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date yr/mo/d/day 05/04/29	design approved		plot scale 1:1 M
scale 1:200	authorised		doc. code CAD file type DWG
dwg no. PD-02-1029			ver 00

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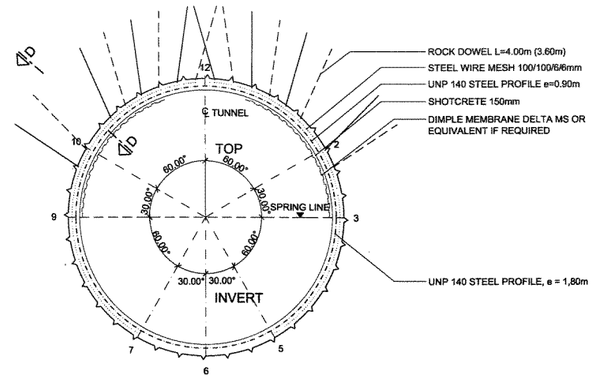
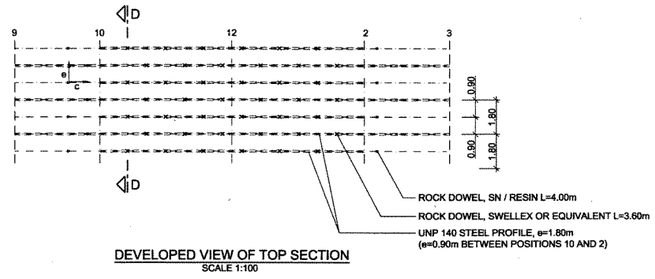


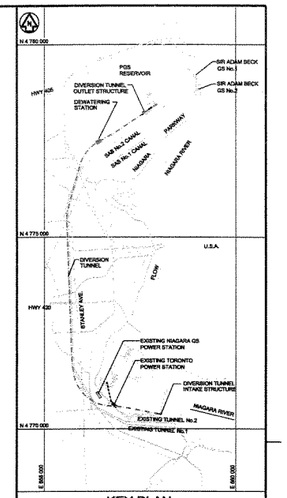
ROCK SUPPORT TYPE 4Q
GROSS SECTION, SCALE 1:100



DEVELOPED VIEW OF TOP SECTION
SCALE 1:100

DETAIL SECTION D-D
SCALE 1:5

EXCAVATION AND SUPPORT TYPE 4Q																					
ROCK MASS CHARACTERISTIC	ROCK MASS STRATIGRAPHY (DOMINANT)	ROCK SUPPORT TYPES	CLASSIFICATION CRITERIA ROCK MASS BEHAVIOUR	PRESENCE OF WATER	RADIAL DEF.	EFFECT ON ADVANCE OF TBM	SUPPORT MEASURES	SUPPORT MEASURES TOP 12 TO 2 (10)	DISTANCE TO EXC. FACE	QUANTITY PER M	TOP 2 (10) TO 3 (9)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 3 (9) TO 5 (7)	DISTANCE TO EXC. FACE	QUANTITY PER M	INVERT 5 (7) TO 6	DISTANCE TO EXC. FACE	QUANTITY PER M	TOTAL QUANTITY	UNIT
CONTINUOUS OVERBREAK DUE ANY OF: - SIDEWALL SPALLING - INVERT HEAVE	QUEENSTON	4Q	WEDGES OF ROCK < 1,0 x 1,0 x 1,0 m APPROX.		< 20 mm 200 m BEHIND TBM CUTTER HEAD																
		4Q A	DRY OR UNLIMITED WATER			CONTINUOUS ADVANCE INTERRUPTED BY SUPPORT INSTALLATION	1. STEEL WIRE MESH 100/100/6/6 MM	1 LAYER, EXTRADOS	< 7 m	15,12	1 LAYER, EXTRADOS	< 7 m	7,56	1 LAYER, EXTRADOS	< 7 m	15,12	-	-	-	37,80	m2
							2. STEEL PROFILES U NP 140	e = 0.9 m	< 7 m	16,80	e = 1.8 m	< 7 m	4,20	e = 1.8 m	< 7 m	8,40	e = 1.8 m	< 7 m	4,20	33,60	m
							3. ROCK DOWELS SWELLEX OR EQ., L = 3.6 m	c/e 2.0/0.9	< 7 m	6,67	-	-	-	-	-	-	-	-	-	6,67	pcs
							4. SHOTCRETE	150 mm	< 40 m	15,12	150 mm	< 40 m	7,56	150 mm	< 40 m	15,12	150 mm	< 40 m	7,56	45,36	m2
							5. ROCK DOWELS SN / RESIN, L = 4.0 m	-	-	-	c/e 4.0/0.9	< 40 m	4,44	-	-	-	-	-	-	4,44	pcs
		4Q B	SUBSTANTIAL INFLOW				6. DIMPLE MEMBRANE STRIPS LxW 4,0x1,0	e = 2.4 m	< 40 m	1,67	e = 1.8 m	< 40 m	1,67	-	-	-	-	-	-	3,33	m2



KEY PLAN
SCALE 1 : 50000

NOTES:

1. LOOSE ROCK TO BE REMOVED
2. LOCAL OVERBREAK TO BE FILLED WITH SHOTCRETE
3. POSITION OF ROCK DOWELS TO BE ADJUSTED TO REACH OF INSTALLATION EQUIPMENT.
4. STEEL WIRE MESH TO BE FIXED IN SHORT HOLES WITH ANCHORS (NOT SHOWN)
5. POSITION 2, 5, 7 AND 10 TO BE ADJUSTED TO ACTUAL GRIPPER POSITION OF TBM
6. QUANTITIES OF SUPPORT MEASURES ARE BASED ON LENGTH OF EXCAVATION LINE
7. SUPPORT MEASURES INCLUDED IN "CROSS SECTION" ARE DRAWN NOT TO SCALE
8.

STEEL PROFILE		UNP 140	UNIT
WEIGHT		16.0	kg/m
2ND MOMENT OF AREA y-y		605	cm⁴
	h	80.0	mm
	b	140.0	mm

1:100 0 2 4 6 8 10 m

1:5 0 0.1 0.2 0.3 0.4 0.5m

mf no/ number	ver/ no	date	particulars	dwn chkd	appd
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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
ROCK SUPPORT TYPE 4Q

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

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chkd			
date yr/m/d/dy 05/04/29	design approved	plot scale	1:1 M
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scale 1:100/1:5	authorized	CAD file type DWG	1:5

dwg no PD-01-1030 — ver 00

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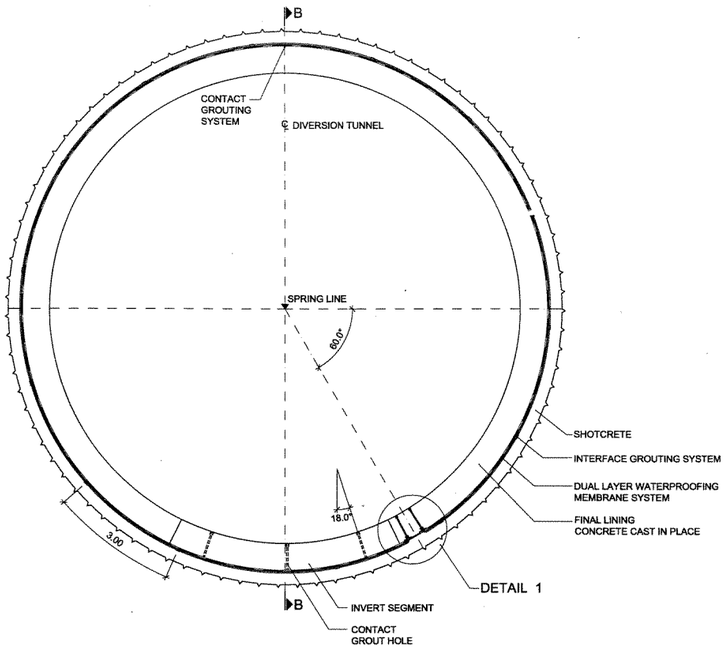
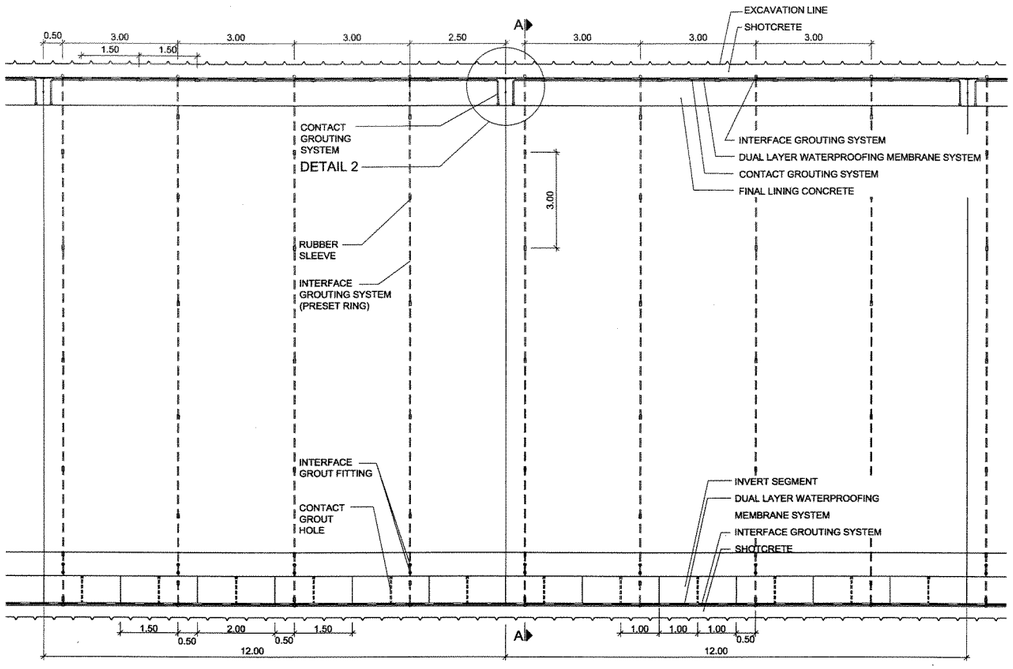
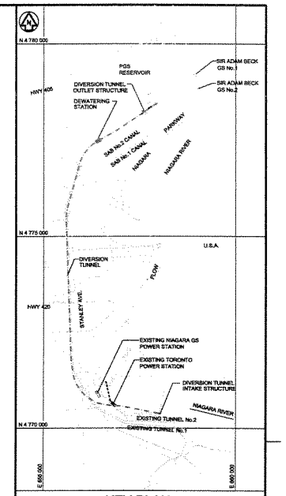


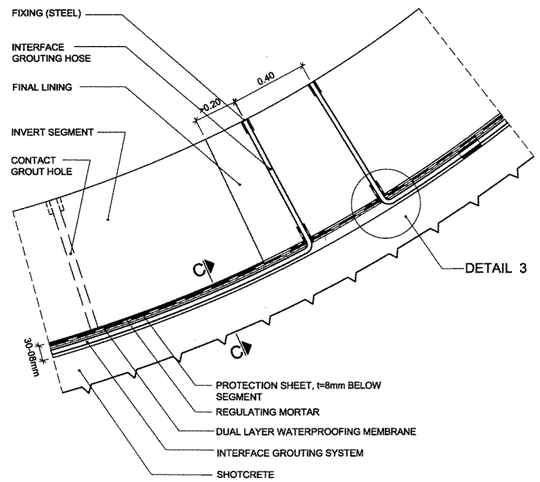
CROSS SECTION A-A
SCALE: 1:50



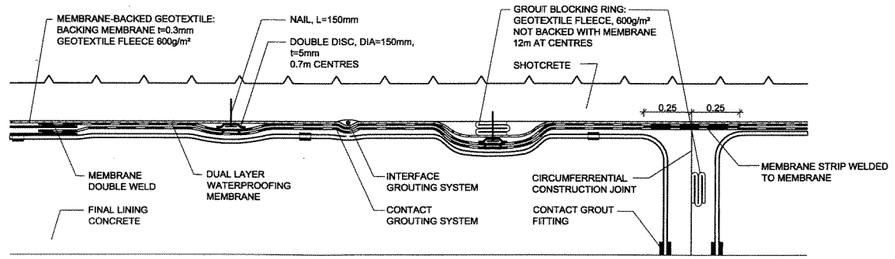
LONGITUDINAL SECTION B-B
SCALE: 1:50



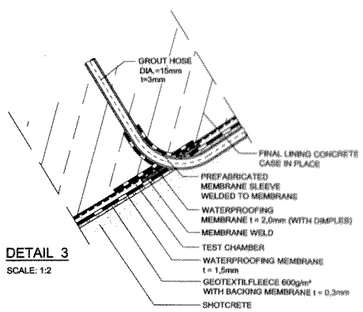
KEY PLAN
SCALE 1 : 50000



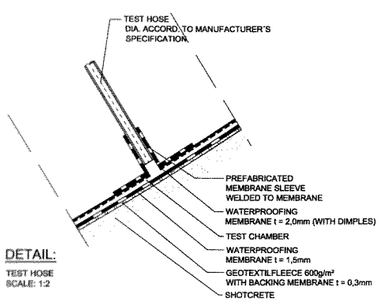
DETAIL 1
SCALE: 1:10



DETAIL 2
NOT TO SCALE
FIXING OF DUAL LAYER WATERPROOFING MEMBRANE SYSTEM AND CONTACT GROUTING SYSTEM



DETAIL 3
SCALE: 1:2



DETAIL:
TEST HOSE
SCALE: 1:2

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1:10	0 200 400 600 800 1000	mm	
1:2	0 50 100 150 200	mm	

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
DIVERSION TUNNEL
DUAL LAYER MEMBRANE SYSTEM AND DETAILS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — FLF CONSULTING ENGINEERS

chkr	designed by		
chkd			
date yr/mo/d/day 05/08/12	design approved		ord scale 1:1 M
scale 1:50, 1:10, 1:2	author/acc		dwg. code CAD file type DWG

dwg no PD-01-1031 — ver 00

© IBI Group 2005 Z:\2012\Niagara-Tunnel\Planet\Plots\dwg\PD-01-1031-00.dwg

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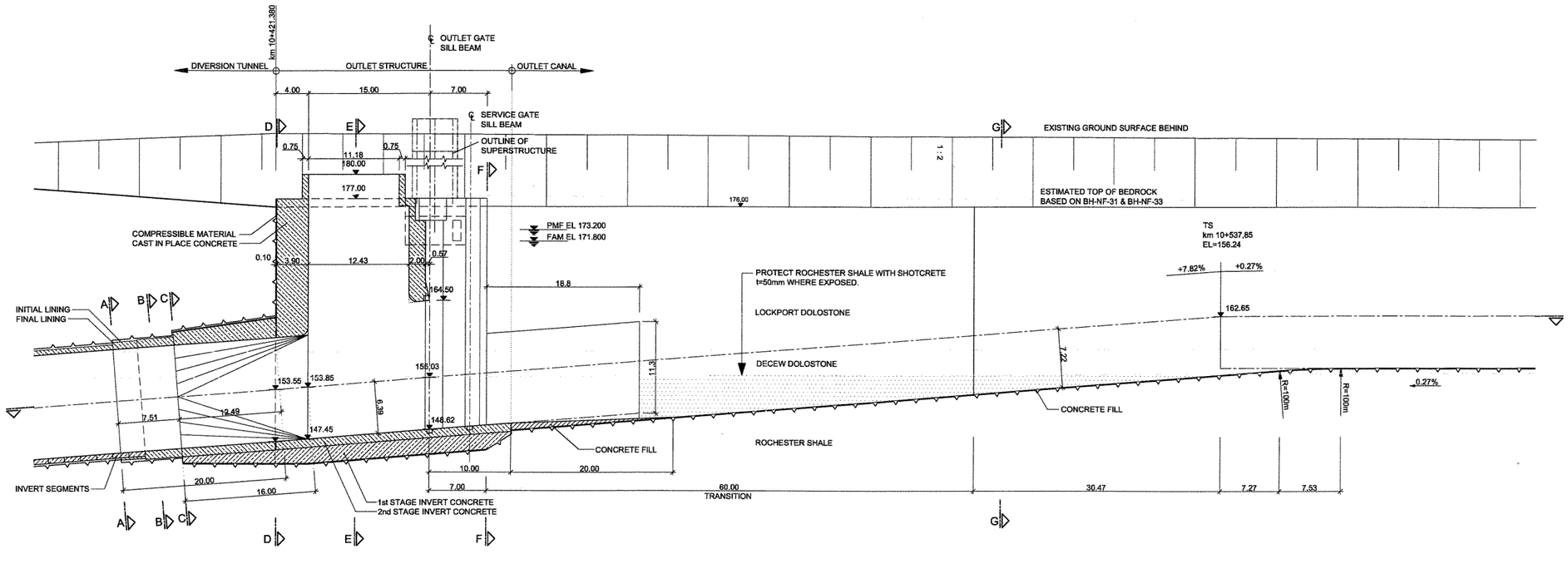
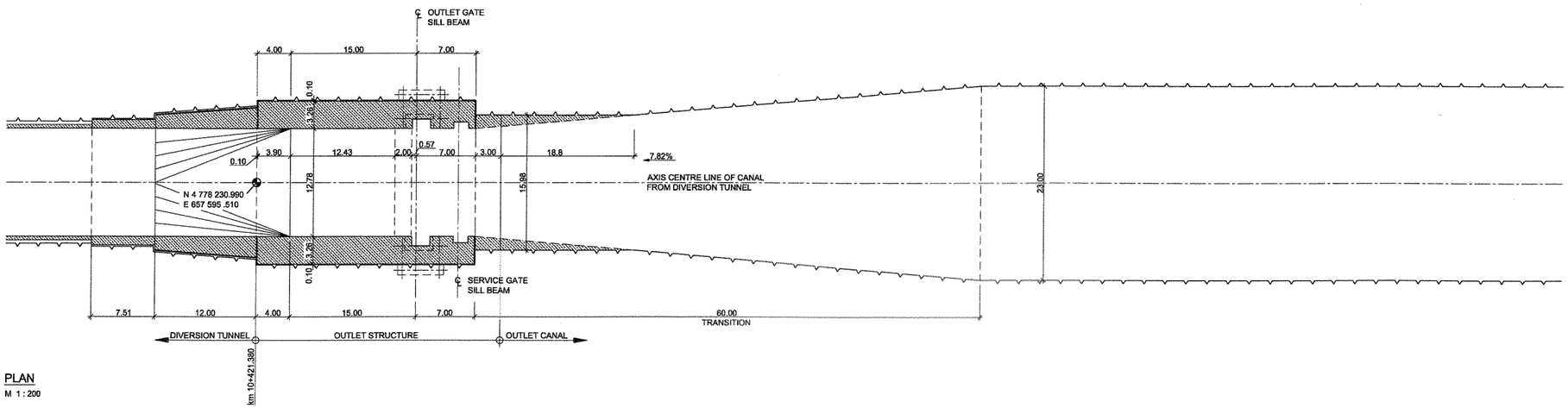


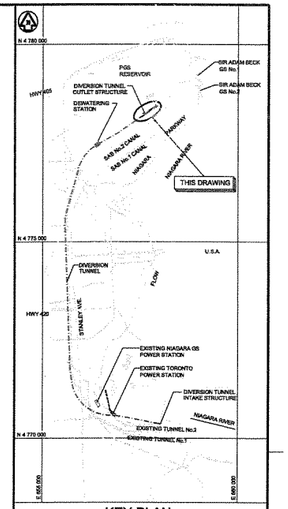
LONGITUDINAL SECTION

M 1 : 200



PLAN

M 1 : 200



KEY PLAN

SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, a/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT
3. SECTIONS A-A, B-B, C-C, D-D, E-E, F-F, G-G ON DRAWING PD-03-1012

LEGEND:

FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

BH ... BOREHOLE

ref no number	ver no	date	particulars	per chkd	appd
	01				
	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET STRUCTURE
PLAN AND LONGITUDINAL SECTION

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — RUT CONSULTING ENGINEERS

dsn	designed by	cont no	
chkd			
date yr/month/day 05/04/29	design approved	plot scale 1:1 M	
scale 1:200	archived	dist. code	
		CAD file type DWG	

dwg no PD-03-1011 — ver 00

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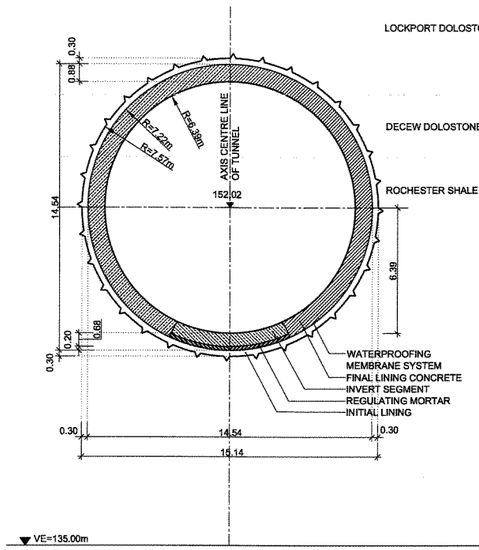
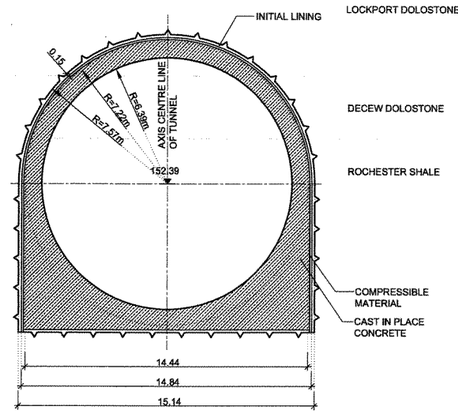
A0 (841 x 1189)

© OPG 2005 Z:\021-Niagara-Tunnel\Planen\Baureife\PD-03-1011-06.dwg



SECTION A - A
M 1 : 100



SECTION B - B
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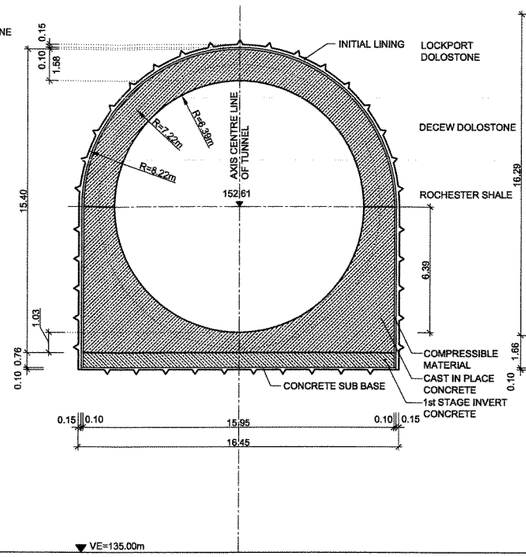
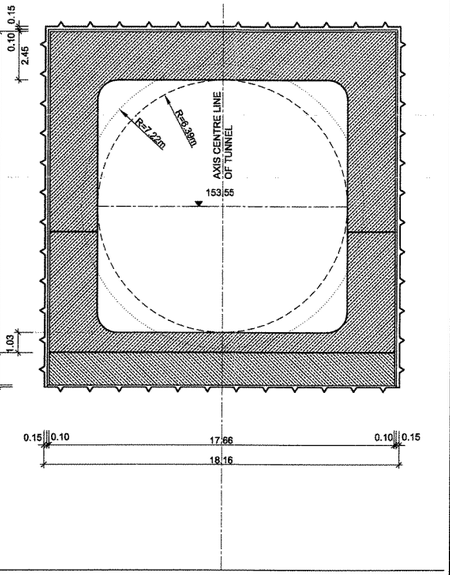


SECTION C - C
M 1 : 100



SECTION D - D
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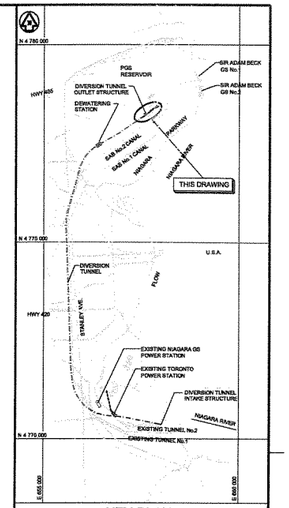


KEY PLAN
SCALE 1 : 50000

NOTES:

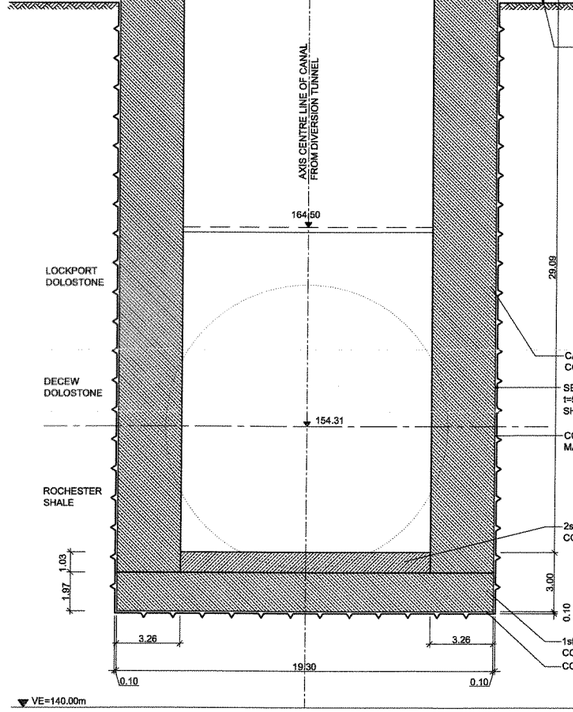
1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT
   IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, e/c=1.20/2.00m
   SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT

LEGEND:

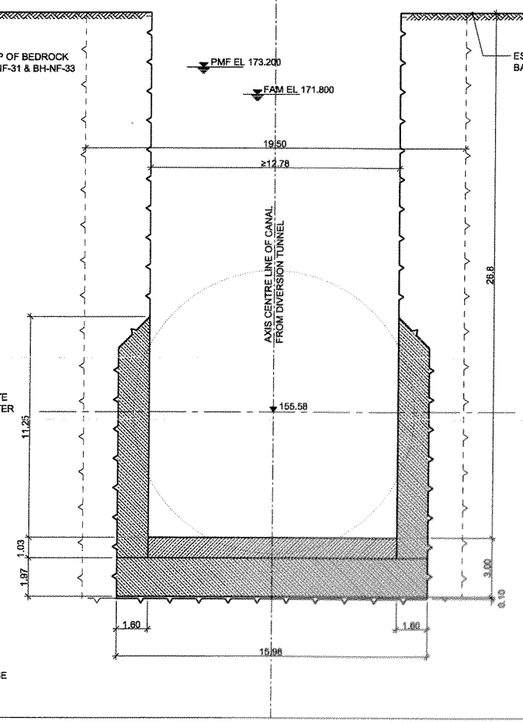
FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

BH ... BOREHOLE



SECTION E - E
M 1 : 100



SECTION F - F
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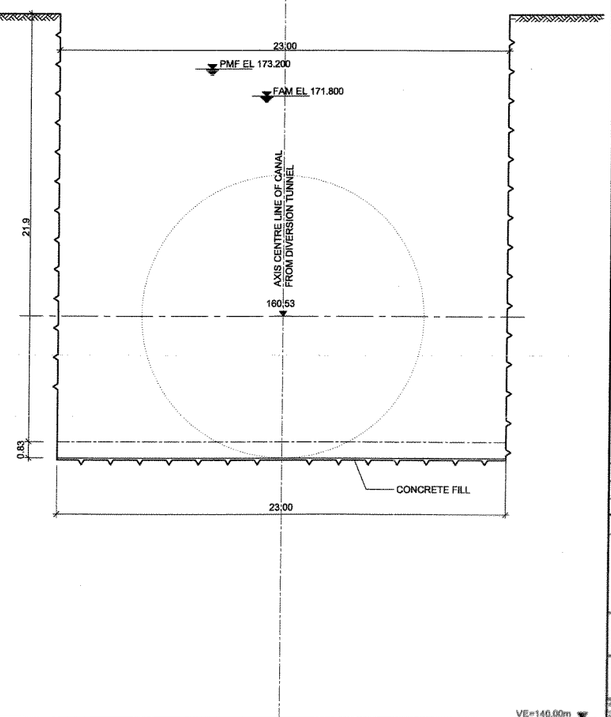

SECTION G - G
M 1 : 100

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ref ref number	ref no	date	particulars	ref chkd	appd

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET STRUCTURE
CROSS SECTIONS

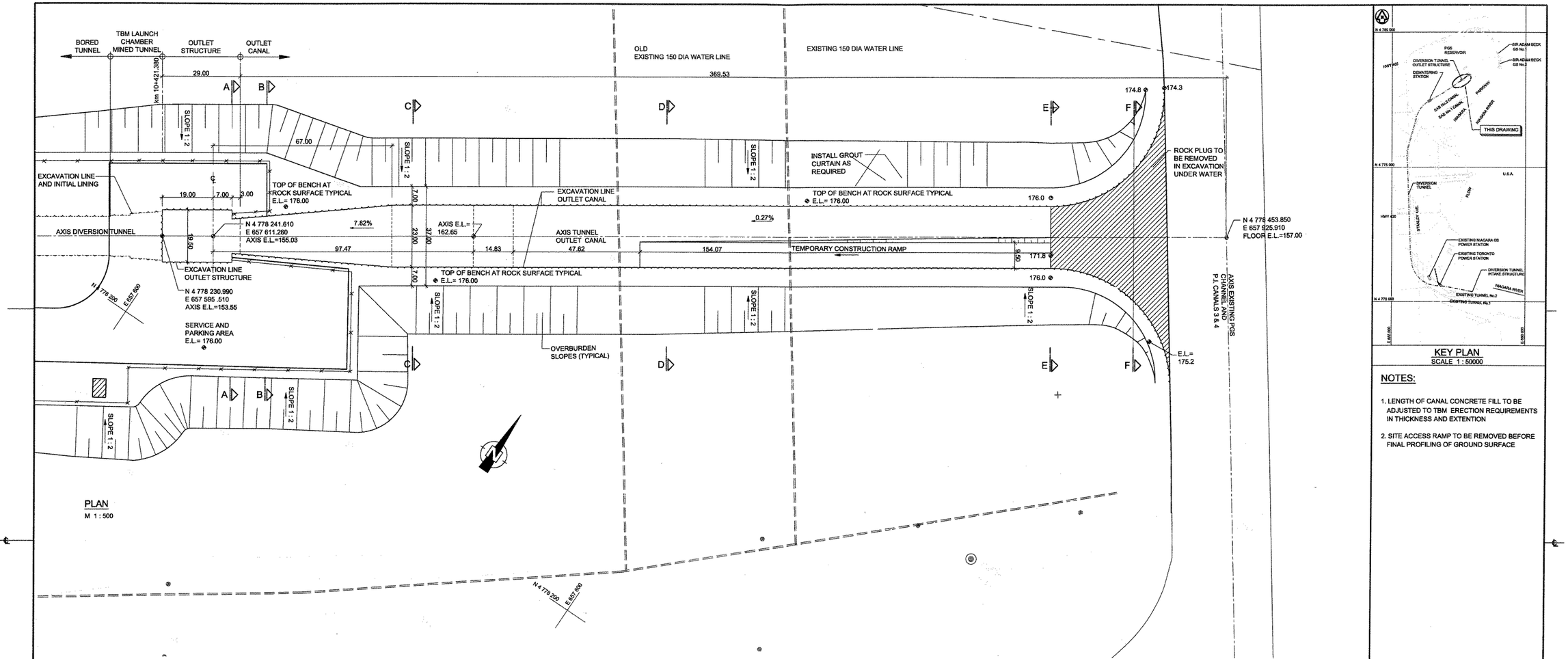
ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

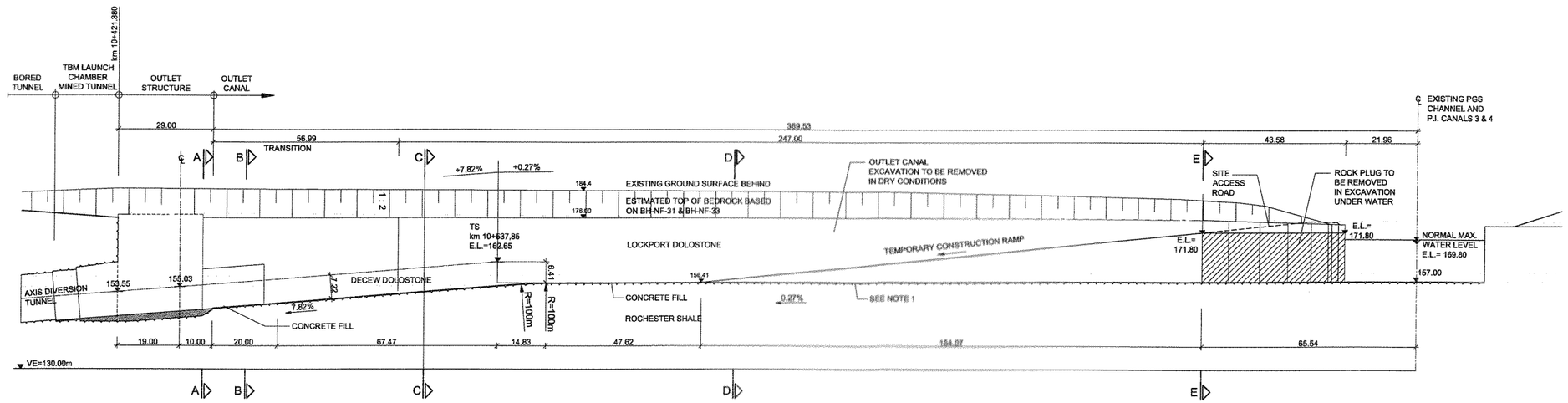
client		designed by	
date	planned date: 05/04/29	design approved	plot scale: 1:1 M
scale	1:200	authorised	plot date: DWG file type
dwg no	PD-03-1012		rev 00

A0 (841 x 1189)

© IBF 2005 Z:\2021-Niagara_Tunnel\Planen\Bauwerke\PD-03-1012-00.dwg



PLAN
M 1 : 500



LONGITUDINAL SECTION
M 1 : 500

KEY PLAN
SCALE 1 : 50000

NOTES:

1. LENGTH OF CANAL CONCRETE FILL TO BE ADJUSTED TO TBM ERECTION REQUIREMENTS IN THICKNESS AND EXTENTION
2. SITE ACCESS RAMP TO BE REMOVED BEFORE FINAL PROFILING OF GROUND SURFACE

ref ed number	ver no	date	particulars	chkd	appd
	01				
	00		FIRST ISSUE		

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET CANAL TBM LAUNCH
PLAN AND LONGITUDINAL SECTION

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

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xtact			
date yyhmmdd/day	design approved	plot scale	1:1 M
05/04/29		disc. code	
scale 1:500	authorized	CAD file type	DWG
dwg no PD-03-1013			ver 00

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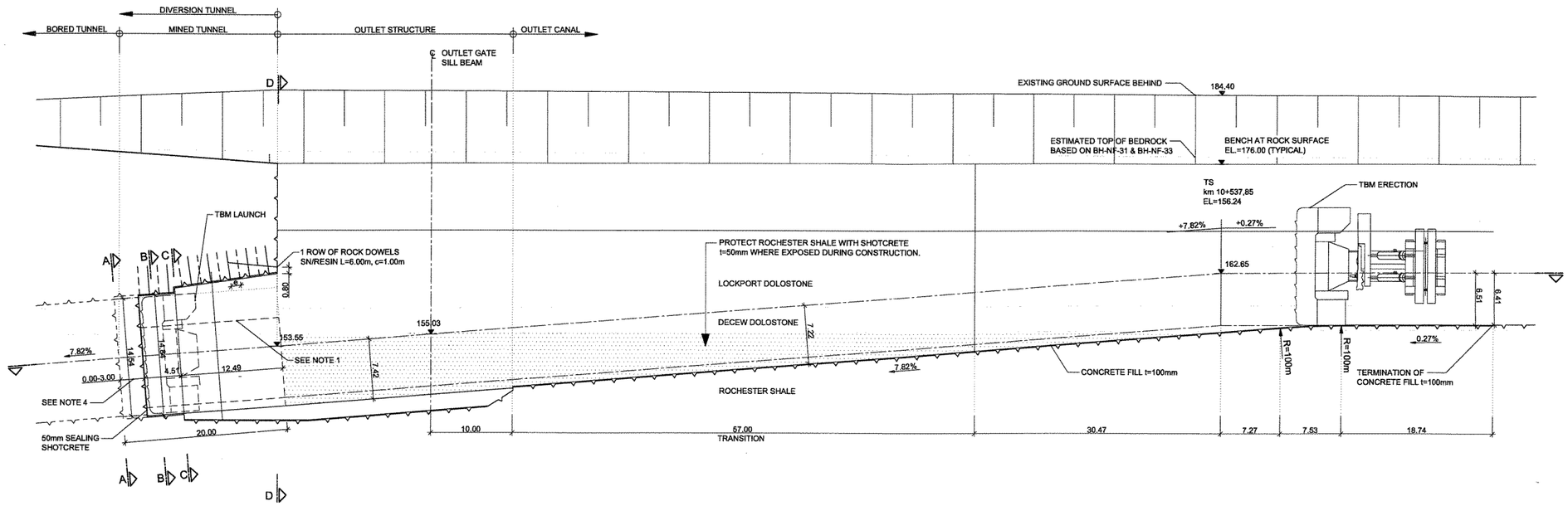
A0 (841 x 1189)

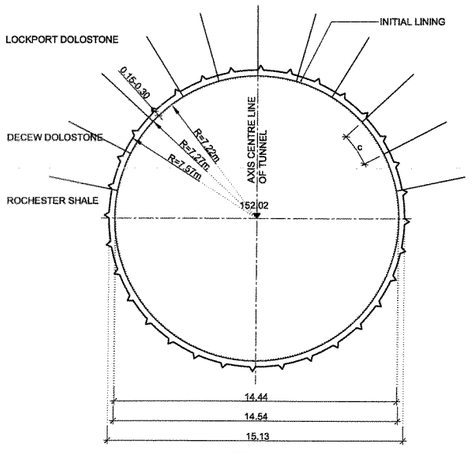
0 10 50 100 200 300 millimetres

© 2005 #3801-Niagara Tunnel\Plans\Drawings\PD-03-1013.00.dwg



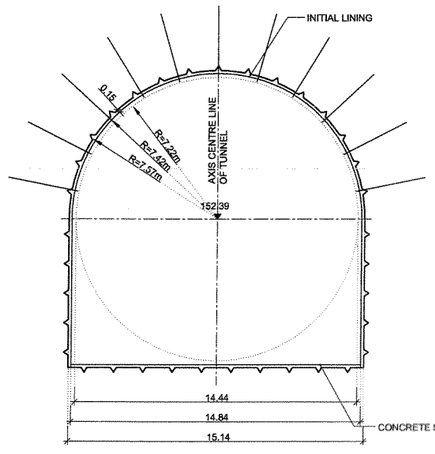
LONGITUDINAL SECTION

SCALE 1 : 200



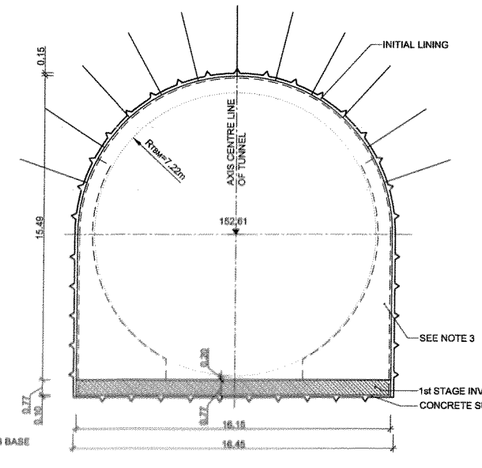
SECTION A-A

SCALE 1 : 100



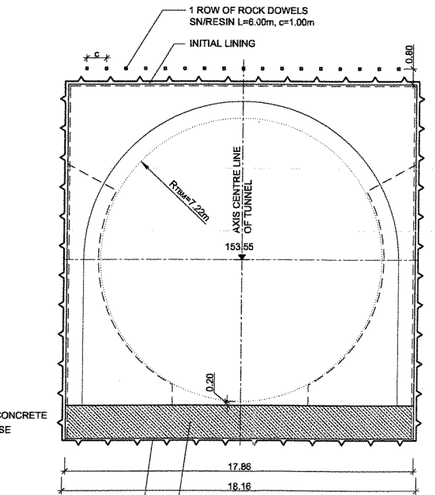
SECTION B-B

SCALE 1 : 100



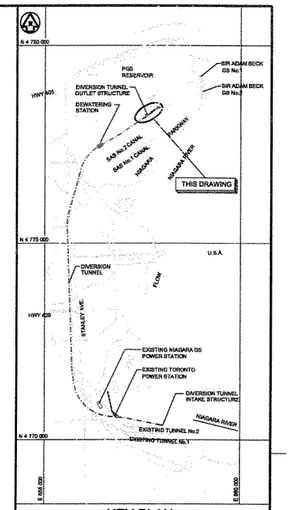
SECTION C-C

SCALE 1 : 100



SECTION D-D

SCALE 1 : 100



KEY PLAN

SCALE 1 : 50000

NOTES:

1. INITIAL LINING CONSISTING OF:
   DIMPLE MEMBRANE DELTA MS OR EQUIVALENT IF REQUIRED
   STEEL WIRE MESH 150/150/6/6mm
   ROCK DOWELS L=3.60m, e/c=1.20/2.00m SWELLEX OR EQUIVALENT
   SHOTCRETE t=150mm
2. COMPRESSIBLE MATERIAL CONSISTING OF STYRODUR OR EQUIVALENT
3. GRIPPER PADS IF REQUIRED TO BE REMOVED AFTER TBM LAUNCH
4. DIMENSION TO BE ADJUSTED ACCORDING TO REQUIREMENT FOR TBM-LAUNCH AND TBM - ERECTION
5. ADVANCE LENGTH OF ONE ROUND OF EXCAVATION AND SUPPORT INSTALLATION IN MINED TUNNEL SECTION TO BE RESTRICTED TO MAX. 1.50m

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET STRUCTURE TBM LAUNCH SECTIONS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — HLF CONSULTING ENGINEERS

drawn	designed by		
check			
date yr/mo/dd/day 05/04/29	design approved	plot scale 1:1 M	
scale 1:100 / 1:200	instructions	CAD file type DWG	
dwg no PD-03-1014			ver 00

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1:200 0 5 10 15 20 m

© 2008 Z:\0911-Niagara Tunnel\Plans\Baseworks\PD-03-1014-00.dwg

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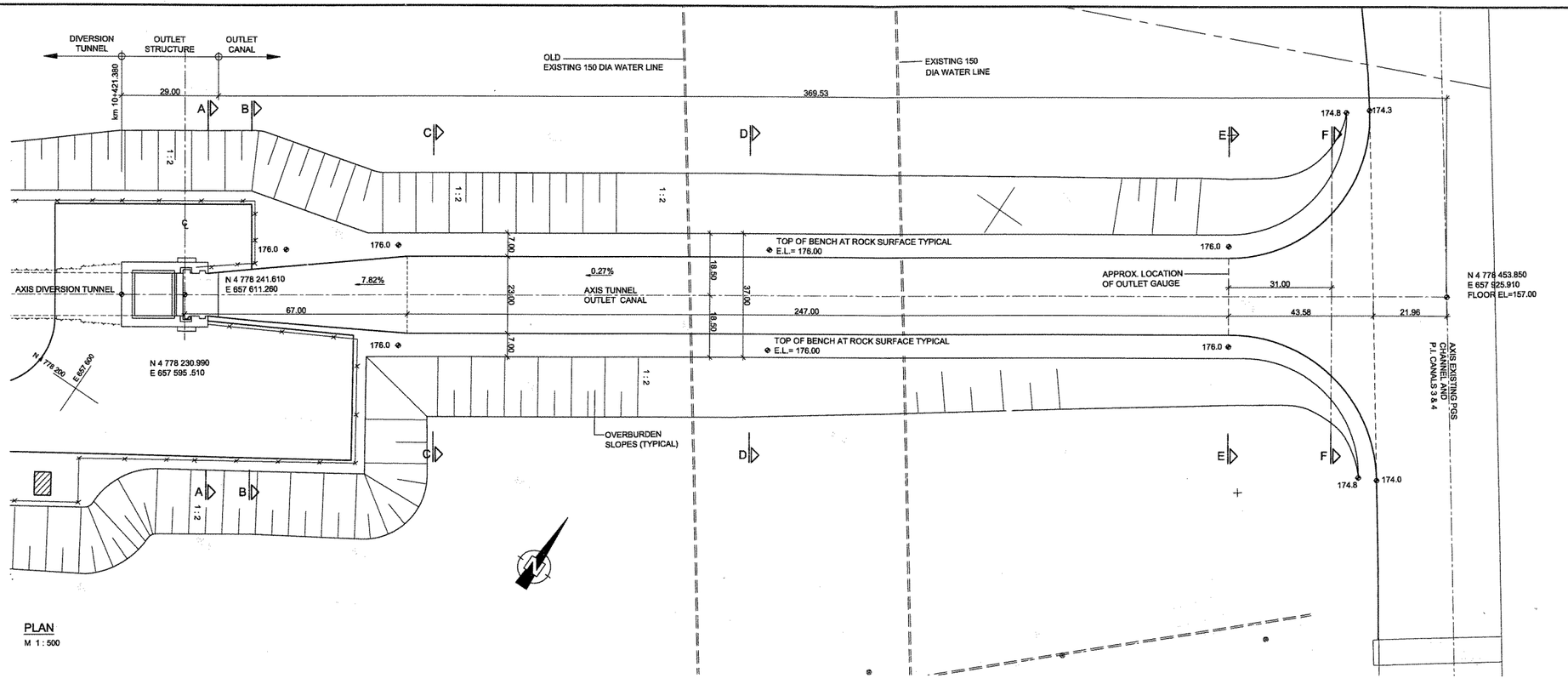
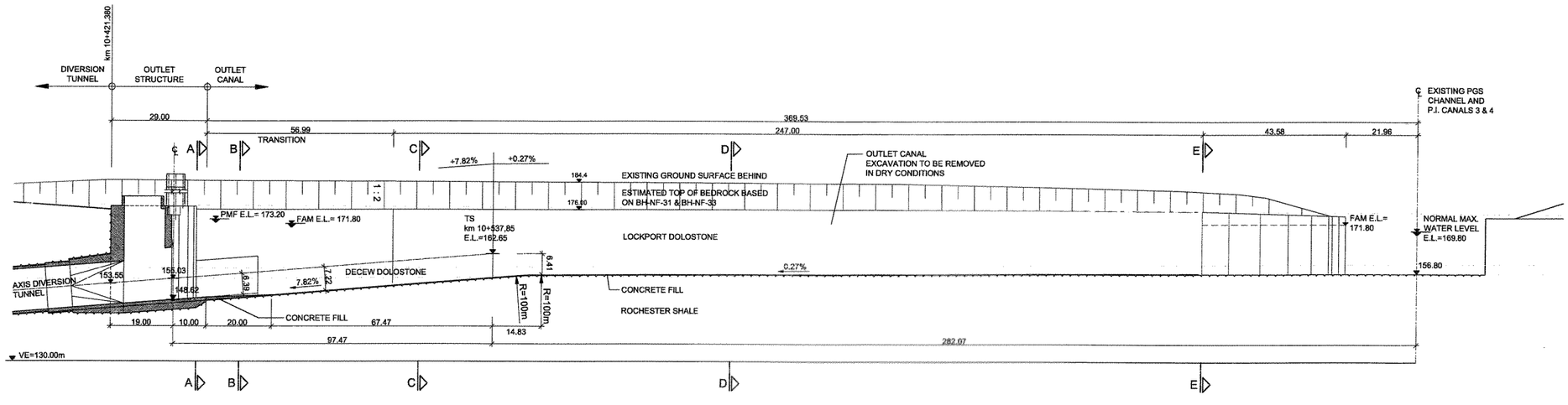
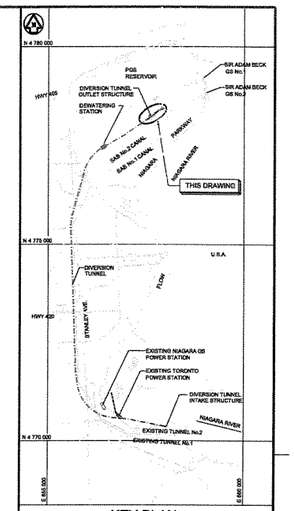
0 10 50 100 150 250 200 millimetres



PLAN
M 1 : 500



LONGITUDINAL SECTION
M 1 : 500



KEY PLAN
SCALE 1 : 50000

LEGEND:

FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

E.L. ... ELEVATION

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET CANAL
PLAN AND LONGITUDINAL SECTION

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

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chkd		cad rel no	
date yy/mm/dd/day 05/04/29	design approved	plot scale	1:1 M
		dsn. code	
scale 1:500	authorized	CAD file type DWG	
dwg no PD-03-1024			rel 00

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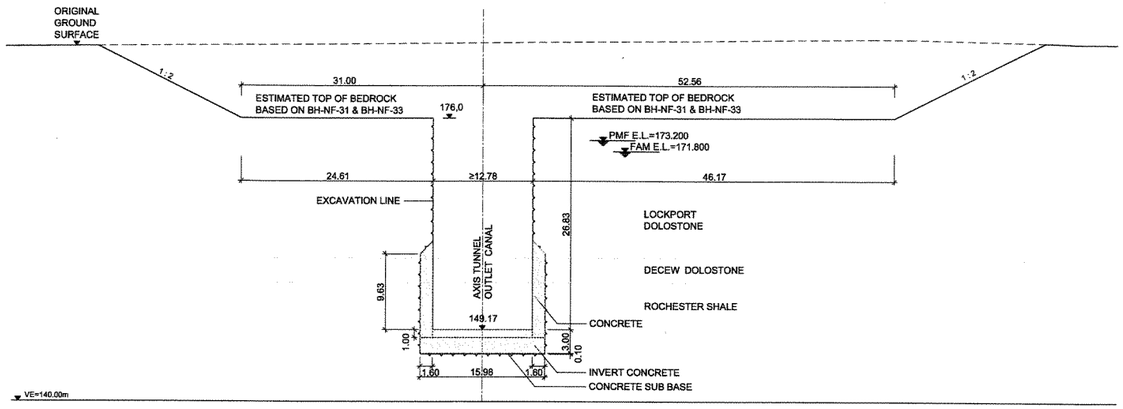
A0 (841 x 1189)

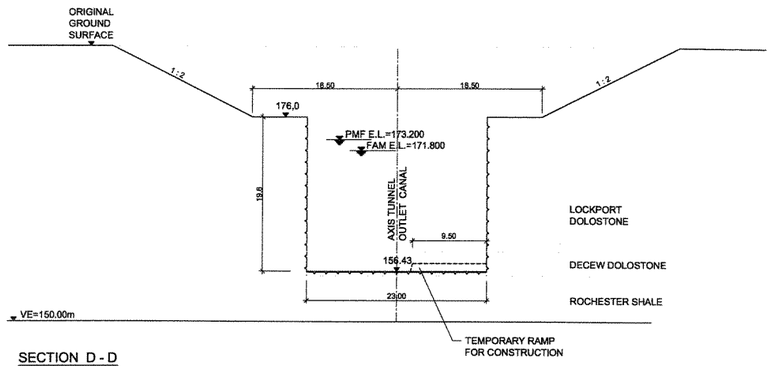
0 10 50 100 200 250 300 millimetres

© OPG 2005 Z:\0921 Niagara Tunnel\Plans\Reports\PD-03-1024-00.dwg



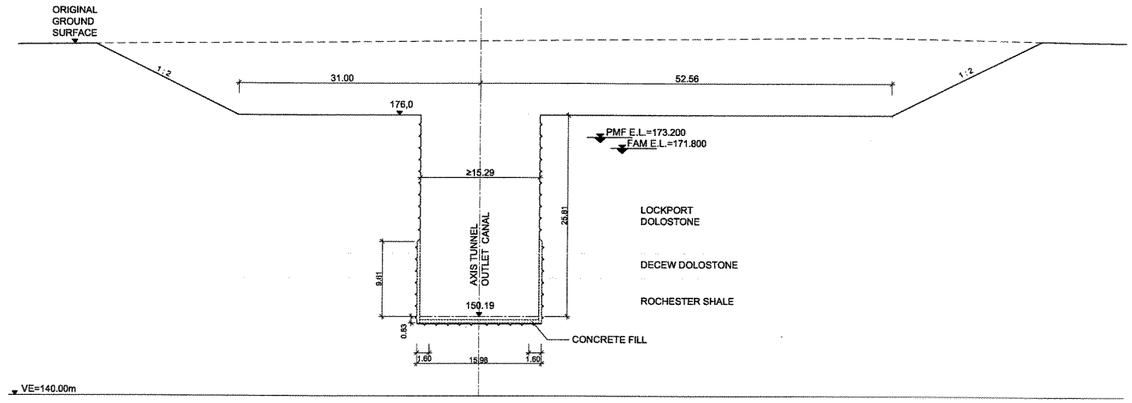
SECTION A - A

M 1 : 250



SECTION D - D

M 1 : 250

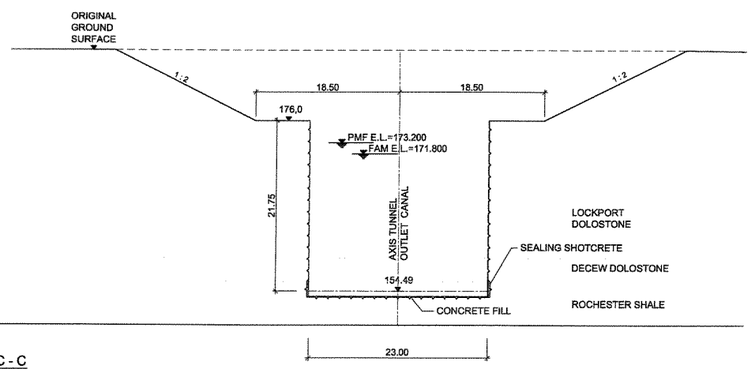


SECTION B - B

M 1 : 250

SECTION E - E

M 1 : 250



SECTION C - C

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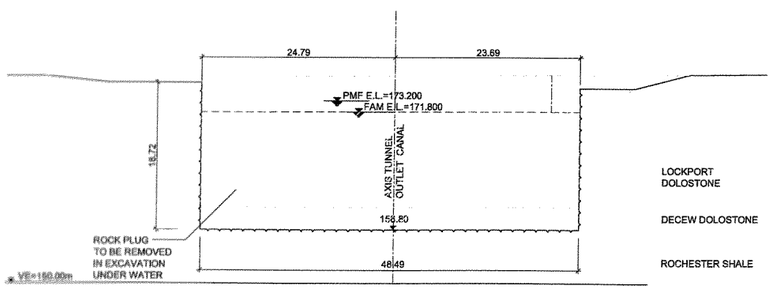

SECTION F - F

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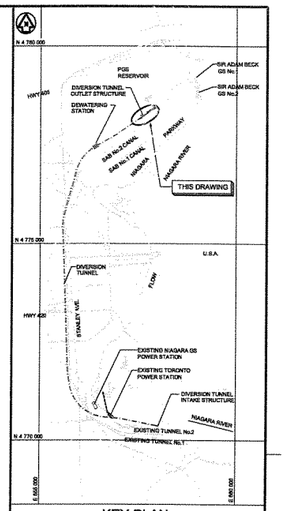

KEY PLAN

SCALE 1 : 50000

LEGEND:

FAM ... FLOW ALLOWANCE MAXIMUM ELEVATION

PMF ... PROBABLE MAXIMUM FLOOD ELEVATION

E.L. ... ELEVATION

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET CANAL
SECTIONS

ONTARIO POWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — ILF CONSULTING ENGINEERS

drwn	designed by	mf ed	
chkd			
date: yr/mon/d/day 05/04/29	design approved	plot scale	1:1 M
scale 1:250	archivist	dwg code	
		CAD file type	DWG
dwg no PD-03-1025			ver 00

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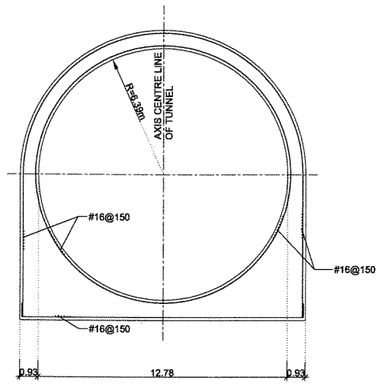
A0 (841 x 1189)

0 10 50 100 250 300 millimetres

© 2005 Z:\892-Niagara Tunnel\Plans\Bauwerke\PD-03-1025.dwg



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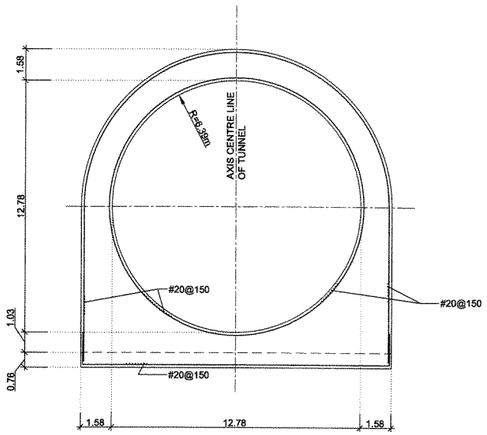
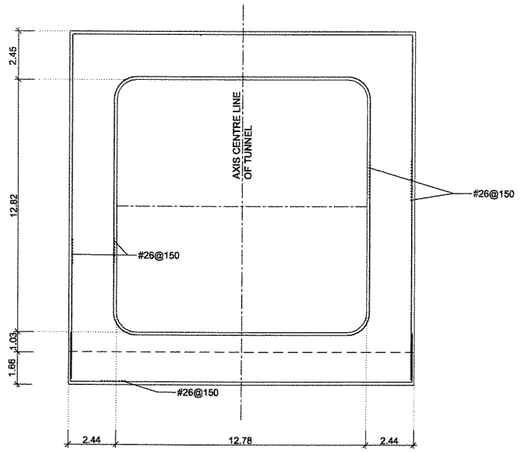


SECTION C - C
M 1 : 100



SECTION D - D
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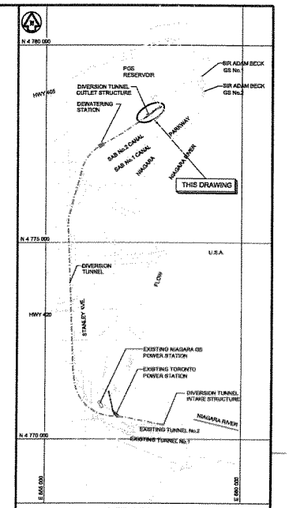
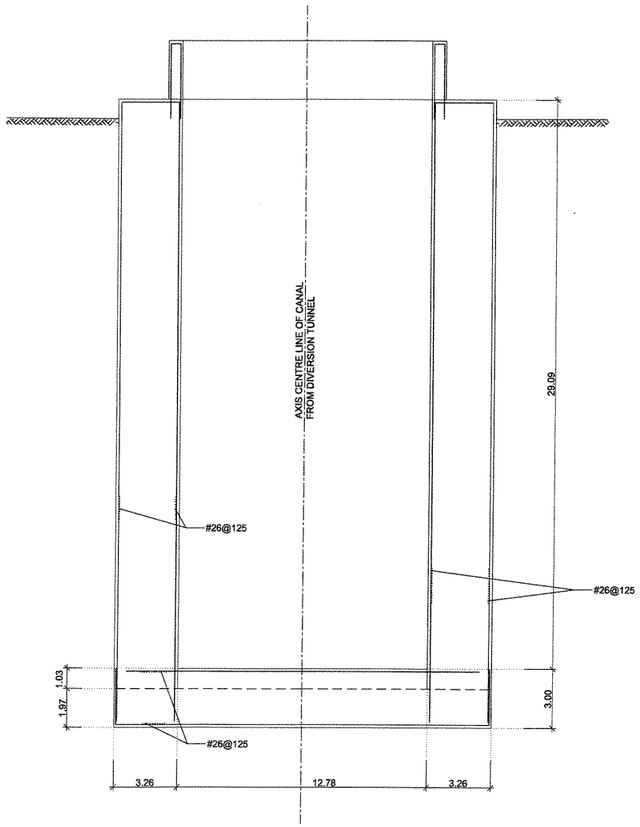


KEY PLAN
SCALE 1 : 50000

NOTES:

1. ARRANGEMENT OF BAR SIZE, SPACING AND LOCATION IS ONLY INDICATIVE
2. FOR AMOUNT OF STEEL 90kg/m³ ARE ASSUMED ON AVERAGE. INCLUDING MAX. 5 kg/m³ OF AUXILIARY REINFORCEMENT (I.E. CHAIRS AND SPACERS)
3. BAR SIZE AND SPACING OF REBAR MAY BE ADJUSTED SUBJECT TO THE RESULT OF DETAILED STRUCTURAL ANALYSIS.



SECTION E - E
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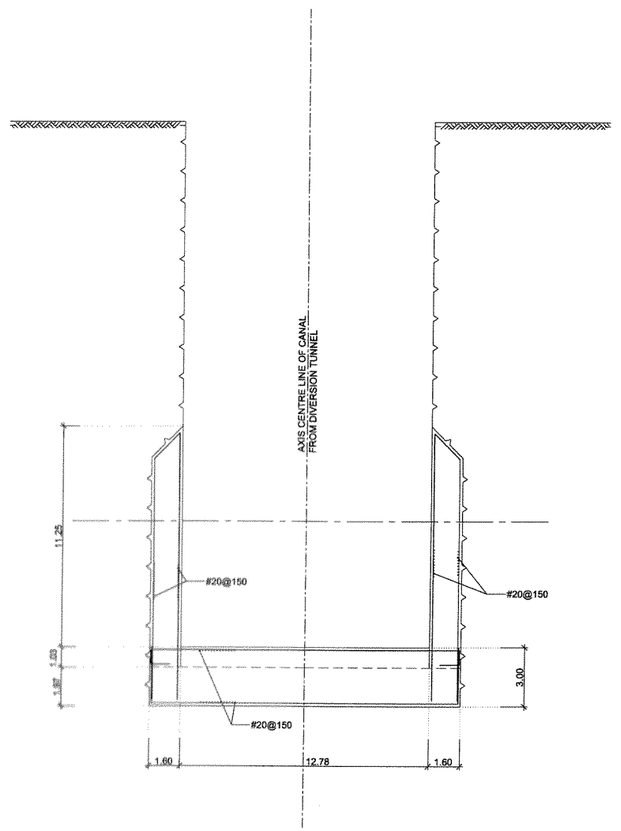

SECTION F - F
M 1 : 100

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	00		FIRST ISSUE		
ref m3 number	ver no	date	particulars	chkd	appr

NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET STRUCTURE
REINFORCEMENT
CROSS SECTIONS

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

own	designed by		
chkd			
date yr/mo/dd/day	design approved	plot scale	1:1 M
05/04/29		disc. code	
scale 1:200	authorized	CAD file type	DWG
dwg no PD-03-1026			ver 00

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A0 (841 x 1189)

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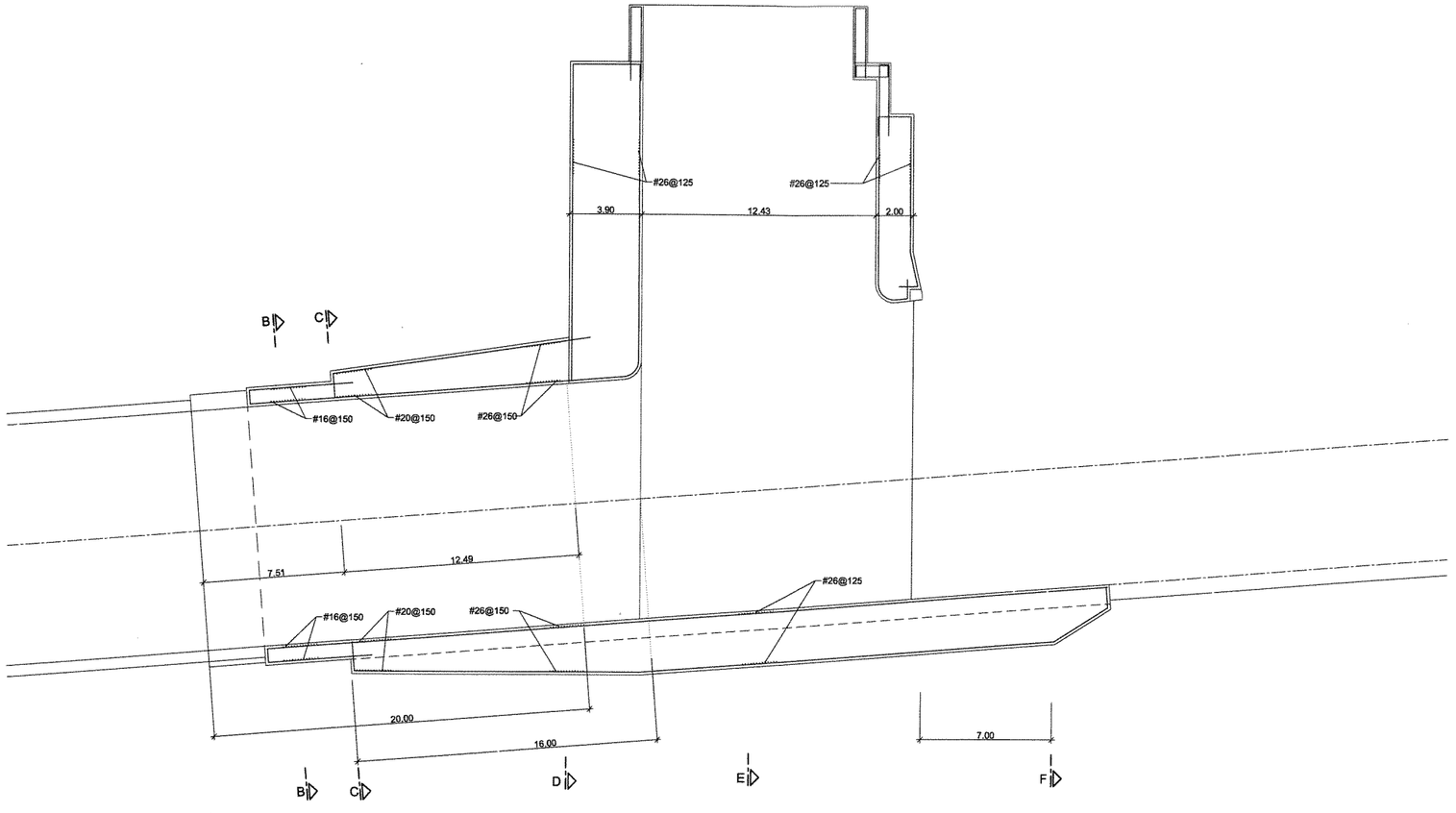
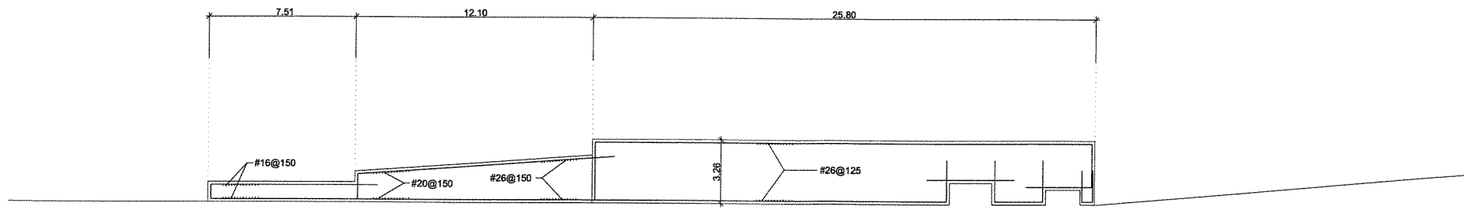
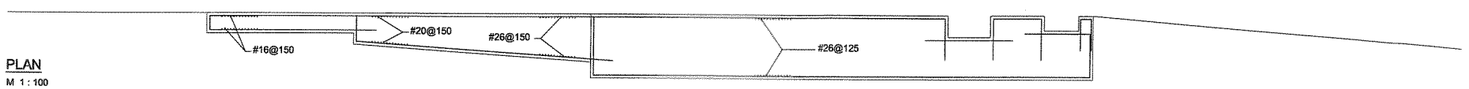


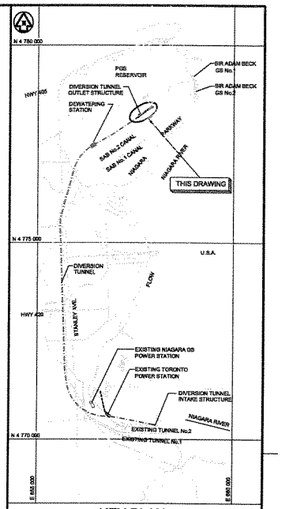
LONGITUDINAL SECTION
M 1 : 100



AXIS CENTRE LINE OF CANAL
FROM DIVERSION TUNNEL



PLAN
M 1 : 100



KEY PLAN
SCALE 1 : 50000

NOTES:

1. ARRANGEMENT OF BAR SIZE, SPACING AND LOCATION IS ONLY INDICATIVE
2. FOR AMOUNT OF STEEL 90kg/m³ ARE ASSUMED ON AVERAGE. INCLUDING MAX. 5 kg/m³ OF AUXILIARY REINFORCEMENT (I.E. CHAIRS AND SPACERS)
3. BAR SIZE AND SPACING OF REBAR MAY BE ADJUSTED SUBJECT TO THE RESULT OF DETAILED STRUCTURAL ANALYSIS.

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NIAGARA TUNNEL FACILITY PROJECT

PROPOSAL
OUTLET STRUCTURE
REINFORCEMENT
PLAN AND LONGITUDINAL SECTION

ONTARIOPOWER GENERATION — Electricity Production - Hydroelectric Technical Services

STRABAG — CONSULTING ENGINEERS

dsgn	designed by		
chkd			
date yy/mm/dd	design approved	plot scale	1:1 M
05/04/29		plot date	
scale 1:200		plot file type	DWG
dwg no PD-03-1027			rev 00

1:200 0 5 10 15 20 m

A0 (841 x 1189)

0 10 50 100 200 250 300 millimetres

Appendix 1.1(t)
Draft Specifications for the TBM

Appendix 1.1(t) - Draft Specifications for the TBM

2. HARD ROCK TBM - DESCRIPTIONS

Machine Diameter	
new cutters	14.44
(worn cutters)	14.41
Main Bearing Three Roller (3-axis)	
Bearing Life	>15,000 L10 Hrs. @ 224 kN cutter load
Cutters	
Number of cutters	(77) 20" and (4) 17" twin disc
Individual Cutter Load	267kN
Average Cutter Spacing (Face)	89mm
Cutterhead	
Recommended Operating	
Cutterhead Thrust	18,156kN
Maximum Thrust	27,900kN
Maximum Gripper Force	71,500kN
Cutterhead Drive – Variable Frequency	
Cutterhead Drive	Electric motors/Gear reducers/VF Drive
Cutterhead Power	15 x 315kW = 4,725kW
Cutterhead Speed	
Constant Torque Range	0 – 2.4 RPM
Constant Power Range	2.4 – 5.0 RPM
Cutterhead Torque	
at 2.4 RPM	18,800 kNm
at 5.0 RPM	9,025 kNm
Breakout Torque	24,000 kNm
Thrust Cylinder Stroke	1.82m
Hydraulic System	
System Operating Pressure	275 bar
System Rated Pressure	310 bar
Electrical System	
Main Drive Motors	690V, 3 phase, 60 Hz
Electric Motors of Hyd & Lube System	480V/60Hz
TBM Lighting	220V, 60 Hz
TBM Control System	24V DC
Transformer (TBM Drives)	4 x 1700 kVA = 6800 kVA
Transformer Backup	1 x 1000 kVA = 1000 kVA
Backup Power	1000 kVA
Primary Voltage	13,800 V, 60 Hz
Secondary Voltage	690V, drive motors 480V, hydraulic pump motors
Specification	Class I – Div II
Essential services	Class I – Div I
Conveyor	
Capacity	1600 tph
Belt width	1400mm
TBM Weight (approx.) 1900 t	

2.2 Tunnel Boring Machine Special Features for the Niagara Tunnel Facility Project

- Cutterhead designed with an inner section and four (4) outer cutterhead sections with 17" front loading/back-loading cutter housings, and grill bars in bucket openings for blocky ground.
    - Cutterhead with minimum peripheral exposure
    - Cutterhead stand off is minimum 150mm
    - Cutterhead using replaceable abrasion resistant wear bars
    - Cutterhead with smooth low cutter profile and radial muck scoops with shallow relief, direct dump buckets for improved face control and reduced raveling at the gauge bucket lips are bolted on for easy replacement.
- High capacity 3-axis roller main bearing for sustained operation at high thrust with long life, L 10 $\geq$ 15,000 hours
- Excess capacity to handle extreme ranges of hard and blocky rock, water conditions, and ground support installation.

- 20" cutters help to minimize the effects of hard abrasive rock while maintaining high production rates and allowing fewer cutter changes.
- Large open area behind cutterhead for ground support.
- Cutterhead is Variable Frequency Drive (VFD), is fully reversible and allows increased torque at startup. Muck pick-up is one direction.
- Large, articulated oversize gripper pads to reduce gripper ground pressure in areas of weak, fractured, unstable rock to reduce fallout of material.
- Slotted gripper pads to allow gripping over ring set.
- Large work area under main beam for cleaning and water draining.
- Continuous steering system, while boring, to maintain line and grade as required.
- Hydraulic roof support shield.
- Two sets roof drills with independent control and bolting while boring, coverage is 180° of crown.
- One sets probe/grout drills dedicated to 360° probing and grouting mounted on a circular support.
- TBM muck removal system with excess capacity to allow high peak rates of advance.
- Water protection for electrical and hydraulic systems IP55.
- Dust control system to confine dust to the cutter face and maintain a good work environment
- Data Logger with remote monitoring
- Dual laser target system to permit continuous steering control and monitoring of line and grade. Electronic guidance system allows precise guidance information, including interface unit + laser theodolite.
- Water spray system for dust control with capability to add foam.
- Equipment monitoring instrumentation displayed at the operator's console to allow speedy fault finding and correction actions.
- Methane gas monitor auto shut down of TBM if acceptable levels are exceeded.
- Class I – Div II electrical system and Class I – Div I for essential services.
- Ground fault protected electrical system standard on all Robbins TBMs.
- High powered proven TBM design, "classic" main beam open gripper.

Appendix 1.1(aa)
Flow Verification Test

Appendix 1.1(aa) - Flow Verification Test

1. PURPOSE OF TEST

(1) A flow verification test (Test) shall be conducted to determine the as-constructed flow amount of the Tunnel Facility Project in order to determine if the Guaranteed Flow Amount is achieved.

2. TEST METHOD AND ACCURACY

(1) The Test shall be conducted using the tracer transit time method and a non-radioactive, non-salt tracer. The following test standards shall be used as the bases for the tests and as otherwise indicated in this Appendix:

(a) International Electrotechnical Commission IEC 41-"Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines"

(b) International Organization for Standardization ISO 2975-"Measurement of water flow in closed conduits-Tracer methods", Part 1 ("General") and Part 6 ("Transit time method using non-radioactive tracers").

(2) Locations for the tracer injection points are at the tunnel intake or at one of the tunnel piezometer wells. Tracer samples may be taken along the tunnel using the equipment installed in the piezometer wells, the dewatering shafts and/or at the tunnel outlet.

(3) The unique features of the new tunnel (*i.e.*, having very large cross sections and high water velocities) may make the use of multi-port tracer injection and detection frames impractical. Therefore, provision for adequate mixing of the dye prior to the first sampling location shall be made.

(4) Transit time measurements shall be determined from two sampling points.

(5) The maximum uncertainty (including the random and systematic errors) for the flow measurement shall be +/-2%.

3. PARTY TO CONDUCT THE FLOW TEST

(1) The Test shall be conducted by an independent third party, mutually acceptable to the Owner and the Contractor (the "Independent Tester") which has significant experience and has carried out flow testing using the tracer methods in closed conduits of similar complexity. The Independent Tester shall be retained by the Contractor as an independent tester for and on behalf of both the Contractor and Owner. The Independent Tester shall be impartial in all respects. Prior to entering into an agreement with the Independent Tester to perform the Test and the related matters described in this Appendix 1.1(aa) (the "Independent Tester Contract"), the Contractor shall deliver to the Owner a copy of the proposed

agreement for review and approval by the Owner. The Contractor shall be responsible for management of the Independent Tester and the Owner and the Contractor shall each be responsible for 50% of all of the costs and expenses properly incurred by the Independent Tester in accordance with the Independent Tester Contract. After receipt of an invoice from the Independent Tester, the Contractor shall be permitted to include 50% of such invoice amount as part of any Application for Payment submitted by the Contractor to the Owner.

(2) Within 6 months after the Start Date, the Independent Tester shall deliver to the Contractor and Owner:

(a) preliminary details of Test procedure;

(b) preliminary details of Test setup and proposed equipment descriptions; and

(c) preliminary details of Test uncertainties (i.e., expected random and systematic errors).

(3) Owner and the Contractor shall have the right to review the proposed preliminary details of Test procedure, preliminary details of Test setup and proposed equipment descriptions and preliminary details of Test uncertainties and, if necessary, make recommendations to the Independent Tester to modify the preliminary details of Test procedure, the preliminary details of Test setup and proposed equipment descriptions and the preliminary details of Test uncertainties.

4. TEST SCHEDULE

(1) The exact Test date and time of performance of the Test requires extensive planning among several parties and also depends on the water availability. Therefore, the Test date and time will be decided by the Owner at its sole discretion. The Owner will make all reasonable efforts to have the test conducted as soon as practically possible following Substantial Completion, preferably within 2 weeks. Prior to Final Completion, the Test must be performed and the final Test report must be delivered to the Owner and the Contractor, all as more particularly described in Section 10 of this Appendix 1.1(aa).

5. TECHNICAL BASIS OF TESTING

(1) During the Test, the Owner's operators at the existing SAB Control Room ("SAB Operations") will attempt to maintain the water levels at a steady state. The hydraulic head on the tunnel conveyance system will be defined as the difference between the elevations of the energy grade line (EGL) at Section 1 (at the intake water surface gauge, in the vicinity of the tunnel intake structure) and Section 2 (at the outlet water surface gauge, in the tunnel outlet canal, immediately upstream from the transition at the junction with the PGS channel). The locations of the gauges are generally as shown on the Concept Drawings.

(2) The Guaranteed Flow Amount (GFA) is specified for the following reference hydraulic head (H_{ref}) and the reference elevation of the energy grade line at Section 2 (EGL_{2ref}):

H_{ref} = 5.60 m

EGL_{2ref} = 165.20 m (NAD83)

(3) The reference elevation of the energy grade line at Section 1 (EGL_{2ref}) will be defined by Equation 1.

$$EGL_{1ref} = EGL_{2ref} + H_{ref} \quad (1)$$

(4) For the purposes of the Test, at Section 1, the velocity head will be assumed to be zero and the hydraulic and energy grade lines considered as equal.

(5) During the Test, the following three values will be measured to evaluate the hydraulic performance of the tunnel:

(a) the measured flow, Q_m (m^3/s) as determined by the tracer transit time method as specified in Section 2 of Appendix 1.1(aa);

(b) the hydraulic grade line elevation at Section 1, HGL_{1m} (m) as measured at the intake gauge; and

(c) the hydraulic grade line elevation at Section 2, HGL_{2m} (m) as measured at the outlet gauge.

(6) The stipulated energy grade line elevation, EGL_{2ref}, will have a corresponding calculable hydraulic grade line elevation, HGL_{2ref}, corresponding to the guaranteed flow, GFA. During testing, an effort will be made to match the measured hydraulic grade line elevation, HGL_{2m} to the reference value HGL_{2ref}. However, it is recognized that there will be some difference between the level achieved and the reference level. During testing, the measured value must be within ±0.3 m of the reference value.

6. DETERMINATION OF REFERENCE TUNNEL FLOW

(1) The measured tunnel energy grade line elevations at Sections 1 and 2 will be calculated by the following formulae.

$$EGL_{1m} = HGL_{1m} \quad [2]$$

$$EGL_{2m} = HGL_{2m} + \frac{\left(\frac{Q_m}{A_{chan2}}\right)^2}{2g} \quad [3]$$

$$A_{chan2} = \left(HGL_{2m} - invert_2\right) \times w_{chan2} \quad [4]$$

where

A_{chan2} = cross-sectional area of the channel at Section 2

$invert_2$ = invert elevation at Section 2

w_{chan2} = width of the channel at Section 2

(2) The discharge that would have been obtained, had EGL_{1ref} and EGL_{2ref} been obtained, is Q_{ref}, calculated as follows:

$$Q_{ref} = Q_m \times \sqrt{\frac{H_{ref}}{EGL_{1m} - EGL_{2m}}} \quad [5]$$

7. TEST PREPARATION

(1) The Independent Tester shall submit the final detailed Test procedure to the Owner and the Contractor for review and acceptance, a minimum of one (1) year prior to the expected Test date.

(2) At least six (6) months prior to the Test, the Independent Tester shall design, prepare and complete an equipment verification test to ensure that the equipment and methodology meet the requirements of the Test. The Independent Tester shall provide sufficient notice to the Owner and the Contractor for their review and acceptance of the equipment verification test and to ensure their availability to witness the testing.

(3) The Contractor will obtain the necessary Approvals to conduct the test a minimum of three (3) months prior to the expected Test date.

8. TEST SETUP

(1) The Test setup shall be designed by Independent Tester and constructed and installed by the Contractor, with oversight by the Independent Tester.

9. TEST PROCEDURE

(1) The following list describes the main steps of the Test procedure. The Independent Tester may make prudent changes which reduce the uncertainty of the measurements, subject to the concurrence of the Owner and the Contractor.

(a) Prior to the Test time, the SAB water diversion system will be brought as close to a steady-state condition as practical by SAB Operations as indicated in Section 5 above and maintained as practically as possible at the steady-state water levels for a minimum of three hours. During this

period, the SAB PGS will not be operated and the gates of the INCW within the Ice Acceleration Channel will be in closed positions.

(b) The Test will start as soon as the Independent Tester is satisfied with the test conditions. The transit time of the tracer is expected to be about 40 minutes or less. The tracer will be injected a minimum of five times in accordance with ISO 2975, Part VI, Section 5.5 (*i.e.*, minimum of five test runs) under the same steady state flow conditions. The Independent Tester will record the test data for each Test run (*i.e.*, tracer time and tracer distributions at the injection and detection points).

(c) If the Independent Tester is not satisfied with any of the Test runs, he may cancel that Test run in his sole discretion. In this case, the Independent Tester shall exclude the results of such cancelled Test from the Test report and shall provide an explanation for the cancellation in his Test report.

(d) If the Independent Tester is not satisfied with any aspect of the execution of the Test, he shall submit a written request to the Owner and the Contractor within 24 hours of the test completion to repeat the Test. Upon receiving the request, the Owner will use all reasonable efforts to manage SAB Operations so as to allow the Test to be repeated as soon as possible.

(e) The Owner and Contractor each have the right to witness the Test at their own costs.

10. **TEST REPORT**

(1) The Independent Tester shall submit the preliminary Test results to the Owner and the Contractor within five (5) Business Days of the test completion. The Independent Tester shall submit copies of the final Test report to the Owner and the Contractor (three copies to each party) within the following 15 Business Days. The Test results shall be presented in the metric SI of units.

(2) The Test report will include the following:

(a) Test objectives

(b) records of all agreements pertinent to the Test

(c) personnel taking part in the Test

(d) description of the Test program

(e) description of the Test setup (including but not limited to the serial numbers and calibrations of the Test equipment)

(f) description of the Test procedure

(g) description of the Test results

(h) complete set of Test readings

(i) measured tunnel flow (Q_{Test}) for each Test run

(j) intake gauge and outlet gauge elevations (HGL_{1m} and HGL_{2m}) averaged over each Test run period

(k) an evaluation of the random and systematic uncertainties of each measured quantity and a calculation of the total uncertainty of data derived from combined measurements for each Test run

(l) statement regarding cancellation of any Test runs.

11. IMPACT OF WATER QUALITY AND WATER TEMPERATURE

(1) The Owner and the Contractor agree that the effects of the water quality, water temperature and seasonal flow variations on the flow Test results are negligible and will not be considered. The Owner and the Contractor also agree that the flow measurements will not be corrected to compensate for the temperature and pressure changes inside the tunnel when the tunnel is filled with water.

12. ANALYSIS OF TEST RESULTS

(1) The Test results shall be analyzed in accordance with the approach given in Section 6 above.

(2) The numerical average of the reference flows (Average Q_{Ref}) of all Test runs completed to the satisfaction of the Independent Tester shall be deemed to be the Performance Test Water Flow Amount (PTWFA) for the purposes of Section 8.3 of this Agreement.

(3) Calculations are to carry all significant figures. No rounding of values is to be done until the final calculation of Average Qref. This value should be rounded to the nearest 0.1 m^3/s based upon the following rules:

(a) when the digit to be dropped is less than five, write the number without the digit; example, 505.844 becomes 505.8

(b) when the digit to be dropped is greater than five, the preceding digit is increased by one; example, 505.86 becomes 505.9

(c) when the digit to be dropped is exactly five, then the nearest even number is used for the preceding digit; example, 505.85 becomes 505.8.

13. FINAL AND BINDING

Provided that the Independent Tester follows the procedures and standards set out in the Appendix 1.1(aa), the Test results, calculations and other determinations of the Independent Tester are final and binding on the Owner and the Contractor and not subject to review by or reference to the DRB or any appeal.

14. CORRESPONDENCE

All recommendations, acceptances and approvals provided to the Independent Tester shall be mutually agreed by the Contractor and the Owner. In the event that the Contractor and the Owner do not agree as to a recommendation, acceptance or approval, the Independent Tester shall consider the positions of each of the Owner and the Contractor and shall proceed in the manner it considers appropriate in the circumstances. To the extent that either the Contractor or the Owner provides the Independent Tester with written instructions or directions, a copy of such instructions or directions shall be concurrently provided to the other party.

Appendix 1.1(nn)
INTENTIONALLY DELETED

Appendix 1.1(nn) - INTENTIONALLY DELETED

Appendix 1.1(qq)
OPG's Delegation Notice

Appendix 1.1(qq) - OPG's Delegation Notice

DELEGATION OF AUTHORITY

(or change in delegation of authority)

To: Strabag Inc. (the "**Contractor**")	Agreement: Amended Design/Build Agreement dated as of December 1, 2008 between the Contractor and Ontario Power Generation Inc. ("**OPG**") Delegation No.: • Date: •

Defined terms used in this Notice have the same meanings given to those terms in the Agreement. In accordance with Section 3.2 of the Agreement, OPG hereby notifies the Contractor that OPG's Representative is Rick Everdell. The duties of OPG's Representative are delegated to the individuals named below for the subject matters and subject to the limitations set out in this Notice. These delegations will continue in full force until revoked by OPG in another delegation of authority Notice.

Title	Delegate	Effective Date	Scope of Authority
■	■	■	•

ONTARIO POWER GENERATION INC.

By: _____

Name:
Title:

Appendix 1.1(uu)
Outline (Technical) Specifications

Appendix 1.1(uu) - Outline Specifications

[See attached]

MH-5002-00
Intake and Outlet
Work Area – Specifications

Ontario Power Corporation Inc.
(OPG)

Niagara Tunnel Facility Project

Proposal No.: Tunnel Facility Project-001

Document: MH-5002-00
Intake and Outlet Work Area – Specifications

May 11, 2005
Project No.: 1051006.00

MORRISON HERSHFIELD

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1.0 OPERATIONS – FOR OUTLET ONLY

Preliminary

1) The contractor will remove the overburden along the footprint of the outlet channel, as depicted in the drawings and cross sections. This overburden will be temporarily stored in the materials yards.

2) The contractor will construct the channel outlet to the rock plug limit by means of rock excavations. The rock that is found to be reusable (estimated at ~ 140,000 M3) will be crushed and reused in:

   - Access road construction
   - Backfill as required in the inlet structural drawings.

3) The overburden that is found to be reusable will be used in constructing the entrance road into the outlet opening. The excess overburden from note #1 above will be removed to the designated disposal site by truck.

Operational Stage

1) Excavated material from the Outlet area is to be loaded on Conveyor 1 and removed to the Temporary Stockpile[1]. This will facilitate initial aeration[2] and discharge of contaminants into the runoff pond. The excavated material will be inspected to ensure that no contaminants were introduced during the tunnel boring process. The size of the temporary stockpile will accommodate the material produced by 15 days of tunnel boring, or ~51,000 m3.

2) After it is determined that the material has no BTEX or other contaminants, it will then be transported to the Material Distribution Pile through Conveyor 2. Conveyor 2 will bridge across the HEPC Canal. This stretch of the conveyor has to be covered/protected to prevent any passage of material into the North HEPC canal.

3) The material will be distributed along the area between the two HEPC canals (designated disposal area), using rock trucks, and in accordance with the drawings and cross sections provided in the materials quantity sheets. The material will be compacted in order to minimize air voids, and in order to minimize the possibility of water infiltrating the bottom layers of the pile and destabilizing it[3].

4) Ground water will be pumped into a retention pond capable of holding ~45,000 m3 of water. The water will pass through a lamella clarifier before being discharged into the north HEPC canal. Water (either ground water trapped in rock or runoff) from the temporary stockpile runoff pond will be fed directly into the clarifier.

---

[1] Conveyor belt to be constructed by STRABAG. It will be able to move 1,200t/hour of material as peak design load
[2] Certain rock formations (description given in OPG Baseline Geotechnical report) contain BTEX contaminants.
[3] Due to the characteristics of Queenston Shale – becomes a slippery clay like material when exposed to water

5) Storm water runoff from the material distributed in the designated disposal area will be collected via ditches in a settling pond (location depicted on OCA drawing). Disposal of runoff can be done in two ways (based on environmental approvals):

- Discharge the contents of the pond through filter cloth into the North HEPC canal (preferable)
- Pump the contents of the pond into tanker trucks and deliver the water to the ground water retention pond, where they will be treated by the clarifier.

Post Construction

1) The material berm at the designated disposal area will be top soiled, sodded and trees will be planted on it in order to prevent long-term erosion.

2) Materials yards, offices yards, retention pond will be restored to their pre-construction stage, including vegetation and trees.

3) The impervious liner of the temporary stockpile will be disposed of in an approved disposal site. The ground will be restored as noted above.

2.0 CONTINGENCY PLANS AND SUBSTITUTES

1) Break down of Conveyor Belt #1 – Material can be removed from the tunnel exit by trucks via Rd. "E" and Rd. "D" to the temporary stockpile.

2) Break down of Conveyor Belt #2 – Material can be removed from the temporary stockpile by trucks via access roads "C"/"B' and access 1. The temporary stockpile will be capable of retaining 15 days of spoils production.

3) Breakdown of Clarifier – Retention pond deemed capable of holding sufficient water volume pending repair. However, additional pond can be constructed adjacent to it in materials yard No. 2[4].

4) Exiting natural ravine unable to cope with increased storm water runoff quantities[5]. Excavate a retention pond in materials yard #1 to supplement the existing pond.

3.0 SPECIAL PROVISIONS

All clauses in all the relevant OPS Specifications and OPG Owner's Mandatory Requirements (Appendix 1.1 uu) are to be read in conjunction with this document except the BASIS OF PAYMENT, wherein the General Conditions pertaining to MEASUREMENT AND PAYMENTS shall be applicable.

[4] Increasing the size of the existing pond is not desirable, as the pond requires heating in winter.
[5] Due to the striping of topsoil and the increase in paved areas.

3.1 GENERAL ITEMS

G.1 Construction Facilities and Temporary Control

Before commencing construction operations, supply, erect and maintain hoarding around entire perimeter of Site as shown on the drawings. Mark with "POST NO BILLS" signs on the outside of the hoarding. Remove hoarding upon Contract completion unless as directed by the Commissioner.

Prevent unauthorized entry to the Site. Barricade, guard, or lock access points to the satisfaction of the Engineer and post "NO TRESPASSING" signs.

Provide barriers around trees and plants designated to remain. Protect from damage.

Provide secure, rigid guide rails and barricades around deep excavations, open shafts, open stair wells, open edges of floors and roofs as required for protection of Work, workers, and the public.

Provide Utilities including lighting and water supply to the construction site. The Contractor shall be responsible for payment of these services including the installation/removal of meters and work associated with connection and disconnection. Washroom facilities shall also be provided by the Contractor.

Protect surrounding private and public property from damage during performance of the Work. Take precautions to prevent fires. Provide and maintain temporary fire protection equipment of a type appropriate to the hazard anticipated in accordance with authorities having jurisdiction, governing codes, regulations, by-laws and to the satisfaction of the Engineer and insurance authorities.

Workers shall comply with the Occupational Health and Safety Act and Regulations for construction projects.

Supply and install offices at the site for the duration of the Work in locations as indicated on the drawings. Provide offices with electric light, heat, air conditioning, telephone and first aid equipment as required by the Workplace Safety and Insurance Board and the Ontario Ministry of Labour. Office shall have adequate electric heating, air conditioning and lighting; washroom and water closet with hot and cold running water and supplies; and labour for daily cleaning of the washrooms and offices. Equip the offices with the following: desks and chairs, tables with drawers, plan table and drafting stool, aluminum wall mounted plan racks and lockable fireproof fire cabinets. Provide and pay for the telephone services with “call answering” and a paper facsimile machine on a separate dedicated phone line for the facsimile machine. Also provide a photocopier capable of making multiple copies up to 11” x 17” in size, complete with sorting capabilities. Provide regular service for fax and photocopy machine for the duration of the Work. All trailer windows must be protected with metal bars and all doors to have metal plate with padlock capability. For all trailers and temporary buildings, provide wood stairs, platform and boardwalk, painted and repainted as required with non-skid abrasive paint.

Remove temporary offices (buildings) upon Contract Completion. Restore area(s) to match the existing surrounding areas.

Maintain the Site and adjacent areas in a clean and orderly condition, free from debris and other objectionable matter. Remove rubbish and surplus material, equipment and structures immediately. If the Site is not cleaned within 48 hours after the Contractor has been instructed to do so, the Engineer may clean the Site and retain the cost from monies due, or to become due, to the Contractor.

Keep haul routes free at all times from materials spilled on street surfaces and maintain streets in clean condition to the satisfaction of the Engineer and the street authorities.

During the progress of the Work, afford access to visitors duly authorized by the Engineer and facilitate inspections or tests they may desire to make. Ensure Site visitors wear appropriate safety apparel.

The Contractor shall provide water trucks for dust control as where required.

G.2 Examination, Protection and Restoration of Property

The Contractor shall examine, protect and restore if damaged by the execution of the Work, all property adjacent to the Work or that may be affected by the Work, including all equipment and services within the properties.

The Contractor, the Commissioner and the structure owner shall jointly examine each of these properties prior to the start of construction. Amendments to the inspection reports, if required, will be carried out by the Commissioner. The reports shall then be signed by all three parties.

The Contractor, the Commissioner and the structure owner shall jointly re-examine each of these properties after construction is completed to record condition differences.

The restriction of joint examination to specific properties does not relieve the Contractor of its responsibility for the examination, protection and restoration of all property adjacent to the Work or which may be affected by the Work.

Locate, protect, support and maintain all equipment and services affected by the Work.

The Contractor shall fully secure the integrity of the foundation of the INCW prior to any blasting work.

On completion, restore equipment and services to their original condition, and relocate where necessary, to the satisfaction of the Engineer.

Repair and restore any part of the property including equipment and services broken or damaged by operations performed under the Contract.

G.3 Safety

For the purposes of the Contract, the term "constructor", as defined in the Occupational Health and Safety Act, shall mean the Contractor who shall be responsible for ensuring that the provisions of the statutes, regulations and by-laws pertaining to the duties, obligations and safe

performance of the Work in accordance with the obligations of the "constructor" as set out in the Occupational Health and Safety Act are to be observed.

Regardless of whether the Commission or the Contractor pursuant to the Occupational Health and Safety Act as the "constructor", the Contractor's representative shall be responsible for ensuring that the provisions of statutes, regulations and by-laws pertaining to safe performance of the Work are observed and that the methods of performing the Work do not endanger the personnel employed thereon and the general public, and are in accordance with the latest edition of the Occupational Health and Safety Act.

Prior to the Contractor's representative being absent from the Site, the Contractor's representative will name another person, in writing to the Commissioner, who is competent to assume these responsibilities. The Contractor shall advise the Engineer of any change in the individual identified as the Contractor's representative.

The Contractor's representative shall ensure that all measures and procedures prescribed by the following Acts and Regulations are carried out on Site and every employer and every worker performing work on the Site complies with all of the requirements:

- The Occupational Health and Safety Act;
- The Regulations for Construction Projects;
- WHMIS Regulations;
- The Environmental Protection Act and regulations,
- Dam Safety Regulation under the Lakes and Rivers Improvement Act;
- All other legislation, regulations and standards as applicable.

During underwater construction, in-service inspection and maintenance of the structures, safety of the divers or personnel shall ensured.

G.4 Traffic

Conduct the Work in such a manner as to ensure the least interference with pedestrians, cyclists and vehicular traffic. Comply with arrangements made with traffic and police authorities and as directed by the Engineer.

Give the Engineer seven (7) calendar days written notice of desire to restrict or close any street or lane permitted under the Contract. Do not put any restriction or closure into effect without the approval of the traffic and police authorities and the Engineer's written approval.

Under the direction of the police and traffic authorities and in accordance with the Manual of Uniform Traffic Control Devices, supply, erect, maintain, and subsequently remove signs, signals, flasher beacons and delineators, which are required by the traffic authorities for the diversion and guidance of vehicular and pedestrian traffic.

Haul routes and the location of any ramps which enter onto any street are subject to the written approval of the Engineer, traffic and police authorities prior to the start of any Work. No ramp may be placed in an area where future construction is planned.

Keep haul routes free at all times from materials spilled on street surfaces and maintain streets in a clean condition to the satisfaction of the Commissioner and authorities having jurisdiction.

The Commissioner may inspect haul routes, the Site and adjacent premises daily and may halt operations, withhold payment or carry out such additional operations as necessary, deducting the cost from monies due, or to become due.

Access and egress to and from the Site shall be at the locations shown on the Contract Drawings.

Maintain access roads, sidewalks, ramps, construction runways and decked areas adjacent to the Site in a safe condition throughout the Contract.

Take precautions to avoid tracking and depositing materials, debris and mud on roads and on the Owner's property from vehicles and equipment operating to and from the construction Site, and be responsible for removal of such deposits by brooming and washing to the satisfaction of the Commissioner.

Maintain access routes, sidewalks, Site roads, trailer area, storage areas as well as Work areas free of ice and snow to maintain safe operating conditions and to maintain progress of the Work. Cleared snow shall be removed from the Site within 12 hours of a snow fall or as directed by the Commissioner.

4.0 ELECTRICAL AND MECHANICAL WORKS ITEMS

4.1 E&M.1 INTAKE AND OUTLET GATES

Under this item, the Contractor shall supply, deliver and install new Intake Gates including all hardware, inserts in concrete, trial operations and delivery to storage as prescribed by OPG. Also included in this item is New Outlet Gates including all hardware, inserts, fabrication, delivery and installation including all lift and full scale trials as requested.

This item also included New Outlet Gates supporting structures are as part of the outlet gate installation.

4.2 E&M.2 SITE ILLUMINATION (TEMPORARY)

4.3 E&M.3 SITE ILLUMINATION (PERMANENT)

4.4 E&M 4 PROVISIONS OF POWER TO SITES

5.0 CIVIL WORKS ITEMS

C.1 CHAIN LINK FENCE

Under this item, the Contractor shall supply and install new approved chain link fence, foundation and associated components (fence, posts, connection hardware, etc) at the following locations:

1. At the Intake Site Area where around possible addition of construction/stockpiling areas as shown on the drawings.
2. Various locations at the Outlet Site Area at specified on the drawings including site offices, restricted woodlands, restricted meadow, Area North of HEPC canals, Adjacent to Whirlpool Rd and Materials Yard 1.

The chain link fence shall meet the requirements of OPSS No. 541 except as specified herein.

The total height of the chain link fence shall not be lower than 2.50 m and the height of the chain link fence on grade shall not be lower than 2.30 m. Lockable gates shall be provided as shown on drawings.

C.2 CLEARING AND GRUBBING (150 MM THICK)

Under this item, the Contractor shall clear and grub the existing ground areas as required to gain access for equipment, materials and personnel, to the work area at both Intake and Outlet Site Areas.

This item shall meet the requirements of OPSS No. 201 and 206 except as specified herein.

This item will be deemed to have included for the removing, carting away and disposing of all vegetation including removal of topsoil from the work zone except for mature trees, which have to be identified prior to the commencement of this operation and relocated as per the directions and sole discretion of the Project Manager. Also prepare the surface ready to commence the permanent works. Mature trees are to be relocated to pre-determined locations. Topsoil is to be stockpiled in a predetermined location for future use.

Prior to any clearing and grubbing, a professional arborist shall be retained to review any tress that the Contractor deemed necessary for relocation. Trees relocation shall be paid elsewhere.

Under this item, the Contractor shall regrade all surfaces affected by construction to original condition or better.

C.3 SILT FENCE

Under this item, the Contractor shall supply and install new silt fence barrier and associated components along the southern edge of the access road adjacent to North Canal and Final Disposal Area at the Outlet Area to prevent passage of material into the waterway as shown on the drawings.

This item shall meet the requirements of OPSS No. 577 and as specified herein.

The specification should be read with particular emphasis on Clauses 577.07.02 and 577.07.03 for construction of the Silt Fence and Clause 577.07.12 for sediment removal and management. Throughout the period of the contract the fence should be serviced and maintained as to fulfill the purpose of its erection.

A 100m stand-by supply of prefabricated silt fence barrier shall be maintained at the site throughout the duration of the contract.

C.4 IMPERVIOUS LAYER IN CERTAIN AREAS

This item shall meet the requirements of OPSS No. 1205 and as specified herein.

In the Temporary Stockpile and Run-Off Pond locations, an impervious membrane has to be provided to prevent percolation of contaminants into ground water. The layer used can be built up or be off the market with the prior approval of the Project Manager.

C.5 EXCAVATION

Under this item, the Contractor shall carry out all required excavation to profiles, specified in the respective drawings, stockpile and disposal of the excavated material (rock and earth) at both Intake and Outlet Site Areas including the Access Ramps to Intake Elevation and to Outlet Entrance during Construction as indicated on the drawings. Excavated material to be used as 'fill' wherever applicable or removed to the designated disposal area.

The sides of the intake channel excavation shall be line-drilled and controlled blasting shall be employed to ensure that the rock beyond the excavation limits is not damaged or destabilized.

Ground water retention pond to be excavated and the excavated material to be placed and compacted in lifts all around to form the water retaining structure as per details provided in the drawings.

The Run-off pond will be excavated as shown in the drawings and will be lined with an impervious layer/membrane to prevent percolation of contaminants into the ground.

The overburden along the path of the outlet channel will be excavated as shown in the drawings and cross sections. Some of the overburden will be reused in constructing the access road into the outlet shaft. The rest will be removed to the designated disposal area via trucking.

The designated disposal area will be surrounded by a ditch and a silt fence, in order to trap sediment and prevent it from accessing the HEPC canals.

This item shall meet the requirements of OPSS 102, 206, 212 and 1010.

Side slopes of the excavation areas shall be keep to 2H:1V or provide stabilized structure such as roadway protection, earth retaining systems otherwise.

Any damaged rock beyond the excavation limits shall be removed and backfilled with concrete adequately tied back to sound rock at Contractor's own expense.

All the excavation limits datum was based on the information and drawings supplied by the OPG.

As part of the work, the Contractor shall indicate the location of any buried utilities by stakeouts prior to any excavation and those utilities shall be protected/relocate at all time during excavation and construction.

C.6 NATIVE FILL

Under this item, the Contractor shall pick-up, transport, place, and compact the stockpiled material that was selected and removed from the site at both Intake and Outlet Areas as indicated on the drawings.

This item shall meet the requirements of OPSS 902, 1010 and 1501.

The Contractor shall confirm the top of backfill material elevations to the required elevations for the Commissioner to review prior to the work.

C.7 GRANULAR 'B'

C.8 GRANULAR 'A'

Under Item C.8, the Contractor shall supply, deliver, place and compact granular materials 'B' at the following locations to the extent shown on the drawings.

1. Access roads at both Intake and Outlet Areas to the depth as indicated.
2. Areas behind the East and West Approach Walls to the elevations as indicated.

Under Item C.9, the Contractor shall supply, deliver, place and compact granular materials 'A' at the following locations to the extent shown on the drawings.

1. Access roads at both Intake and Outlet Areas to the depth as indicated.
2. Platform and construction area at Intake Area.

Granular Materials shall comply with the requirements of OPSS 501, 902, 1010.

All access roads are to be constructed as per cross-sections in the drawings. Sub-base, out of native material, is to be well compacted and ready to receive base course of granular material.

Submit all delivery tickets to the Commissioner. The Contractor shall confirm the top of backfill material elevations to the required elevations for the Commissioner to review prior to the work.

C.9 ASPHALT

Under this item, the Contractor supply, deliver and place the hot mix asphalt on the access roads and platform at Intake and part of main access roads at the Outlet Areas as shown on the drawings. Also included in this item is the all access roads will have ditches in order to control storm water runoff. The water flow in the ditches will be directed towards the existing grounds' natural drainage – roughly in the area of the new dewatering structure.

Work shall be performed in accordance with OPSS 311, 313 except as modified herein.

Work shall be done by an approved asphalt contractor.

Compaction equipment can be by small roller or the use of vehicle roller. The asphalt material shall be 75 mm HL3 mix.

C.10 TREE PLANTING

Under this item, the Contractor shall plant the trees at both the Intake and Outlet Areas. Also included in this item is the tree planting at the Intake disturbed areas including shrubs and evergreens. Each trees shall be planted in every 100 m2 area.

The Contractor shall retain a Professional arborist to review any tress that the Contractor deemed necessary for removal. Trees designated for removal or pruning shall first be approved b the Commissioner before performed by the Contractor using a qualified tree-removal Sub-Contractor. The Contractor shall remove all debris resulting from cutting or pruning.

All work shall be in accordance with OPSS 565 and Canadian Standard for Nursery Stock.

All plant materials are to be bolled and burlapped.

No cutting of tress permitted between May 1st to June 15th unless by owner's permits.

C.11 CULVERTS

C.12 CONCRETE PIPES

Under item 11, the work includes supply, deliver and place pipe culverts under the access roads at both the Intake and Outlet Site Areas as indicated on the drawings.

The size of the culverts varies from 675 mm – 900 mm diameter.

Under item 12, the Contract shall supply, deliver and place concrete pipes from the ground water treatment plant to the HEPC canal.

The size of the concrete pipes varies from 1500 mm – 2000 mm diameter.

All work for these items shall be in accordance with OPSS 421 and OPSS 1820 except as specified herein.

Depth of excavation and placing of culverts and pipes to be governed by the Frost Line – Pipes to be placed below Frost line and to be on granular bedding.

C.13 SANITARY SEWER

This item will be deemed to have included for all works for the connection to the existing sewer at both the Intake and Outlet Site Areas.

All work shall be in accordance with OPSS 406.

C.14 SANITARY SEWER MANHOLE

This item will be deemed to have included for all works for the construction of sanitary sewer manholes at the connection to existing sanitary sewer Line at the Intake Area as well as to Stanley Ave at the Outlet Site Area.

All work shall be in accordance with OPSS407.

C.15 WATERMAIN

This item will be deemed to have included for all works to construct watermain and all associated components for the connection from the Intake Area and the Outlet Site Area to Stanley Avenue to feed offices area.

All work shall be in accordance with OPSS 701.

C.16 LANDSCAPING AT FINAL DISPOSAL AREA

This item will be deemed to have included for all works to landscape the Final Disposal Area at the Outlet Site Area.

All work shall be in accordance with OPSS 570 and 571.

C.17 CONVEYOR BRIDGE

Please refer to the specification item prepared by Strabag.

C.18 NOISE BARRIER

This item will be deemed to have included for all works to design, supply and construction of noise barrier by Durisol Retained Soil System (RSS) or equivalent at the Intake Site Area as shown on the drawings.

Reference:

- OPSS 206, OPSS 501, OPSS 609, OPSS 1350, OPSS 1352
- SGSB 1-GP-181-M1977 & March 1978 Amendment – Coating; Zinc Rich, Organic, Ready Mix
- CSA Z107.9-00 Standard for Certification of Noise Barriers February 2000
- CAN/CSA-S6-00 Canadian Highway Bridge Design Code
- CSA G164-M1981 Hot Dip Galvanizing of Irregularly Shaped Articles
- CSA W 47.1-1983 Certification of Companies for Fusion Welding of Steel Structures
- CSA W 59.1-1982 Welded Steel Construction (Metal-Arc Welding)
- CAN3-A23.2-M77 Method of Test for Concrete
- CAN3-A5-M 1983 Portland Cement/Masonry Cement/Blended Hydraulic Cement

The Contractor shall submit to the Commissioner of all shop drawings for noise barriers at least four (4) weeks prior to the commencement of construction. The shop drawings shall show full

details of noise barrier related items, erection procedures and if applicable, connections to structures. All shop drawings shall bear the seal and signature of an Engineer.

The Contractor shall construct a noise barrier with the following minimum design features:

- Reference wind pressure: 380Pa.
- The minimum acoustical characteristic of the noise barrier shall be such that the noise barrier is sound absorptive on the construction side.
- Final colour selections will be determined by the Contract Administrator at the point of manufacture from samples prepared by the Manufacturer.

Noise barriers shall be supplied in accordance with OPSS 128. All welds shall conform to CSA W59.1 and CSA W47.1.

Steel posts to which special attachments are welded shall be hot dip galvanized after fabrication according to the requirements of CSA Standard G164-M. Silicone sealant shall be CGE SILPRUF 2000 Series. Concrete in post footings shall be 20 MPa according to the requirements of OPSS 1350.

Where footings are to be installed in earth,concrete for drilled footings shall be cast entirely against undisturbed soil. If other than drilled footings are necessary, the footing shall be formed and the excavation shall be backfilled with granular materials and compacted to at least 95% Proctor. For concrete posts, the concrete working slab below the construction joint in the footing shall be placed a minimum of 4 hours prior to installing the post. Where required, the tops of all footings are to be shaped to provide for full horizontal seating of panels, the remaining surface area is to be sloped away from the post so as to shed water. Stepped footings are to be constructed to suit grade changes.

The concrete in the footings shall be cured for a minimum period of 5 days before the noise panels can be installed.

When rock is encountered within the specified excavation depth for footings in earth, the footing shall be constructed in accordance with the "Footings in Earth" design down to a minimum of 300 mm into the solid rock or 1.5 m below the top of footing grade, whichever is the greater depth.

All excavations into rock shall be backfilled entirely with concrete. The excavation above the top of rock may be formed to the required dimensions and the remainder of the excavation backfilled with granular material.

C.19 TRAIL RELOCATION

This item will be deemed to have included for all works to relocate the existing recreation trail at the Intake Site Area as shown on the drawing. Also included in this item is to connect the relocated portion of recreation trail to the existing trail at both ends. Relocate the recreation trail back to the original position upon the completion of the work.

All work shall be in accordance with OPSS 128.

The new trail layout and material used shall be match the existing recreation trail or to a better condition.

C.20 TOP SOIL AND SODDING

This item will be deemed to have included supply and place topsoil and sodding to the following areas:

1. Reapplying topsoil to the disturbed areas at the Outlet Site Areas including construction offices, materials yard, Final Disposal area, Temporary Stockpile Area for restoration.
2. Applying 150 mm depth topsoil and sodding to the embankment slope behind the East and West Approach Walls at the Intake Areas.
3. Reapplying seeding at all other disturbed Areas.

Also include in this item is to water the placed sod over the warranty period. Any dead sod spots shall be replaced at the Contractor's own expense.

It is noted that the salt content of the rock from the tunnel may make it difficult to get seed growth.

Work to be done by an approved sodding Contractor.

C.21 Remove and Relocate Existing Watermain

This item will be deemed to have included remove, dispose all material off-site and relocate the existing OPG Watermain at the Outlet Area. All work shall be performed by a qualified Subcontractor.

Two relocation options are proposed:

1. Install approximately 1000 m of new pipe adjacent to the pumping station and bridge the new canal (23 m)
2. Erect a new structure over the existing canal (43 m) adjacent to dewatering structure.

All work shall be in accordance with OPSS 510.

Prior to commencing removal of the existing watermain pipe, the Contrctor shall notify the owner of the watermain and also to ensure that the existing watermain has been by-passed, disconnected and/or unoperated.

C.22 REMOVE EXISTING DEWATERING STRUCTURE AT PGS

This work will encompass the removal and disposal all material off-site the existing dewatering structure at the Outlet Area.

The structure will be removed to the bottom of canal bed elevation

All work shall be in accordance with OPSS 510.

C.23 SURFACE PROTECTION FOR GROUND WATER RETENTION POND

This item will be deemed to have included surface protection for the ground water retention pond at the Outlet Area.

Protection can be provided through by the following material:

- Riprap
- Impervious synthetic material
- Clay layer

All work for riprap and impervious synthetic material shall be in accordance with OPSS 511.

C.24 CRUSH STONE

This item will be deemed to have included supply and place crush stone at the following areas:

1. Embankment behind the East and West Approach Walls to the depth as shown on the drawings at the Intake Area.

The crush stone size shall be 150 mm diameter. Stones shall consist of sound, natural, round stone.

No backfill of crush stone shall be placed behind the approach walls until rockfill has been placed up to the desired top level and capped with concrete cover slab.

The depth of the stone shall be placed and layout as shown on the drawings.

C.25 UTILITIES RELOCATION (IF REQUIRED)

This item will be deemed to have included relocate the existing Utilities if required. Prior to the commencement of any work, the Contractor shall stake out and verify all Utilities locations to determine if there are Utilities needed to be relocated at both Intake and Outlet Areas. Upon the completion of the work, the Contractor shall reinstate the Utilities as directed by the Utilities Companies or Agencies.

Any damage to the existing pipe and all associated components / supports that are not specified to be removed shall be repaired by the Contractor to the satisfaction of the Commissioner.

C.26 RESTORATION

The item will be deemed to have included the removal of all temporary installations at both Intake and Outlet Areas (temporary buildings, fences, and all other items deemed removable by OPG), reapplication of topsoil to disturbed areas and to the material berm, providing seeding and cover, and tree planting. The reapplying of topsoil and tree planting is paid under other items elsewhere.

C.27 STRAW BALE

This item will be deemed to have included supply and place straw bale at theboth sides of the ditch for the following areas:

1. At the intersection of the access roads at the Intake Area and Outlet Area.
2. Along all access roads at every 250 m internal.
3. At the approach of the culverts.

The straw bale is to slow down the flow and to prevent erosion.

6.0 STRUCTURAL WORKS ITEMS

S.1 TEMPORARY DOCK AND ACCESS

Under this item, the Contractor shall provide temporary dock at the Niagara River Shoreline at the location as indicated on the drawings for the transportation and access to the Intake Area Site. The item shall also include other temporary installations/structures for facilitate the removal and deliver material to the intake structure/channel including stairs platform/or construction elevators/tower crane.

Also included in this item is the removal of the temporary dock and installations/ structures upon the completion of the Intake Area Work.

All docks must be constructed and designed with engineering certification as to structure durability and effectiveness for the river location. The dock must be completed by a Certified Dock Builder or the owner of the property where the structure is located.

All construction docks must have the plans, specifications, and required calculations submitted and signed by a Professional Engineer experienced in dock design with boat/batch size, wind conditions, and anchorage design equal to or greater than the design being submitted.

American Society of Civil Engineers (ASCE) Manuals and Reports on Engineering Practice No. 50, Planning and Design Guidelines, is a recognized standard and may be used along with the requirements herein. The requirements provided in this specification shall govern over the ASCE No. 50 standard.

All docks shall be constructed with environmentally safe materials.

Structural framing members shall provide corrosion resistance and strength as required by a Professional Engineer.

Anchorage shall be designed with a minimum working load safety factor of 3.0 for cables and 2.0 for chains. Anchorage shall also be galvanized or stainless steel. Anchor design shall be completed with sound engineering practice and the soil properties assumed (if soil testing was not completed) shall be shown on the plan documents. Submerged anchors must be positioned to accommodate low water levels, as not to present a navigational hazard.

S.2 COFFERDAM AND ICE PROTECTION GROYNE

The requirements of OPSS 517 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall design, provide and maintain a cofferdam system including anchors, rip rap and crush stones to the limits at the Intake Area as shown on the drawings. Also included in this item is the removal of Cofferdam including all bracing after the completion of the structure work, care being taken not to disturb or otherwise damage the finished structure.

Cofferdams shall be carried to adequate depths and heights, and be safely design and constructed, and be made as watertight as is necessary for the proper performance of the work which must be done inside them. Cofferdams shall provide sufficient clearance for the construction of forms and shall permit pumping outside the forms.

Cofferdams shall be designed by a Professional Engineer and the plans bearing the Professional Engineer's stamp and submitted to the Commissioner for approval 10 weeks after the work commencement. These plans shall also contain information as to the design loads and the de-watering and excavation sequence.

S.3 GROUTING

Under this item, the Contractor shall provide a continuous, durable and effective grout zone at the Intake area to the limits as shown on the drawings, appropriate and suitable for the existing subsoil and site conditions, to control all seepage of groundwater and re-grouted where necessary until water ingress is controlled by monitoring.

The Contractor shall be responsible for the design of the multiple grout curtains design. Submit grouting procedures in accordance with the site conditions, working window, and schedule, including the layout of the grout plant and accessory equipment, material storage, fume and dust exhaust and ventilation, access equipment, and other pertinent details, particularly designed to address the space limitation, time restriction, confinement of the tunnel, power supplies, etc. Also submit manufacturers product data, recommended handling and mixing instructions, recommended installation instructions, site conditions which would affect installation procedures, and site conditions which would impose performance limitations.

Monitoring work will be the responsibilities of the Contractor supervised by representatives of the Commissioner.

S.4 SANDBAGS

Under this item, the Contractor shall supply and place cemented sandbags for the precast unit support for the following as shown on the drawings:

1. Leveling the locations of East and West Approach Walls.
2. Leveling the locations of the New Acceleration Wall.

S.5 ROCKFILL

The requirements of OPSS 511 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall supply and place rock for the following as shown on the drawings:

1. Rock fill within the concrete precast units up to the level at the East and West Approach Walls.
2. Rock fill within the concrete precast unit up to the level at the New Acceleration Wall.
3. Rock fill on the overburden slopes for the outlet channel.
4. Rockfill at the ice protection groyne at the Intake Area.

The size of the rock shall be 500 mm diameter. Rocks shall consist of round and natural shape. It shall consists of clean rock gragments and shall be free from organic material. Rockfill shall be reasonably uniformly graded in size up to a maximum of 500 mm and such that not more than 10% by weight shall be less than 150 mm and more than 50% by weight shall consist of particles 300 mm or larger in size.

S.6 REMOVE GUARDRAIL AND POSTS (AS REQUIRED)

Under this item, the Contractor shall remove and salvage the existing guardrail and posts at the Intake Site Area as required to the limit as indicated on the drawings.

Any damage caused to the guardrail and posts by the Contractor's operation shall be repaired or replaced to the Commissioner's satisfaction at the Contractor's expense.

Included in this item is reinstating the guardrail and posts to original details upon the completion of work.

S.7 REMOVE EXISTING ACCELERATION WALL

Under this item, the Contractor shall remove and dispose off site, the acceleration wall system including concrete cap, timber bracing, rock fill and all associated components in stages and sequences to the limit as indicated on the drawings. As part of the removal operation, the Contractor shall supply all necessary equipment and operators to load, haul and dispose of material and debris resulting from the removal work.

The demolition method of the wall shall be undertaken to minimize impact on the operation of the INCW and the environmental impact. Prior to all in-river activities, the Contractor shall coordinate with and obtain approval from Ontario Power Generation.

The Contractor shall ensure that no debris from the removal operations enters into the Niagara River watercourse.

S.8 REMOVE PARTIAL EXISTING PIERS FOR WIDENING

The requirements of OPSS 904, 928 and 929 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall remove and the existing concrete piers including reinforcement to the limit as indicated on the drawings. As part of the removal operation, the Contractor shall supply all necessary equipment and operators to load, haul, and dispose of material and debris off site resulting from the removal work.

Removal method shall be selected to ensure no detriment to the structural integrity of components that will remain during and after the work. Extreme care must be taken not to overbreak the concrete beyond the limits of removal.

No debris and water resulting from removal operations will be permitted to enter the watercourse of the Niagara River unless complying with applicable Municipal by laws and with relevant MOE Standards.

The use of hoe-rams or large impact hydraulic breakers is strictly prohibited. The explosives or implosion procedures is also prohibited.

S.9 CONCRETE – MASS CONCRETE

S.10 CONCRETE – TREMIE CONCRETE

S.11 CONCRETE – CAST-IN-PLACE CONCRETE

Under these items the Contractor shall supply and place concrete for the structure components to the dimensions, shape, thickness, elevations and depths shown on the contract drawings, except for the precast units which will be described and paid under separate items. These components are defined below pertinent to each individual item. The provisions of OPSS 904, 919 and 929 shall apply unless otherwise specified below. All properties of the mix are as describe below, and in accordance with CSA Standard 23.1-00 depending on the exposure of the component.

Under Item S.9, the Contractor shall supply, deposit and compact mass concrete at locations necessary for the construction of the West Approach Slab at the Intake Area (Section C) as shown on the Drawing 2.

Under Item S.10**,** the Contractor shall supply, deposit tremie concrete at the following locations:

1. Areas necessary for the base of the both East and West Approach Walls construction that are not in dry condition.
2. Areas between the Existing gravity wall and the East Approach Wall.
3. Head and tip of the new Acceleration Wall.

Prior to the placement of mass concrete, the area shall be cleaned of silt and debris. When the mass concrete area cannot be kept water free, procedures for underwater concreting shall be established to include concrete mix design, appropriate admixtures, placement schemes,

inspection plan, and concrete sampling plan to ensure competent concrete is achieved. When the concrete surface has been brought above the water line, regular concrete shall be placed in the dry after all laitance has been removed from the surface of the concrete.

Under Item S.11, the Contractor shall supply, place concrete for the following work as shown on the Drawings:

1. In-fill between the turning area at the West Approach Wall.
2. Concrete cover slab at both East and West Approach Walls, as well as New Acceleration Wall.
3. Extensions at Piers 1 and 2.

The Contractor is also responsible for design of any temporary shoring, and the steel casing with associated strut systems as required for the bridging components and the nose section of the accelerating wall.

Construction activities must not hinder the efficient movement of ice in the vicinity of the INCW.

Work also includes the provision for construction of expansion joints as well as filling, caulking and other accessories shown, sandblasting and roughening of existing concrete surfaces and application of bonding agent where necessary for the proper bonding of new concrete with existing concrete. Compressible filler over existing deck, vent and weep holes at the pier extensions are also part of this item and will not be measured separately. The dowels are not part of this item and will be measured elsewhere.

All concrete work and field testing shall conform to the requirements of CSA Standard A23.1-00 and A23.2-00.

The Contractor shall supply the details of the proposed mix, test results of trial batches of the proposed mix, and bagged samples of the mix constituents for testing by the Region. No concrete shall be placed until the proposed mix has been proven by test results and written authorization to proceed has been issued by the Commissioner.

Calcium chloride shall not be used in the mix under any circumstance. Construction joints other than those shown on the Contract Drawings are not permitted. Construction joints shall be formed as follows:

- Joints shall be neat and properly formed and well bonded
- The exposed face of the concrete at construction joints shall be formed and prepared as shown on the Contract Drawings.
- All faces shall be cleaned prior to placing concrete or cement paste so that all dirt, grease, dust or debris is removed. An excessively rough concrete surface shall not be permitted.
- The surface film laitance and mortar shall be completely removed from the joint face of the hardened concrete to present a clear, sound concrete face that has the aggregate particles exposed.

- After completion of the above preparation, the joint face of the hardened concrete shall be thoroughly wetted (free standing water will not be permitted) and covered with a 10 mm thick brush coating of neat cement paste (1 part cement, 1 part sand and water) immediately before placing fresh concrete.

All dust and loose particles shall be removed from inside the forms using compressed air just prior to placing of concrete. Any surface against which concrete is to be placed shall be pre-wetted just prior to placing the concrete. No standing water shall be permitted in the formwork.

Concrete shall not be placed until all reinforcement and formwork has been inspected by the Commissioner. Access for such inspection shall be provided by the Contractor.

Concrete shall be cured by covering exposed, fresh concrete with at least one layer of wet burlap covered with opaque white plastic sheets for a period of at least seven (7) days. The white filter fabric shall be kept continuously soaked with clean water. Strips of wet burlap shall overlap by at least 150 millimetres. Plastic sheets shall be at least 4 mil thick and shall be of standard commercial quality, free from snags, tears or other flaws in order to provide a tough, pliable moisture barrier. The plastic sheets shall overlap by a minimum of 300 mm and shall be held in place against displacement by wind.

Removal of the forms shall be subject to the following conditions:

- Forms shall not be removed until the concrete has reached a strength of 20 MPa
- Joint faces of hardened and fresh concrete shall be prepared in accordance with the requirements as specified elsewhere in the contract

The Contractor shall remove and dispose of off site all formwork at the completion of the work.

Cold and hot weather concrete shall be in accordance with A23.1-00. No additional payment will be made for cold and hot weather concrete operations.

Formwork and falsework are deemed to be included in the concrete items and will not be measured for payment.

Concrete shall conform to the requirements of A23.1-00 except as noted in this special provision. The Contractor will be responsible for the concrete mix design as specified in CSA Standard A23.1-00 and for providing concrete of the required properties.

When submitting the mix proportions, the Contractor shall specify the source of the coarse and fine aggregate and the manufacturer of the cement.

Structure	Intake- mass concrete, In-fill	Intake – Pier Extensions	Intake - Concrete Cover Slab	Intake – Precast Modules	concrete subbase - tremie concrete
Dimension (thickness)	refer to drawings	refer to drawings	0.5 m to 0.8 m	refer to drawings	refer to drawings

strain		freezing and thawing severe sulphate attack (C.S.A.)	freezing and thawing severe sulphate attack (C.S.A.)	freezing and thawing	freezing and thawing severe sulphate attack (C.S.A.)	no special requirements
Additional requirements		water tight concrete structure				
Aggregates	coarse aggregates, form	rounded or cubic crushed	rounded or cubic crushed	rounded or cubic crushed	rounded or cubic crushed	
	range of size	0 / 32 mm	0 / 75 mm	0 / 32 mm	0 / 32 mm	0 / 20 mm
Cement	Type	portland cement	portland cement	portland cement	portland cement	portland cement
	Type	10	10	10	10SF	10
	Description	sulphate resitent, low heat of hydratation property	sulphate resitent, low heat of hydratation property	low heat property	sulphate resitent, low heat of hydratation property	no special requirements
	recommended volume	270 kg / m^3	270 kg / m^3	270 kg / m^3	270 kg / m^3	400 kg / m^3
Cementing materials	type	fly ash	fly ash	fly ash	fly ash	
	Specifiaction acc. to CSA 23.1	F	F	F	F	
	recommended volume	50 kg / m^3	50 kg / m^3	30 kg / m^3	50 kg / m^3	
Water	type	potable	potable	potable	potable	potable
	water / cement ratio (maximum)	0.45	0.45	0.55	0.45	<0.60
Admixtures	type	water reducing admixtures, plasticizer				
Requirements (minimum values)	release strength					
	28 days strength	25 MPa	35 MPa	30 MPa	50 MPa	
	final strength (reached after 90 days)					25 MPa
	Youngs modulus	32 GPa	32 GPa	32 GPa	32 GPa	
	air content acc. to CSA 23.1	3 - 6 %	3 - 6 %	3 - 6 %	3 - 6 %	

water tightness	water infiltration depth acc. to German Standard 1048 testing method	30 mm	30 mm	30 mm	30 mm	
Exposure Class		F-1	F-1	F-1	F-1	N

S.12 CONCRETE – PRECAST CONCRETE

The requirements of OPSS 919 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall fabricate, supply, deliver, store and install precast concrete units to lines and level and construction details at the Intake Area as shown on the drawings. The work includes:

- 4500 mm x 4270 mm precast concrete box units for the East and West Approach Walls including special units as specified on the Drawings.
- 6000 mm x 2000 mm precast concrete box units for the Acceleration Wall.

Shop drawings shall be submitted within 6 weeks from Contract Commencement which shall include detailed calculations, reinforcing steel schedule, concrete mix design and trial mix result, location of concrete plant and unit manufacturing plant, curing information, storage and transportation details. A plan showing the methodology of lifting the precast units into position shall also be submitted. No manufacturing of the units shall commence until approval to proceed is issued by the Commissioner. The Contractor shall allow a review period of 4 weeks by the Commissioner for the initial submission, and 10 working days for subsequent revisions.

The Contractor shall also place smooth bar at corners for docking as shown on the Contract Drawings. Other features such as grouting, joint fillers, and other as shown on the drawings, shall be deemed to be included in the lump sum bids for this item.

Before the work commencement of the Acceleration Wall and Approach Walls construction, the Contractor shall carry out field survey including hydrographic surveys.

for the alignment of the walls for every 5 m interval to verify all dimensions and position for the placement of Walls.

S.13 REINFORCEMENT – UNCOATED REINFORCEMENT

The requirements of OPSS 905 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall supply and place all uncoated reinforcing steel including dowels as shown on the Contract drawings. Reinforcement shall be Grade 400 unless otherwise specified.

All reinforcing steel shall be conform to CAN/CSA Standard G30.18M92 (R1998).

The Contractor shall be responsible for the preparation of the bar schedule and shall submit the bar schedule for approval to the Commissioner at least 14 days prior to ordering the coated reinforcing steel. Fabrication shall not commence until the Contractor has received the Commissioner's written approval.

S.14 DOWELS INTO CONCRETE

This item specifically refers to the provision and installation of uncoated dowels, for the construction of the pier extensions, approach walls and acceleration wall at the Intake Areas.

Included in the construction of the dowels are the drilling of correct diameter holes into existing concrete mass to the depths shown, supply and placement of approved epoxy grouts, and the supply and installation of steel dowels.

Reinforcing steel used for the dowels are deemed to be included in this items and will not be measured under reinforcing steel items. Additionally, no separate payment will be made for the drilling and grouting for these dowels.

Prior to the construction the Contractor shall submit for the Commissioner's approval literature and samples of the proposed epoxy grout to be used for the anchoring of the dowels. The materials shall be one selected from the list of Designated Source of Materials of the MTO. All work in this item shall meet the requirements of OPSS No. 904 and 905. All reinforcing steel shall be conform to CAN/CSA Standard G30.18M92 (R1998).

Dowels shall be free from dirt, oil or paint, and shall be installed according to the provisions of OPSS 904.07.10. Drilling though existing reinforcing steel for the installation of dowels is not permitted. Positions of dowels may be slightly shifted to adjust for physical difficulties.

All dowels shall be capable of developing the full yield strength of the steel after installation and cured. The Commissioner will carry out pull-out test to confirm the capacity of each dowel. All dowels which fail to meet the requirement shall be reinstalled at the Contractor's expenses.

S.15 DOWELS INTO ROCK

This item specifically refers to the provision and installation of rock reinforcing dowels, for the construction of the pier extensions at the Intake Areas as shown on the Drawings.

Included in the construction of the dowels are the coring of correct diameter holes into existing concrete mass to the depths shown, supply and placement of approved epoxy grouts, and the supply and installation of steel dowels.

All dowels in rock shall be installed using either cementitious or resin-type grout with procedures recommended by the manufacturer.

Reinforcing steel (Dywidag bars) used for the dowels are deemed to be included in this item and will not be measured under reinforcing steel items. Additionally, no separate payment will be made for the coring and grouting for these dowels.

Prior to the construction the Contractor shall submit for the Commissioner's approval literature and samples of the proposed epoxy grout to be used for the anchoring of the dowels. The materials shall be one selected from the list of Designated Source of Materials of the MTO. All work in this item shall meet the requirements of OPSS No. 904 and 905. All reinforcing steel shall be conform to CAN/CSA Standard G30.18M92 (R1998).

Protect rock reinforcing dowels at all times from damage and corrosion. Corrosion, pitting or damage to the dowel may be cause for rejection. Damage includes, but is not limited to, abrasions, cuts, nicks, welds, and weld splatter. Dowels shall be free from dirt, oil or paint, and shall be installed according to the provisions of OPSS 904.07.10. Additionally, all rock reinforcing dowels, accessories, and hardware shall have an approved corrosion protection coating. Core holes to the diameter and depth recommended by the manufacturer. Unless otherwise directed, align core holes normal to the rock face or as specified. Positions of dowels may be slightly shifted to adjust for physical difficulties.

All dowels shall be capable of developing the full yield strength of the steel after installation and cured. The Commissioner will carry out pull-out test to confirm the capacity of each dowel. All dowels which fail to meet the requirement shall be reinstalled at the Contractor's expenses.

S.16 REINFORCEMENT – MECHANICAL COUPLERS

Under this item, the Contractor shall supply and install mechanical couplers to connect reinforcing steel at the West Approach Wall (Section C) as well as at the Pier extension for the rock dowels as indicated on the contract drawings. Mechanical couplers required arising from the Contractor's chosen method of construction or fabrication mistakes shall be borne by the Contractor. All work in this item shall meet the requirements of OPSS No. 905. All reinforcing steel shall be conform to CAN/CSA Standard G30.18M92 (R1998).

All mechanical couplers shall be of approved type by the Ministry of Transportation and named in the list of "Designated Source of Materials" and shall be appropriate for the type of construction encountered in this project.

S.17 SEALING FOR DOWNSTREAM CLOSURE

Under this item, the Contractor shall supply, install and maintain the sealing system at the downstream closure between Pier 1 and Pier 2 at the intake area during the construction as shown on the Drawings. This item also includes removal of the sealing system upon the completion of the work with the approval of the Commissioner.

S.18 GEOTEXTILE

Under this item, the Contractor shall supply and place geotextile behind the East and West Approach Walls at the Intake Location as well as on the overburden slopes for the outlet channel as shown on the Drawings. Placement of the geotextile shall be limited to the length as shown on the Section C of Drawing 1. This item also includes surface preparation for existing ground necessary for the proper installation of the geotextile.

Geotextile shall be Class 1, non-woven geotextile FOS 75-150 μm or approved equal. All work in this item shall meet the requirements of OPSS No. 1860.

S.19 MISCELLANEOUS STRUCTURAL STEEL

Under this item, the Contractor shall fabricate, deliver, and install miscellaneous structural steel including, but not limited to:

1. Steel nosing at the Pier 2.
2. Steel cover at the Piers 1 and 2.
3. Steel casing at end panel of new acceleration wall.
4. Access opening floor door with including ladder and safety post at Piers 1 and 2.

The work shall be done using structural steel Grade 400 and in accordance with the requirement of OPSS 906.

All steel shall be atmosphere corrosion resistant weldable steel, CSA G40.21-350A and hot-dip galvanizing shall be to CSA G164-92, OPSS 911 and double-dipped. A company certified in Division 1 or Division 2 of CSA Standard W47.1-92 shall complete all welding. All field welds to galvanized steel shall be painted with two coats of zinc rich paint.

S.20 ARMORING BOULDERS

The requirements of OPSS 511 shall apply to this tender item except as modified herein.

Under this item, the Contractor shall supply and place armouring boulders at the ice protection/deflection groyne as shown on the drawings.

The size of the boulder shall be 2 m x 2 m x 1m. Boulders shall consist of round and natural shape. It shall consists of clean rock fragments and shall be free from organic material.

S.21 SHOTCRETING

Under this item, the Contractor shall provide and place shotcreting at the Outlet area to stabilize the rock above the elevation 165.5.

Shotcrete shall be produced by wet mix process achieving a minimum compressive strength of 18 MPa in 7 days and 30MPa in 28 days. Shotcrete will be accepted based on 28-days strength. The Contractor shall submit a proposal for expediting the work. The contract's proposal shall detail methods to ensure that the minimum required 28-days strength is attained.

Provide equipment capable of delivering the premixed material accurately, uniformly and continuously through the delivery hose. Follow recommendations of the equipment manufacturer on they type and size of nozzle to be used and on cleaning, inspection and maintenance of the equipment. Ready mixed shorcrete shall be delivered in transit mixers.

Provide undisturbed gun finish of shotcrete as applied from nozzle without hand finishing. A clean area at base of each lift is required to ensure good bonding interface between lifts.

After each stage of cut, in anticipation of shotcreting, clean surfaces of all loose material, mud, rebound from previously placed shotcrete and other foreign matter that will prevent bonding of shotcrete shall be removed from the cut surface and dampen surface before shorcreting.

The shotcrete shall be applied from the bottom up to prevent accumulation of rebound shotcrete deposited on the surface still to be covered. Shotcrete shall emerge from the nozzle in a steady uninterrupted flow.

PR-00-5001
Steel Ribs

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the steel ribs forming part of the support measures for the tunnel excavated at the Niagara Tunnel Facility Project

1.2 Range of Technical Specification Application

This TS is a bid and contract document used in the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of steel ribs incl. all the components and the entire equipment to the site

b) installation and fixing of steel ribs

c) quality control for material and workmanship.

The Scope of Work is defined for the crown and the sidewalls of the main tunnel during the excavation and support period.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 ROLLED STEEL RIBS

Steel ribs shall be installed as a means of immediate support at the working face over the entire length of the last excavation advance to prevent spalling, to improve the load distribution and to enhance the effectiveness of the rock dowels.

The steel ribs are produced of rolled steel and delivered in segments. They will be assembled on site to the complete arch required. Each steel rib segment has welded steel plates at both its ends for connection with others. The segments are prefabricated.

1.3.2 CONNECTIONS

The steel rib segments will be connected on site to their complete form. The connection will be done by linking the steel plates at the ends of the segments with screws or bolts. The type of connection, hinge or stiff, has to be arranged in line with the design. Bolts have to be secured against dropout by split pins.

Hinge connections shall be capable of transferring the full section axial compressive forces and shear forces. The adequacy of connections may be demonstrated by calculation or by load test.

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Stiff connections shall be capable of resisting the full sectional bending moments, axial forces (tension and compression) and shear forces. The adequacy of these and other more complex connections shall be proven by testing.

The connections shall be designed to allow complete covering with shotcrete or surrounding by concrete, so that no voided areas are created behind the connections.

1.3.3 WELDING

Welding is used to connect the steel segments. The welded segments shall be of the same steel type and quality. The welded connections shall satisfy the same requirements as the original steel profiles. All welding works shall be carried out in accordance with the corresponding standards in force.

Welding on site, in the tunnel should be avoided due to the danger of fire.

1.3.4 FIXING

Steel rib supports shall be fixed to the excavation surface with rock dowels, or shall be supported by shim wedges on sound undisturbed rock or soil base. Timber wedges or blocks shall not be permanently incorporated in the lining.

Adjacent ribs shall be tied and braced as necessary for stability.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to carry out their work in a safe and proper way.

2. Materials

Steel ribs are made of rolled steel according to CSA G 40.20 and G 40.21. Rolled steel ribs and attachments thereto, ties, spreaders and collar braces shall consist of weldable structural steel and shall have a minimum characteristic strength of 240 MPa.

The steel ribs shall be cold worked to the required radii. The rolled profiles shall comply with the required dimensions and masses shown on the drawings and shall be within a tolerance of 2.5 % of the mass per unit length and within a tolerance of + 3 mm and - 1 mm of the required depth. The shape of the rib shall conform to the true design templates at the ends of the segments, while intermediate points may depart by up to 10 mm from the true templates, provided that no point shall depart more than 3 mm from a template section 1 m long.

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The steel ribs shall be free of cracks and flaws and shall be well finished, without rough or jagged edges or other imperfections. The ends shall be clean, smooth and, where necessary, dressed before despatch.

The blocking shall be hardwood unless otherwise specified. Foot plates shall have adequate bearing capacity.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

4. Transport

All components of the steel ribs shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

The Contractor shall present an organisational chart and time schedule of the works to the Engineer for approval. These documents shall give due consideration to all conditions accompanying the execution of the works.

The type, size and spacing of the rolled steel ribs shall be as shown on the Drawings. The steel ribs shall be erected within the specified tolerances and shall be firmly set off the rock or the shotcrete by spacers arranged around the periphery of the rib as shown on the Drawings.

Fully detailed fabrication drawings and specifications for all steel rib components shall be prepared prior to any manufacturing. The manufacturing process shall be in accordance with these drawings and specifications.

At the time the steel ribs are encased in shotcrete or concrete, they shall be free of mud, oil, paint, concrete retarders, loose rust, loose mill scale, grease or any other substance which could adversely affect the steel or concrete chemically, or reduce the bond.
Rust can be tolerated subject to approval by the Engineer.

Each rib set, when assembled with the connections fully and tightly bolted, shall lie within $\pm$ 25 mm of a true plane. The ribs shall be erected within $\pm$ 150 mm of the positions shown on the drawings unless otherwise approved by the Engineer and shall not deviate by more than $\pm$ 50 mm from the profiles shown on the drawings.

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6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

To achieve a sufficient quality of the installed product, suitability tests and work tests have to be carried out for the individual components as well as for the installed products.

The strength of the steel ribs shall be demonstrated by calculations or by load tests. Where tests are necessary, they shall be performed in accordance with the test procedures approved by the Engineer.

Tests shall be in conformity with the following requirements:

(a) The test piece shall consist of a straight steel rib with a length of 4.5 m restrained by a pinned support at one end, and a pinned roller support at the other end.

(b) A uniformly distributed vertical loading of 5.0 kN/m shall be applied over the entire length of the girder. At the same time a horizontal compressive load of 125 kN shall be applied at the roller support. The rib shall not collapse under the combined loading.

Where the strength of the ribs is demonstrated by calculation, an ultimate limit state check shall be carried out using the loads specified in Subchapter 3 above with a partial safety factor for loads of 1.0. The partial safety factor for material strength shall be 1.15.

7. Units

The quantity survey unit of the steel ribs shall be ton. The numbers and types of the steel ribs depend on the individual excavation and the support type executed. The respective numbers and types are documented in the corresponding drawings.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification,
- other written statements by the Engineer commenting on the execution of the works.

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8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

CSA G 40.20/ G 40.21- 98	General requirements for rolled or welded structural quality steel / structural quality steel

American Standards

ASTM Standard A 992 / A 992M	Standard specification for steel for structural shapes for use in building framing

German Standards

DIN 17100	Common structural steel, quality of material
DIN 4100	Connections in steelworks

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PR-00-5002
Reinforcement

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of reinforcement, wire mesh and reinforcement bars forming part of the support measures for the Diversion Tunnel, as well as for the pits of the intake and outlet structures at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of reinforcement incl. all components and entire equipment to the site

b) installation and fixing of wire mesh and reinforcement bars,

c) quality control for material and workmanship.

The Scope of Work is defined for the crown and the sidewalls of the main tunnel during the excavation and support period.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 WIRE MESH

The wire mesh is used for:

- reinforcement required in the shotcrete lining
- first protection against breakout (in combination with steel ribs or rock dowels)
- improvement of shotcrete's composite behaviour

The wire mesh shall have a square pitch pattern of 100 mm in both directions. The wire diameter shall range between 5 mm and 8 mm. Standard sizes shall be preferred. If the required reinforcement area can not be covered with standard sizes, the above mentioned criteria have to be considered. Twin bars in the bearing direction are admissible.

1.3.2 REINFORCEMENT BARS

Reinforcement bars are generally used to connect the reinforcement of the individual excavation stages (starter bars). Adequate measures have to be taken to ensure that the bars will be protected against damage during the excavation of the next phase.

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Bars can also be added to the wire mesh in case the required reinforcement exceeds the wire mesh dimensions locally.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to carry out their work in a safe and proper way.

2. Materials

The wire mesh should be of high-tensile steel quality with a characteristic strength of 500 MPa and a yield strength of 550 MPa. The steel should be classified as weldable.

The reinforcement bars should be of high-tensile steel quality with a characteristic strength of 500 MPa and a yield strength of 550 MPa. The steel should be classified as weldable.

If lower quality steel is used (e. g. characteristic strength = 420 MPa, yield strength = 500 MPa), the conversion of the required reinforcement shall be made with the ratio of the characteristic strength.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

4. Transport

All components of the reinforcement shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

The Contractor shall present an organisational chart and time schedule of the works to the Engineer for approval. These documents shall give due consideration to all conditions accompanying the execution of the works.

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The wire mesh shall be installed in such a way that it follows the contours of the excavated and sealed excavation surface as closely as possible. The spacing between the excavation surface and the wire mesh should not exceed 10 cm.

The wire mesh shall be placed firmly, shall securely be held in position and shall be cleaned from rebound before shotcreting. It shall be fastened with short bolts, reinforcement bars, length approx. 30 cm, which are drilled and fixed in the surrounding rock mass, or supported by installed steel ribs.

Larger overbreak shall be filled with shotcrete before wire mesh is installed.

The wire mesh shall be installed in the longest practical length. Adjoining pieces shall be overlapping:

Radial overlap: minimum 30 cm.

Longitudinal overlap: minimum 15 cm.

The steel bars, used as connection bars between the heading and bench reinforcement shall be covered and protected against damage in the case of bench excavation.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

The correct construction, in accordance with the corresponding drawings, specifications and method statements shall be checked by visual inspection.

7. Units

The quantity survey unit of the reinforcement (wire mesh and steel bars) shall be ton (weight).

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

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- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification,
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

CSA A23.1-94	Concrete materials and methods of concrete constructions

German Standards

DIN 1045 (EC 2)	Concrete structures: design and construction

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PR-00-5003
Rock Dowels

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the rock dowels forming part of the support measures for the tunnel excavation and other cavities or pits at the Niagara Tunnel Facility Project

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of rock dowels with all components and equipment to the site

b) installation of rock dowels,

c) quality control for workmanship and material.

The Scope of Work is defined for the crown and the sidewalls of the excavation of the main tunnel and for the excavation of pits for the corresponding adjacent structures (e. g. intake, outlet).

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 ROCK DOWELS SWELLEX TYPE OR SIMILAR

This type of rock dowel is manufactured from a mechanically reshaped steel tube. Bushings are pressed onto the ends, which are sealed through welding. The lower bushing has a flange to hold a face plate in place. High-pressure water (300 bar) is injected into the steel tube through a hole in the lower bushing. This causes the steel tube to expand and to adjust to the irregularities of the drilled hole. A 200 mm long sleeve tube made of steel prevents the dowel from swelling at the drillhole mount. As the swelling process occurs, the lower part of the steel tube shortens, pulling the face plate firmly against the rock face. The water pressure is released after installation and the water is allowed to drain out of the expanded steel tube. The drillhole diameter has to be adjusted to suit the size of the rock dowel.

1.3.2 ROCK DOWELS SN TYPE – RESIN OR RESIN GROUTED

This type of rock dowel is an untensioned rod inserted into a drilled hole and grouted along its entire length using cement grout and resin capsules or resin capsules exclusive. The rock dowel consists of a high-yield steel deformed ribbed bar with cut or rolled threads at one end, a face plate, shim plates and a nut.

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1.3.3 ROCK DOWELS SELF-DRILLING TYPE - GROUTED

This type of dowel is equipped with a drill bit on one end and is made from high tensile steel tubes. The rock dowel is directly drilled in the borehole and afterwards grouted "under pressure" through the tube to the end of the rod and on the outside back through the borehole. These dowels shall be used in very weak soil and rock formations. If the required dowel length is longer than the diameter of the tunnel, couplings shall be used to adjust the length of the dowel.

1.3.4 GENERAL WORK REQUIREMENTS

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to carry out their work in a safe and proper way.

2. Materials

1. A detailed statement of the types and sources of manufacture of the rock dowels proposed for use in the works, shall be prepared.
2. The characteristic strength / yield strength of the steel should not be less than 420 / 500 MPa. The steel plates, washers and nuts should have the corresponding quality and shall comply with the requirements of the corresponding standards.
3. The characteristic load F of rock dowels is defined with the bearing capacity of the dowel at failure. The safety against failure should be 1.3.

   The design load is defined with:
   100 kN for dowels with a length up to 4 m (type I)
   200 kN for dowels with a length of more then 4 m (type II)
4. For rock dowels of the SN type, the minimum steel cross-section should not be smaller than:

   250 mm^2 for rock dowels - type I
   450 mm^2 for rock dowels - type II
5. Face plates shall be of dished shape in steel and shall have a hemispherical seating and a centralized slot to suit the dimensions of the different rock dowels. The dimensions of the face plates shall be (length / thickness)

Ø 60 / 6 [mm]	for rock dowels of the Swellex type
100 / 100 / 6 [mm]	for rock dowels of the SN type (type I)
150 / 150 / 8 [mm]	for rock dowels of the SN type (type II)

6. Cement for cement grout shall be ordinary Portland or rapid hardening Portland cement.

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7. Aggregates for cement grout shall contain high-quality quartz sand with a particle size of up to 1 mm.
8. Cement grout shall achieve such a characteristic strength that the dowel will be able to bear 40% of its capacity after 6 h and 100% of its capacity after 12 h.
9. Admixtures shall be plasticizers and expanding agents. The admixtures used shall have no detrimental effect on the performance of the rock dowels. Admixtures containing chlorides shall not be used.
10. Resin capsules shall be of the fast setting type conforming to the manufacturer's specification and compatible with the cement grout, in case they are used as a hybrid doweling system.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

The mortar pump must be capable of producing a minimum pressure of 3 MPa at its mouth.

4. Transport

All components of the dowels shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

The Contractor shall present an organisation chart and time schedule of the works to the Engineer for approval. These documents shall give due consideration to all conditions accompanying the execution of the works.

In addition, further issues have to be considered:

1) The rock dowels shall be installed in the positions, the sequence and at the spacing shown on the drawings. The exact locations of the dowels shall be adapted to suit the prevailing geological conditions. When necessary to ensure the safety of the works, rock dowels shall be installed at and immediately behind the excavation face.
2) The holes for the installation of the rock dowels shall be drilled into the ground to the lengths indicated or stated on the drawings and shall be inclined in such a way that the dowels are generally installed perpendicular to the designed surface of the excavation. The holes shall be drilled with an accuracy of ± 15°.

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3) The holes shall be drilled using sharp bits to produce straight holes of the required length. On completion of each drillhole and prior to the installation of each dowel, the drillholes shall be cleaned removing debris. In clay formations, sensitive to water, flushing the drillhole with water shall be avoided (auger drilling technique). The drillhole diameter shall be within the range recommended by the rock dowel manufacturer to match the particular rock dowel diameter and any couplers required for extending the dowel. It shall be not less than 2 times the rod diameter.

4) The installation shall be carried out in accordance with the rock dowel manufacturer's recommendations, generally adopting the following procedure:

   (a) A regular surface, normal to the drillhole, shall be provided to seat the face plate. Some preparation of the ground or shotcrete surface in the vicinity of the drillhole / dowel location may be necessary, involving trimming local surface irregularities or forming pads of quick-setting mortar. Where mortar pads are required they shall be larger than the face plates and the edges shall be chamfered at 45°.

   (b) The dowels shall be installed in accordance with the drawings and site instructions given by the Engineer. 24 hours after installation, nuts shall be screwed tightly so that the face plates are held firmly against the surface using hand wrenches.

   (c) With cement grouted dowels, the grouting material shall be injected starting from the furthest end of the drilled hole such that the dowel rod is completely encased in grout. Tremie and vent pipes shall be provided as necessary for grouting and the open ends of holes shall be sealed to prevent grout loss. Any grout on the exposed threads of the dowels shall be cleaned off.

   (d) The cement mortar grout shall be chosen to be of such consistency that it does not flow out of the borehole even if the borehole is vertical upward. Dowels installed in overhead positions shall be supported where necessary until the grout has set.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use. To achieve a sufficient quality of the installed product, suitability tests and work tests have to be carried out for the individual components as well as for the installed products.

6.1 Testing of Components

6.1.1 TESTING OF CEMENT GROUT

Sets of six cubes of cement grout shall be taken once every month when installation of grouted rock dowels is in progress. Sampling, preparation, curing and testing shall be in accordance with EN 196-1.

Half of the cubes shall be tested at 1 day and the remainder at 28 days. The average compressive strength determined from any group of four tests shall be at least the specified characteristic strength.

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The strength determined from any single test result shall not be less than the specified characteristic strength minus:

1 N/mm^2 for cement grout tested after 1 day

3 N/mm^2 for cement grout tested after 28 days

6.1.2 TESTING OF THREADED BARS

Tensile tests shall be carried out on a number of steel dowel bars, covering the threaded length of each batch of bars. At least three bars in every 1000 shall be tested to destruction. Tests may be carried out at the manufacturer's works or on site. Test certificates shall be provided.

6.2 Trials and Testing of Dowels

6.2.1 SUITABILITY TESTS

1. Prior to the installation of the dowels, 10 trial rock dowels of each type of dowel to be used in the works shall be installed and tested. 5 of the trial Swellex-type rock dowels shall be tested immediately at 60 % of the characteristic load and 5 of the resin-grouted rock dowels shall be tested after 1 hour. The remaining dowels shall be tested at the characteristic load between 3 and 21 days after installation.
2. Trial dowels shall be installed in similar rock conditions to those which are likely to be encountered during installation in the works and shall be in accordance with this Specification.
3. Additional rock dowel tests shall be carried out if the procedures adopted for the installation of the dowels do not match those adopted for the preconstruction suitability tests. If the test results on dowels used in the works when compared with the results of the original trial tests show inadequacies in the load-carrying capacity, a detailed investigation and further tests to identify and rectify the inadequacies shall be carried out.

6.2.2 WORKS TESTS

1. Five percent of the installed dowels shall be tested to the characteristic load between 3 and 21 days after installation. The quality control criteria are met, if the design load is reached within a maximum deformation (tension) of about 10 mm.

   The proportion of the dowels tested to characteristic load may be varied, if consistent test results were obtained for the previous 50 dowels tested, subject to approval by the Engineer.
2. The in-situ tests shall in general be carried out by pull-out tests or in accordance with a method for determining the strength of a rock dowel proposed by the Contractor.
3. The rock dowels shall be deemed to be acceptable provided the working load is sustained for at least 10 minutes.

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6.2.3 EVALUATION

Records shall be kept for each dowel tested in accordance with the procedures agreed with the Engineer, and copies of all records shall be maintained on site after installation of the dowel or completion of the testing, as appropriate.

The number of dowels which do not reach the quality criteria is extrapolated to the total number of the testing cycle. The Engineer together with the Contractor will have to decide on an additional installation of dowels or adequate substitute measures.

7. Units

The quantity survey unit of the dowels shall be piece. The numbers and types of dowels depend on the individual excavation and the support type executed. The respective numbers and types are documented in the corresponding drawings.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

9. Applicable Regulations

9.1 Standards

Canadian Standards

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German Standards	
DIN EN 196-01	Testing of cement, testing of the strength
DIN 21521	Rock dowels for mining and tunneling
DIN 21522	Plates for rock dowels for mining and tunnelling

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PR-00-5004
Shotcrete

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the shotcrete lining forming part of the support measures for the excavated tunnel and other cavities or pits at the Niagara Tunnel Facility Project

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment to the site

b) execution of shotcrete works

c) quality control for material and workmanship.

The Scope of Work is defined for the crown, the sidewalls and the invert of the excavated main tunnel and for the excavation and support of pits for the corresponding adjacent structures (e. g. intake, outlet).

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force. Special definitions shall be presented below.

1.3.1 SHOTCRETE

Shotcrete is a mixture of cement, aggregate and water, which may contain admixtures, projected from a nozzle into place to produce a dense homogeneous mass.

1.3.2 DRY METHOD

A method of producing shotcrete, in which a mixture of cement, aggregates, and admixtures (if required) is weight batched, thoroughly mixed in a dry condition and fed into a purpose-made machine in which the mixture is pressurised, metered into a dry air stream and conveyed through hoses or pipes to a nozzle, where water as a spray is introduced into the mix which is projected without interruption into place.

1.3.3 WET METHOD

A method of producing shotcrete, in which cement and aggregates are weight batched and mixed with water at the shotcreting location or in mixer trucks prior to being pumped through a

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pipeline to a nozzle where air, and admixtures are injected - if necessary - and the mix is projected into place without interruption.

1.3.4 LAYER

A term used for a discrete thickness of shotcrete built up from a number of passes of the nozzle and allowed to set.

1.3.5 REBOUND

A term used for all the material having passed through the nozzle which does not adhere to the surface on which shotcrete is being applied.

1.3.6 BASE CONCRETE

A term used for all the concrete of a design intended for use in shotcrete, but produced without admixtures.

1.3.7 CEMENT AND LATENT HYDRAULIC BINDERS (LHB)

Hydraulic cement is an active hydraulic binder formed by grinding clinker.

Latent hydraulic binders are added to the cement in two forms:

- as hydraulic binder, manufactured by a controlled process in which Portland cement clinker or Portland cement is combined in specified proportions with a latent hydraulic binder consisting of pulverized fuel ash (pfa).
- as hydraulic binder, manufactured in the concrete mixer by combining Portland cement with a latent hydraulic binder consisting of pulverized fuel ash and/or silica fume.

1.3.8 ADMIXTURES

A term used for materials which are added to the base concrete such as accelerators, plasticizers and retarders.

1.4 General Work Requirements

The Contractor shall be responsible for quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to carry out their work in a safe and proper way.

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2. Materials

2.1 Water

The water shall be clean and free of harmful matter in such quantities as would affect the properties of shotcrete in the plastic or hardened state.

2.2 Cement

It is of particular importance to use cement of uniform chemical composition and uniform fineness. The required characteristic values shall be approved by the Engineer. For the entire cement delivered, the manufacturer shall make the cement analyses and the standard test results available. Quality control measures are detailed below.

The cement shall comply with the following requirements:

- Only cement with a suitable fineness of grinding shall be used.
- Chrome content (Cr^{6+}): not more than 2 mg/kg.
- Fineness: not less than 340 m^2/kg.
- Bleeding: not more than 20 cm^3.

2.3 Aggregates

Aggregates shall comply with the following requirements:

The maximum particle size shall not exceed 11 mm.

Single size aggregates shall be combined in the proportions determined during the site trials.

Fine and coarse aggregates shall be clean. The grading shall remain within the acceptable range and wherever possible within the desired range according to the grading curve - Figure 1

- The coarse fraction of the aggregate shall not exhibit excessive fragmentation during delivery. The percentage of particles smaller than 0.075 m shall not exceed 3 %.
- Frozen aggregates shall not be used.
- For the dry method, at the time of mixing, the moisture content of the combined aggregates shall not exceed the saturated surface dry value by more than 5% unless otherwise approved by the Engineer.

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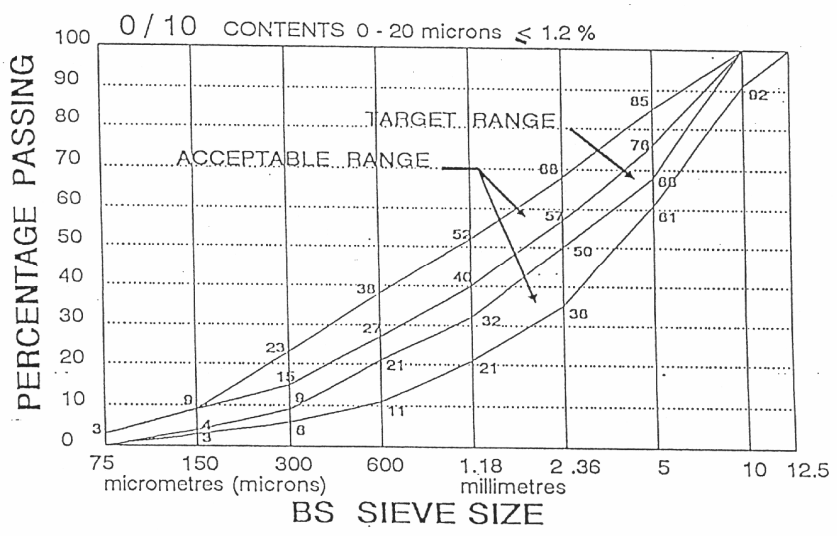

Figure 1 - Aggregates for Shotcrete - Grading Curve

2.4 Admixtures

2.4.1 GENERAL

The Engineer shall consider any potential for admixtures contaminating groundwater by giving or withholding approval for their use.

Retarding and plasticizing admixtures shall comply with ENV 206 or the corresponding Canadian Standards.

The compatibility of all admixtures with each other and with all other shotcrete constituents shall be verified during the site trials (reference is made to Subchapter 5.1.3, Shotcreting Trials)

2.4.2 ACCELERATORS

Only the minimum quantity of accelerators necessary shall be permitted in normal shotcreting operations, and this quantity shall be determined by trials as specified herein.

Testing of accelerators, with regard to setting time and strength decrease at a later age (28 days), shall take place in due time before commencement of shotcreting. For this purpose the method specified in Subchapter 6.2.2, Testing of Accelerators shall be used. All components - unless otherwise specified in the test method - shall be fully representative of those which will be used in the works.

If the sulphate (SO_4) content of the groundwater is more than 600 mg/l, the water-soluble aluminate in the accelerator shall not be greater than 0.6 % by weight of the cement content.

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The accelerators delivered to the site shall be tested in accordance with this Specification not less than once every two months for their reaction with the cement used (setting behaviour and strength decrease). In the case of accelerators in liquid form, their stability during storage shall be visually inspected and checked for crystallisation at similar intervals. Storage times and working temperature ranges shall be in accordance with the manufacturer's recommendations. The manufacturer's safety instructions shall be observed.

The required characteristic values and the regularity of delivery shall be agreed with the accelerator manufacturer before commencement of the shotcreting works.

Provided the characteristic strength requirements are met, accelerators can be dosed up to a maximum of:

10 % by weight of cement for accelerators in powdered form

9 % by weight of cement for accelerators in liquid form

15 % by weight of cement for water glass

2.4.3 PLASTICIZERS AND RETARDERS

With the wet method, plasticizers and retarders may be used to reduce the quantity of the mixing water and to improve the pumpability of the concrete. The effects of the plasticizers shall be determined in site trials. Shotcrete made by using plasticizers and retarders shall be checked regularly for setting time, water reduction and the development of strength as compared with the base concrete.

2.5 Shotcrete Requirements

Shotcrete shall be capable of being applied in layers of up to 150 mm in thickness with good adhesion to the ground or to the previous layer of shotcrete, with a good bond to the reinforcement and without sagging.

The characteristic strengths shall be:

0.5 MPa after 30 minutes

6 MPa after 24 hours

22 MPa after 28 days

Strength requirements shall be based on core samples taken in both directions from the test panel for site trials and on cores drilled in the direction of shotcrete application for quality tests.

Shotcrete shall be dense and homogeneous without segregation of aggregates or other visible imperfections.

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3. Equipment

3.1 General

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

All transport pipes consisting of hoses or pipes of uniform diameter that carry shotcrete ingredients shall be laid straight or in gentle curves and protected so that the flow of ingredients through them is not restricted.

The shotcrete machine shall be adjusted to suit the length of the pipe that carries the shotcrete mix. The equipment shall be leak-proof. Residual deposits of materials shall be removed after each usage.

The air and water supply system shall be capable of supplying the delivery machine and hose at the pressures and volumes recommended by the manufacturer of the machine. No air supply system shall be used that delivers air contaminated by oil.

The shotcreting equipment shall be capable of feeding materials at a regular rate and ejecting shotcrete from the nozzle at velocities that will allow adherence of the materials to the surface being shotcreted and compaction of those materials with a minimum of rebound and maximum adhesion and density.

The placing equipment shall be arranged in such a way that the nozzleman may use air and water in any combination to prepare raw surfaces or to clean completed works.

Equipment shall be provided to allow application of shotcrete to all surfaces with the nozzle at the distances from the work specified in Subchapter 5.3, Shotcrete Application.

A boom mounting (robo-jet) or similar device shall be provided for the spray nozzle for use in conditions where manual spraying is unsafe or otherwise, unsuitable or undesirable.

3.2 Equipment for Dry Method

The nozzle shall be capable of controlling the quantity of water to be added and of ensuring effective mixing of all shotcrete ingredients.

Admixtures in powder form shall be added by means of mechanical batching devices located at the shotcrete machine. The batching device shall be capable of ensuring continuous accurate batching of the admixture. If necessary, it shall be possible to adjust the batches mechanically or manually for a larger or smaller quantity of admixture. The batching devices shall be protected against water, dust and weather and shall be cleaned at regular intervals.

Liquid accelerators shall be metered uniformly into the water. If this is carried out by pumps adding a specified quantity of accelerator to the water, special screens shall be incorporated to eliminate foreign substances.

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3.3 Equipment for Wet Method

The equipment for the wet method shall be set up according to the recommendations of the manufacturer.

Pumping shall ensure a continuous conveyance of base concrete including any admixture except accelerators. The equipment shall incorporate a suitable metering device for liquid admixtures.

The accelerator shall be added close to the nozzle through an individual pipe.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

For shotcrete produced using the dry method, the dry mixture may be delivered by truck mixers or non-agitating transport units. The dry mixture shall be effectively protected against any influence exerted by weather.

For shotcrete produced using the wet method, the base concrete including any admixtures except accelerators shall be transported by any suitable means providing complete mixing during transportation such that segregation of the mix components is prevented. The mixture shall be effectively protected against any influence exerted by weather.

5. Workmanship

5.1 Site Trials

5.1.1 GENERAL

Site trials shall be started early enough to ensure that the required shotcrete mix is developed and all trials are completed satisfactorily by the time shotcreting commences in the works. Shotcreting shall not commence until the trials and the laboratory tests have been completed satisfactorily.

The site trials shall employ the equipment which will be used in the works and constituent materials shall be fully representative of those to be used in the works.

5.1.2 DEVELOPMENT OF MIX DESIGN

The design of the shotcrete mix shall be developed in two stages:

(a) Production of a suitable base concrete

(b) Production of shotcrete from the base concrete

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The target mean strength for the base concrete shall be such that the strength reduction specified in Subchapter 2 is not exceeded for shotcrete with accelerator and that the specified strengths are achieved.

5.1.3 SHOTCRETING TRIALS

1) A trial mix shall be designed and prepared with the constituent materials in the proportions proposed for use in the works. Sampling and testing procedures shall be in accordance with the relevant specifications. A clean dry mixer shall be used and the first batch shall be discarded.

2) From the trial mix, an experienced nozzleman shall prepare sufficient test panels. Each panel shall be at least 600 x 400 mm in size and shall be 200 mm thick. The panels shall be prepared by shotcreting into vertical rigid plywood boxes. The shotcrete in the panels shall adhere well to the backform, be properly compacted and exhibit no sagging.

3) Cylindrical test specimens shall be cored from each test panel and tested as listed below. Drilling and dimensions of test specimens shall be in accordance with the relevant specifications. The drilling of cores shall be performed at locations, avoiding areas of possible rebound.

4) Cores to be tested at different ages (1 day (24 hours) and 28 days) may come from the same panel. For each test at least one spare specimen shall be provided.

   (a) Compressive strength in spray direction after 1 and 28 days on 4 cores each. The test cores shall be 100 mm in diameter and 100 mm in length.

   (b) Compressive strength perpendicular to spray direction after 1 and 28 days on 4 cores each. The test cores shall be 100 mm in diameter and 100 mm in length.

5) Target workability values shall be determined for the wet method.

6) Each cored cylinder shall be provided with a reference mark and the date and time of shotcreting.

7) The panels shall be stored without disturbance at a temperature between 10°C and 25°C covered by a polythene sheet until the time of coring. Cores for 1 and 28 days compressive strength tests shall be obtained from the panels at the same day. The cores for 28 day strength test shall be stored in water.

8) The testing for compressive strength shall be in accordance with the relevant specifications.

9) Additional test panels shall be prepared as necessary to calibrate indirect test methods approved by the Engineer or his delegated personnel. For the purpose of calibration, a minimum of four tests shall be carried out at each age for each indirect test method and shotcrete mix.

10) The strength of shotcrete cores from test panels shall be acceptable if both the compressive strength results for samples with their axes parallel to the direction of spraying and the compressive strength results for samples with their axes perpendicular to the direction of spraying comply with the following requirements.

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(a) The average strength determined from the 4 cores from a particular trial shall be at least the specified characteristic strength.

(b) Any individual core strength result shall not be lower than the specified characteristic strength by more than:

2.0 MPa for 1 day strength
3.0 MPa for 28 day strength

11) The test results shall be passed to the Engineer or his delegated personnel responsible for the design of shotcrete structures.

12) The site trials shall be repeated if the source or quality of any of the materials or the mix proportions are changed.

5.1.4 PROFICIENCY OF OPERATIVES

The nozzleman shall have had previous experience in the application of shotcrete, or shall work under the immediate supervision of the foreman or instructor with such experience. Production shotcrete shall be applied only by nozzlemen who have successfully demonstrated their competence and their ability to produce shotcrete complying in all respects with this Specification and have been issued a certificate indicating their competence.

5.2 Batching and Mixing

The individual components for the production of shotcrete shall be measured by weight with an automatic batching device, except liquid admixtures. They may be measured by volume. The batching accuracy shall be within 3% for cement, water and aggregates and within 5% for admixtures. The method of batching used shall ensure that the accuracy can be easily checked. The accuracy shall be checked at least once a month.

Mixing shall be carried out in a mixer suitable for the efficient mixing and discharge of dry or wet batched materials as appropriate. Regular checks shall be made to ensure that complete mixing is consistently achieved.

The mixing time for the dry method shall be sufficient to produce complete mixing and shall be not less than 1 minute. The mixture shall be delivered by means of appropriate equipment and segregation shall be avoided.

Mixed materials for the dry method may be used up to 3 hours after the addition of cement, provided that the shotcrete can be applied satisfactorily. After this time, any unused material shall be discarded. Testing according to Subchapter 6.1.1, Strength Tests to verify the strength of shotcrete used more than 2 hours after batching will be required.

Accelerators for the dry method shall not be added until immediately prior to depositing the materials in the placing equipment, or, if in liquid form shall be accurately proportioned into the water supply at the shotcreting equipment. The mixed base concrete for the wet method shall be applied within three hours, depending on the type of cement used and the temperature of the base concrete and the atmosphere. Retarders may be used to extend the time for placing. Accelerators for the wet method shall be added immediately prior to the application of shotcrete at the application nozzle

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5.3 Shotcrete Application

Before the application of shotcrete, the excavated surfaces shall be cleaned with compressed air and, as far as the local conditions permit it, with an air-water mixture as necessary to remove all material which may prevent proper adhesion of the shotcrete to the ground surface. Loose rock shall be cleared from behind the steel mesh. The surface to receive shotcrete shall be damp and where possible without free water prior to the application of shotcrete.

Action shall be taken where necessary to control groundwater and to prevent that it affects the shotcrete lining adversely. Water inflows which might cause deterioration of the shotcrete, or prevent adherence, shall be diverted by channels, chases, pipes or other appropriate means to the invert or to the groundwater drainage system.

Where necessary, pressure relief holes shall be provided through the lining to ensure that no hydrostatic pressure develops behind the lining.

Shotcrete shall only be applied by experienced nozzlemen. The preferred distance between the nozzle and the surface being shotcreted shall be 2.0 m with the dry method and 1.5 m with the wet method. The nozzle shall, as a general rule, be held perpendicular to the application surface. However, when shooting through reinforcing bars, the nozzle shall be held closer and at a slight angle in order to permit encasement and to minimise rebound.

No rebound material is to be covered with shotcrete and incorporated in the works. The rebound material shall be removed from the tunnel and shall not be reused in the works.

Each layer of shotcrete shall be built up by making several passes of the nozzle over the working area. The shotcrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause the nozzleman shall direct it away from the work until it becomes constant again.

Where a layer of shotcrete is to be covered by succeeding layers, it shall first be allowed to set and loose material and rebound shall be removed. The surface shall be finally cleaned and wetted using a blast of air and water.

For vertical and near vertical surfaces, application shall commence at the bottom. The thickness of the layer shall mainly be governed by the requirement that the material shall not sag. Where thick layers are applied, the top surface shall be maintained at a slope of approximately 45 degrees.

Shotcrete may not be applied through two or more layers of wire mesh except for laps between mesh panels, unless approved by the Engineer.

5.4 Shotcrete Thickness

The inner surface of shotcrete may follow the contours of the rock surface, with the necessary rounding of the edges and corners, provided that protruding, sound blocks of rock still firmly linked to the ground mass have a minimum shotcrete cover of the thickness specified in the drawings.

Steel arches, steel mesh and the like shall be surrounded with at least 30 mm of shotcrete unless otherwise shown on the drawings.

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Any sealing shotcrete layer or flash coat shall be at least 20 mm thick, or as otherwise shown in the drawings or directed on site by the Engineer.

5.5 Reinforcement

Reinforcement mesh shall be securely fixed in place. The reinforcement shall be cleaned of any previously deposited material which might prevent a proper bond.

Ties, anchors and supports for the mesh shall be of steel and suitable spacers shall be provided where necessary. Timber packings shall not be used. The method of fixing the mesh shall be such that shotcrete can be compacted soundly behind the reinforcement at all points.

5.6 Application of Shotcrete in Cold Weather

When shotcrete is placed at air temperatures of less than 5°C, measures shall be taken to maintain shotcrete temperature above 3°C for at least 1 day after application.

No frozen materials, ice or snow shall be allowed to enter the mixer.

Cement shall not be heated. If water is introduced at the nozzle, it shall not be heated above 20°C.

5.7 Curing

Measures shall be taken to ensure that shotcrete exhibits proper strength gain and a minimum of cracking. Curing measures shall be applied as necessary to achieve these requirements.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

6.1 Works Tests

6.1.1 STRENGTH TESTS

Compressive strength tests shall be performed on cores taken from shotcrete in the works. The time of coring shall be as close as possible to 24 hours after placing. Cores required for 28 day strength tests may be obtained at the same time as those for 1 day strength tests and stored in the laboratory.

The frequency of coring shall be such as to obtain 3 cores each for 1 and 28 day tests for every 200 m^3 of shotcrete used in the works. Depending on the compliance of test results with this Specification, the circumstances of application and the importance of construction, the frequency of work tests and the amount of test sets may be reduced (to every 500 m^3, 1 and 28 day strength respectively) or increased (to every 100 m^3) subject to previous approval of the Engineer or his delegated personnel. The cores shall be drilled through the whole thickness of

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the shotcrete and visually inspected to verify that the shotcrete is dense and homogeneous without segregation of aggregate or other visible imperfections.

Reinforcement incorporated in the in-situ shotcrete may lead to improper test specimens (e. g. too much wire mesh, rebound traps), which must not be used for testing. Samples should therefore be taken at different points of the in-situ shotcrete. Individual values deviating by more than 15% from the arithmetic mean must be disregarded. For computing the arithmetic mean, at least three proper samples must be available.

Instead of testing cores taken from shotcrete placed in the works, indirect penetration and pull-out test methods may be used to determine the 1 day strength of shotcrete as approved by the Engineer. Tests for 1 day strength shall be carried out between 22 and 48 hours preferably at 24 hours $\pm$ 2 hours. Individual calibration has to be developed specifically for the test equipment used. The test results shall be related to the characteristic strength of one day. Mechanical rebound hammers shall not be used to determine the indirect compressive strength of shotcrete.

Where the nominal required shotcrete thickness is less than 100 mm, the cores for compressive strength testing shall be taken from areas where the actual thickness is greater than 100 mm. Alternatively, additional shotcrete thickness shall be applied in selected areas for subsequent test coring as directed by the Engineer.

The strength of shotcrete measured by cores taken from the works (or by indirect test methods as specified above) shall be acceptable if the compressive strength results comply with the following requirements:

(a) The average strength for any group of four consecutive test results shall be at least the specified characteristic strength.

(b) Any test result (mean of 3 core strengths) shall not be lower than the specified characteristic strength by more than:

2.0 N/mm^2 for 1 day strength
3.0 N/mm^2 for 28 day strength

If the shotcrete fails to meet the compliance requirements specified herein, the validity of the test results shall be checked prior to implementing one of the following courses of action:

(a) Confirm the requirements for remedial action by assessing the results of geotechnical measurements and/or back-analyses.

(b) Make good deficiencies by the application of additional shotcrete thickness at past or future works until compliance with the requirements is confirmed.

(c) Following an approved procedure, remove the defective shotcrete and replace by new shotcrete.

(d) Install additional rock dowels – if needed

The course of action to be adopted shall be approved by the Engineer.

The hardening of young shotcrete shall be checked by penetration tests and / or Kaindl Meyco tests at timely intervals.

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6.1.2 STABILITY TESTS

Tests shall be carried out once, at the beginning of works with a new shotcrete design mix, to assess the load-bearing capacity of the shotcrete in the works under site conditions. These tests may be carried out on cores taken from panels.

One set of tests shall be carried out for each mix type.

These panels shall be produced in the works under site conditions. The panels shall be stored underground in the works (with the same climatic conditions as the shotcrete placed in situ). Core samples shall be taken from the panels just before testing, or at least on the same day as testing.

Cylindrical test specimens shall be cored and tested as listed below. The dimensions of the test specimens and the testing procedure shall be in accordance with Subchapter 5.1.3, Shotcreting Trials.

(a) Compressive strength in the spray direction after 1 and 28 days on 3 cores each.

(b) Modulus of elasticity in the spray direction after 1 and 28 days on 3 cores each. The core shall be 100 mm in diameter and 200 mm in length. The strain shall be measured on the central part of the sample, the upper test limit being 1/3 and the lower test limit being 1/30 of the compressive strength.

The modulus of elasticity at different ages shall be determined on the same sample, the compressive strength being measured after 28 days.

If the stability of the tunnel is endangered because shotcrete does not meet the specified strength requirements, the affected shotcrete shall be replaced carefully or where practicable the deficiencies shall be compensated by the application of additional shotcrete or rock dowels as approved by the Engineer.

6.1.3 WORKABILITY TESTS

The workability of shotcrete produced by the wet method shall be measured by slump tests following the addition of plasticizer. Samples shall be tested for every 50 m^3 produced.

The target workability values shall be determined during site trials.

The workability of wet method shotcrete shall be within $\pm$ 25 mm or $\pm$ one third of the target value, whichever is the greater.

6.1.4 THICKNESS TESTS

The thickness of placed shotcrete shall be checked using studs, double headed nails, or steel mesh bars bent perpendicular to the surface. Where closely spaced lattice girders ($<$ 1.6 m) are used, no other routine shotcrete thickness check will be required.

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6.2 Testing of Materials

6.2.1 TEST PROCEDURE FOR BLEEDING OF CEMENT

Put exactly 98 g of water with a temperature of 20°C into a 250 ml glass beaker with a small magnetic stirring rod. At medium stirring rate add 115 g of cement little by little within 20 seconds. Combine the mixture for 2 minutes until a homogeneous, relatively thin cement paste (water/cement ratio = 0.85) has been achieved.

Fill the homogenised mass into a 100 ml measuring cylinder up to the 100 ml index mark by means of a glass rod (do not pour directly into cylinder). It is absolutely necessary that the measuring cylinder be kept in a higher glass beaker filled with water of 20°C during the entire period of testing. Fluctuations in temperature shall not exceed $\pm$ 2°C.

After 120 minutes the amount of cement that has settled can be read from the scale, i.e. the amount of supernatant water may be determined. The reading is in ml corresponding to % by volume of repelled water.

6.2.2 TESTING OF ACCELERATORS

Setting Time

The dosage of accelerator, as % by weight of cement required to provide an initial setting of 60 sec $\pm$ 20 sec and a final setting of 150 sec at a maximum shall be determined in accordance with the following procedure.

(a) The temperature of the cement and water shall be 20°C $\pm$ 1°C.

(b) 1200 g of cement shall be placed in the mixing bowl of a mortar mixer (Hobart 5 litre mixer).

(c) When testing powder accelerators, the powder shall be weighed and then added to the cement in the mixing bowl and mixed on speed no. 1 for 2 minutes to ensure even distribution. Liquid accelerators shall be added to the mixing water.

(d) 420 ml of water shall be added to the mixture in the bowl within approximately 2 sec with the mixer on speed no. 1. After 5 sec the mixing speed shall be changed to no. 2 for a further 15 sec.

(e) The cement paste shall be taken from the mixing bowl by means of a spatula and placed in a vicat mould and lightly tamped to ensure no entrapped air is present in the sample. The top surface shall be struck off level and the mould shall be placed on the vicat apparatus within 20 sec upon completion of mixing (i.e. 40 sec upon addition of water).

(f) The initial set shall be determined in accordance with EN 196-3 and the final set shall be determined by continuing the use of the initial set method and recording the time at which the needle penetrates the top surface by less than 1 mm. The times shall be measured from the moment of water addition.

(g) If the initial set is less than 40 sec or more than 80 sec or the final set is more than 150 sec, the test shall be repeated using a smaller or higher dosage of accelerator.

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Strength Decrease

The testing of the strength decrease for the selected type(s) of accelerator shall be carried out at the following dosages to establish the variability with dosage:

Dry Method

- accelerators in powder form: 3.0, 5.0, 7.0%
- accelerators in liquid form: 2.0, 4.0, 6.0%

Wet Method

- water glass: 8.0, 12.0, 15.0%
- accelerators in liquid form: 2.0, 4.0, 6.0%

The above percentages are by weight of cement.

At the dosage chosen for use in the works, the decrease in strength at an age of 28 days, as determined in Subchapter 2.9.2 - Testing of Accelerators, shall not exceed the following:

- accelerators in powder form maximum 45%
- accelerators in liquid form maximum 30%

The decrease in strength shall be determined according to the following procedure:

Mortar cubes shall be used in accordance with EN 196-1.

A comparison of the 7-day and 28-day strengths of mortar shall be carried out as follows:

- The strength shall be determined without accelerator (A)
- The strength shall be determined with accelerator adopting the dosage used for the setting time tests (B)

  The decrease in strength is $\frac{A-B}{A}$ x 100

Mortar Tests - With Accelerator

The mortar strength with accelerator shall be determined in accordance with the following procedure:

(a) The temperature of the mortar constituents shall be: 20° $\pm$ 1°C.

(b) 370 g of mix water shall be poured into the dry mortar mixing bowl.

(c) Accelerator shall be added to and blended with the mix water at the dosage determined in accordance with 2.9.2, Item 1 - Setting Time.

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(d) 1,710 g of standard sand shall be added to the water in the mixing bowl with the mixer running at low rotation speed.

(e) 570 g cement shall be poured into the bowl within 5 sec and the mortar mixer shall immediately be switched to high speed for a mixing time of 30 sec.

(f) The moulds shall be filled with mortar as quickly as possible. The mortar shall be compacted by vibration for a period of 15 seconds only.

(g) The bulk density of the compacted mortar cubes shall be determined and compared with the bulk density of mortar cubes prepared without accelerator in order to check whether the appropriate compaction has been achieved. (The maximum admissible difference of bulk density to cubes prepared without accelerator shall not exceed $\pm$ 5 %).

(h) The cubes shall be removed from the moulds at an age of 4.5 hours and stored in a moist curing chamber at 20°C.

(i) Compressive strength testing of the specimens shall be undertaken after 7 and/or 28 days.

Mortar Test - Without Accelerator (Basic Mortar Mix)

The compressive strength of mortar cubes without accelerator shall be determined. The following mix ratio shall be used:

370 g water

570 g cement

1,710 g sand

7. Measurements

The quantity survey unit of the shotcrete shall be m^3. The volume (thickness) depends on the individual excavation and support type executed. The respective values are documented in the corresponding drawings.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, with the Technical Specification and the written instructions of the Engineer.

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8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based u:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards	
CSA 23.1-94	Materials and method of concrete construction
German Standards	
DIN 267	Fasteners and similar parts, technical specifications, generalities
DIN 1045, ENV 206	Structural concrete
DIN 1164	Portland - blast furnace - pozzolanic cement, definitions, components, requirements, delivery
DIN 18200	Control (quality control) of construction materials, construction components, and construction designs; general principles
DIN 18851	Shotcrete – fabrication and testing
European Standards	
EC 2	Design of concrete structures
EN 196	Methods of testing cement

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PR-00-5005
Monitoring

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1 Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of all monitoring measures at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components including the entire material and equipment required to the site

b) installation of all the components within the construction sequences

c) measuring of individual parameters as required

d) evaluation and interpretation of the results obtained

e) quality control for material and workmanship.

The Scope of Works is defined for the construction period in both the main tunnel and the corresponding adjacent structures (e. g. intake, outlet) as well as for the monitoring activities during the operation period.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force. The monitoring measures are separated into measures executed during construction and measures performed during operation.

1.3.1 Monitoring during Construction Period

The monitoring objectives during construction are:

a) To check the adequacy of ground support in tunnels and excavations and to determine any support modifications required.

b) To determine the effects exerted by the construction work on the existing structures below ground, forming part of the works.

c) To check the adequacy of initial and final tunnel linings, and of various structural elements of underground structures.

Monitoring shall continue throughout the life of the contract with the objective to evaluate whether the behaviour of the underground structures and the ground conditions actually

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complies with the design expectations, to ensure that safety is maintained, and to assist in defining the scheduling and implementation of necessary maintenance tasks.

The following monitoring activities shall be carried out throughout the works as a minimum requirement:

a) Deformations of tunnel linings and junction openings

b) Deformations of adjacent structures

c) Ground movements adjacent to the tunnel

d) Groundwater pressure adjacent to the tunnel

1.3.2 Monitoring during Operation Period

The monitoring during operation shall meet the following objectives:

a) to evaluate the adequacy of ground support in tunnels and excavations

b) to verify the long-term loadings and the long-term underground behaviour

c) to monitor the load-bearing capacity of the structure

Monitoring shall continue throughout the facility's life cycle to ensure that the load-bearing capacity of the structures is maintained and to assist in defining the scheduling and implementation of necessary maintenance tasks.

The following monitoring activities shall be carried out as a minimum requirement:

a) Ground movement adjacent to the tunnel

b) Groundwater pressure adjacent to the tunnel

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall make suitable allowance in his overall work programme for the installation, testing, calibration, reading, and maintenance of instruments, the interpretation of field readings and the implementation of appropriate corrective measures. The monitoring program shall extend over the entire construction and maintenance period.

Notwithstanding any other provisions in the contract in respect of the Contractor's staff, the personnel responsible for the installation, testing, calibration, reading, maintenance and surveying of the instruments, shall be qualified and experienced in the field of instrumentation, geotechnical monitoring and survey, as appropriate.

The Contractor shall provide his instrumentation personnel with all the equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way at the appropriate time intervals stipulated in this Specification.

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1.4.1 PROVISION OF MEASURING DEVICES

The Contractor shall present an organisation chart and time schedule of the works to the Engineer for approval. These documents shall give due consideration to all the conditions accompanying the performance of the measurements and the presentation of results.

All equipment and installation accessories, required for the operation of the instrumentation system and the recording of measurements, shall be supplied by the Contractor and shall be available on site prior to any construction works being performed in the area in which they are to be installed and shall be stored securely where they will not suffer any physical damage or any damage arising from excessive moisture, temperature extremes or other adverse conditions.

All measuring devices shall be as specified and shall be manufactured by companies with a proven record of experience in the field of tunnel and/or geotechnical instrumentation. All materials, designs and constructions shall be of the highest quality to provide robust, corrosion and vibration resistant instruments. Instruments embedded in concrete linings shall be capable of withstanding vibrations from compacting equipment (e.g. shotcrete application). The accuracy and dependability of the equipment shall not be significantly affected by changes in temperature, humidity, stray currents or other adverse conditions that may be encountered. Calibration certificates, where appropriate, shall be provided by a reputable testing company.

1.4.2 INSTALLATION AND MAINTENANCE OF INSTRUMENTS

The location and type of instruments shall be as shown on the Drawings or as otherwise specified.

The location and arrangement of the instruments shall be planned so that monitoring can continue, if specified, after completion of the works with all electrical and mechanical equipment etc. in place. Adequate access for maintaining and reading the instruments shall be provided. Remote control instruments should be capable of being read without interruption to other site activities.

A stock of additional instruments shall be available and installed as found necessary in the event of unforeseen conditions being encountered, for which more extensive monitoring might be required.

The Contractor shall install the equipment according to the manufacturer's recommendations. Testing shall be undertaken as necessary to ensure satisfactory functioning of the equipment at each stage of the installation. In particular, adequate precautions shall be taken to protect the instruments against harmful effects resulting from construction works and groundwater seepage. Instruments found to be malfunctioning at any time shall be replaced at the earliest opportunity.

All instruments shall be securely fixed in accordance with the Drawings and their Specifications including any attendant wiring and terminal panels, and shall be adequately protected against mechanical damage and ingress of water and dirt.

As far as practicable, instruments and terminal boxes built into concrete linings shall be kept clear of reinforcement.

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The installation of instrumentation in underground excavations shall be carried out at the earliest opportunity, following the advance of the tunnel face, consistent with the needs to ensure safe working methods and adequate equipment protection.

The Contractor shall take every practical measure to prevent damage to the instruments and ancillary equipment during handling, installation and subsequent operation. The Contractor shall maintain all the instruments required for long-term monitoring in a satisfactory working order for the entire duration of the monitoring program.

The readout boxes shall be capable of being placed at adequate distances to their associated transducers without the specified accuracy of the instrumentation being impaired.

Measures shall be taken to ensure that electrical instruments will not be adversely affected by other temporary or permanent electrical services.

1.4.3 INSTRUMENT READING AND RECORDS

A logical reference system for all instrumentation equipment shall be established by the Contractor so that records for any particular location can easily be recovered for interpretation or review.

Instruments shall be read as soon as possible after installation to obtain datum readings, which shall be established from a minimum of two independent reading operations producing consistent results. Datum readings and reading frequencies specific to a particular instrument are stated in the relevant chapter describing the details and the use of the instrument.

Readings shall continue to be taken once each day until the rate of change in the readings falls off sufficiently to allow a lower frequency to be adopted with confidence that the safety of the works is not in doubt and that the amount of data retrieved will allow trends with time to be clearly identified and evaluated.

In the event of any change in circumstances, for example the influence of the construction on other structures nearby or of junctions and openings, the reading program shall be resumed.

In particular during excavation of a tunnel in the vicinity of an instrumented ground section, daily readings shall be resumed not later than four days before the working face reaches the instrumentation section and in any event once the working face is within 50 m of the instrumented section.

Where seasonable considerations are expected to influence the instrument readings, at least four readings per year shall be taken.

When recording instrumentation readings, all site conditions that may affect the results shall be recorded, including temperature, air pressure and humidity, temperature of recently placed concrete, progress of excavation, progress of other construction activities such as lining erection and grouting, time lapse between construction and taking of first readings, tunnel air movements, machinery vibration, activity and progress in adjacent tunnels. Instrument type, location reference, data and time of reading, personnel carrying out the readings, measuring instruments or readout unit references shall also be recorded.

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Instrument readings shall be recorded on record sheets designed for this purpose or preferably directly on tape, disc or any other digital storing device for subsequent computer analysis. Corrections shall be made for temperature difference or other factors as appropriate. Immediately after the readings have been taken, the measurement results shall be entered into time-deformation and time-stress diagrams respectively, to evaluate the stability behaviour of the underground structure.

The diagram used shall also show:

a) the project title

b) the type of measurement, e. g. deformation, extensometer, piezometer.

c) the diagram page reference

d) the location and chainage of the measuring points

e) a sketch of the tunnel cross-section, clearly marking the position of the measuring points.

f) the details of the excavation process such as:

- distance of measuring point from the face
- excavation of crown, bench and invert in relation to the measurements
- location of adjacent openings

g) the duration shall be recorded between the excavation and the datum reading taken at the measuring section

h) new datum readings shall be clearly indicated.

i) the scale of diagrams shall be uniform and shall not be changed with the magnitude of measurement results.

The same recording devices, e.g. tape extensometers, pressure gauges, digital readouts, etc. shall be used at any given location throughout the monitoring program. If for any reason this becomes impractical, due to instrument breakage for example, new datum readings shall be taken immediately with a replacement instrument, i.e. the new instrument used for the future readings. Similarly, should a monitoring location become unavailable, the instrument previously read from this point shall, as soon as practicable after becoming unavailable, be read from an alternative point, the latter than being used for subsequent readings.

Readings shall, wherever possible, be taken by the same personnel. Should the person need to be replaced for any reason, a series of duplicate readings shall be carried out by the out-going person and his replacement.

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2 Materials

2.1 General

A detailed statement of the types and sources of manufacture of the geotechnical measurement components, proposed for use in the works, shall be prepared.

The instrument manufacturer shall provide drawings and data describing the principal features, the mode of operation, the measuring range and the degrees of accuracy of the equipment. The manufacture of all items shall be in accordance with the Drawings and the Specification(s) provided.

Where instruments shall be capable of being monitored remotely by portable remote readout units, the readout units and the appropriate plug-in leads shall be compatible with the instruments being monitored. The readout units shall plug into appropriate readout boxes.

2.2 Technical Requirement of Instrumentation

2.2.1 GENERAL

The instruments to be used for the monitoring of underground structures shall include but shall not be limited to:

a) Theodolite and targets to measure the lining deformations (for general use)

b) Levelling studs and geodetic levelling equipment (if theodolite for optical measurements is not used)

c) Tape extensometer (if theodolite for optical measurements is not used)

d) Rod extensometers

e) Piezometers

2.2.2 CONVERGENCE MEASURING INSTRUMENTS

The convergence measuring bolts shall be made of high-yield tensile steel with a quality corresponding to the reinforcement quality. The top shall have a screw thread for a target or geodetic levelling stud or the pin of a tape extensometer to be fixed to it.

The tape extensometer to be used shall be made of corrosion-proof metal and fitted with a dial gauge and tensioning device. It shall be suitable for measuring over the required lengths and in any direction from a measuring bolt. It shall have a resolution of 1 mm and shall be capable of measuring absolute lengths to an accuracy of ± 1 mm.

Levelling studs shall be manufactured from stainless steel and fixed to the tunnel linings in the same manner and to the same standards as convergence reference points. Geodetic levels shall have robust tripods. They shall be designed in such a way that their use in conjunction with the appropriate geodetic instruments allows precision levelling to an accuracy of ± 1mm.

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The theodolite used for convergence measurements shall have an accuracy of ± 1 mm.

2.2.3 ROD EXTENSOMETER

Rods shall be fabricated from aluminium alloy or glass-fibre reinforced resin. The cross-sectional dimensions of the tunnel shall not be a restriction to the maximum extensometer length to be installed.

Extensometers shall be designed in such a way that the measurement of both elongations and reductions in the length between anchorage point and measuring head are possible. The head of the extensometer shall be exchangeable.

Reading facilities shall be either:

- portable mechanical measuring devices which shall include a dial depth gauge and a calibration device. The accuracy of the device shall not exceed 0.1 mm and the measuring range shall be ± 15 cm.

or

- electric displacement transducers for remote reading from a terminal box with an overall accuracy of 0.1 mm and a measuring range of ± 15 cm. The transducers shall be waterproof to full hydrostatic head.

The cabling terminal box shall be capable of accepting up to four extensometers. A battery-operated digital readout device capable of reading to the required overall accuracy shall also be provided. The readout equipment shall be compatible to the measuring system and shall ensure an automatic data acquisition throughout the operation period.

2.2.3 PIEZOMETER

The piezometer shall be of a type and manufacture approved by the Engineer. The piezometer used shall be of the vibrating wire (vw) type. It shall be made of stainless steel and shall include a stainless sintered filter.

The piezometer shall be installed in such way that it will be exchangeable throughout the facility's life period. The readout equipment shall be compatible to the measuring system and shall ensure an automatic data acquisition throughout the operation period.

The piezometer shall be capable of measuring the water head at the piezometer tip to a repeatability of ±0.1 m.

3 Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

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4 Transport

All components of the monitoring equipment shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5 Workmanship

5.1 General

This section relates to the instrumentation to be provided to aid in determining the support necessary for the excavation in accordance with the use of the New Austrian Tunnelling Method (NATM) and the use of the Tunnel Boring Machine (TBM).

The instrumentation shall be installed as soon as practicable in the cycle of excavation and underground support. It shall be adequately protected against mechanical and environmental damage and shall be accessible at all times for survey purposes.

The Contractor's instrumentation personnel shall be responsible for all measurements and for proper data recording. There shall be staff based on site, available any time during construction, and capable of analyzing the data in terms of adequacy and in relation to the actual ground support measures. The results shall be entered into diagrams in compliance with the requirements of the Engineer responsible for ground support. The diagrams shall be updated immediately after a set of measurements has been completed to permit an evaluation of the stability of the structure.

At locations where lining stresses and ground pressures are measured, lining deformations shall be recorded as well.

Provisions in the final lining for a continued monitoring of the instrumentation shall be made as specified by the Designer.

Details describing the installation of the instruments shall be recorded, such as the exact position and orientation of the instruments, the length and orientation of possible drill holes, the shotcrete thickness and the ground formations encountered at the measurement location.

5.1 Details and Use of Instruments

5.1.1 DEFORMATION MEASUREMENTS (CONVERGENCE MEASUREMENTS)

Lining deformations shall be monitored by observing the movement of measuring bolts installed immediately after excavation. Measuring bolts shall be fixed during the tunnel advance, before or after shotcrete application.

The following measurements shall be taken:

a) Optical measurements generally using a theodolite

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b) Tape measurements, especially where optical measurements cannot be taken

Deformation measurements shall be taken in sections of up to 500 m along the tunnel. The positioning of the measuring bolts shall be adjusted to suit the excavation sequence adopted.

Deformation results shall be assessed in conjunction with a visual examination of the tunnel surfaces to record signs of distress such as cracks and sections of splitting and falling ground or a loosening or overstressing of support measures. Subject to the findings of both, the deformation results and any signs of distress, any adjustment to the existing support shall be made in accordance with the design and subject to the Engineer's approval.

The ambient temperature shall be taken at the time of each reading. The instrument shall be used and read in accordance with the manufacturer's instructions. Three dial gauge readings shall be taken and recorded for each measurement and averaged prior to making the temperature correction.

The instrument shall be checked against a calibration bar before and after each set of readings. If a convergence line becomes unavailable, e.g. due to final service installations obstructing the measurement, dual readings shall be taken with its replacement. If this is impossible due to construction works, then readings shall be taken on the old line at the latest possible time and the new line shall be established and read as soon as possible.

5.1.2 ROD EXTENSOMETERS

Rod extensometers employed in the works shall take the following form:

A rod anchored at the remote end of a drill hole shall pass into a plastic tube fixed in a reference collar at the open end of the hole. The relative movement between the end anchor and the reference collar shall be measured with either a dial gauge or an electric transducer on the free end of the rod. A range adjustment device fitted at the reference collar shall extend the reading range beyond that of the dial gauge. In case this multiple arrangement is employed, it shall be calibrated on one single rod extensometer installed in close proximity. Rods are installed in a single hole with each rod of a different length so that displacements at various drillhole depths may be recorded. Each rod shall be individually isolated by its own plastic sleeve. The complete assembly shall be grouted in place, fixing the anchors to the ground but allowing free movement of each rod within its sleeve.

A single reference housing shall receive all rods from one drillhole and provide protection to the reference head. The number of rods per drillhole shall be as shown on the drawings.

Other characteristics of the instrument shall be as follows:

The anchor points shall be according to the manufacturer's recommendation.

The extensometers shall be installed to the lengths shown on the drawings, where the lengths specified refer to the overall lengths of rod plus anchorage bar.

The accuracy of drilling shall be such that the drill hole shall be straight and shall not deviate from its intended orientation by more than four degrees.

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5.2 Evaluation, Interpretation

5.2.1 REPORTING

The Contractor shall compile a weekly summary of geotechnical records and monitoring measurements which shall contain such comments as:

a) comparison with design expectations

b) schedule of measurements taken

c) any unusual circumstances

d) any special measurements taken during the previous week of construction

5.2.2 DESIGN ASSESSMENT

The Contractor shall be responsible for the interpretation of geotechnical measurements such as the comparison of measuring readouts and calculation results. The Contractor shall issue processed monitoring results promptly and regularly. He shall immediately inform the Designer of any discrepancies between calculation results and actual results and shall make recommendations for a design variation.

In case of serious discrepancies arising between the calculated and the measured results, a back-analysis shall be initiated to confirm these discrepancies and in a subsequent step, the structures still to be built shall be re-analyzed.

6 Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

The Contractor shall be responsible for keeping records of all calibration certificates and for sending equipment off site for recalibration by reputable testing laboratories when required.

The Contractor shall ensure that the entire instrumentation in use has been correctly calibrated. The Contractor shall also carry out periodic checks to confirm the validity of equipment calibration in accordance with the manufacturer's instructions and to carry out adjustments if found necessary. Suspect readings shall be repeated.

7 Measurements

The quantity survey unit of the measuring device shall be piece (installed measuring device). The quantity survey unit of the measurements and readings shall be piece (measurement) per measuring point.

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8 Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9 Applicable Regulations

9.1 Standards

Canadian Standards

German Standards

* * *

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PR-00-5006
Underground Injections

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of underground grouting measures performed inside the Diversion Tunnel, at the intake and outlet structures and from the ground surface to achieve a ground improvement and a reduction in ground permeability at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) drilling of boreholes for the grouting works required

c) mixing of the grouting components (materials) required

d) injection of planned underground space

e) quality control for material and workmanship.

The Scope of Work is defined for the Diversion Tunnel during excavation and support.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 BOREHOLES

The boreholes for the grouting measures can be installed by hammer drilling or rotary drilling. Boreholes in poor ground, which are not stable, have to be cased with tubes à manchette (perforated pipes with rubber sleeves).

The diameter of boreholes with casing must be such as to allow for the installation of tubes à manchette (dia 50 mm) and screen pipes (dia 50 mm) before recovery of the casing.

Borings without casing are only admissible if the ground is firm enough to prevent the borehole from caving in. The drilling diameter is to be selected to permit the use of packers being inserted by means of pipes with a diameter of 20 mm.

1.3.2 GROUTING COMPONENTS

The main components for underground grouting are:

- water

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- cement
- sand

In addition,

- bentonite
- additives like hardeners or plasticizers
- chemical components like water glass

can be used for special requirements to be met. The individual components are specified in Subchapter 2, **Materials**

1.3.3 GROUTING EQUIPMENT

For grouting, the following equipment components will be needed on site:

- mixing plant
- pumping system
- injection lines
- packers
- measuring facilities

The components listed are specified in Subchapter 3, **Equipment**.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their works in a safe and proper way.

Grout injections may be carried out from the ground surface or from the tunnels. Special care is to be taken to ensure that the injection (grouting) equipment is selected and installed in a way, which does not impair existing utilities, structures and buildings.

Before commencing the grouting works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the grouting work stages, the selection of grouting material, as well as the injection pressures and rates to be applied.

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2. Materials

2.1 General

The suitability of the individual materials for the respective ground and grouting operation must be verified by testing.

2.2 Water

The water used for grouting works must not contain more than 1.5 ‰ of soluble substances. The percentage of sulfates must drop below 1 ‰. Water polluted by organic substances is not suitable for the execution of grouting works. In order to determine chemical processes in the water, adequate water analyses shall be carried out prior to the works.

The water temperature during mixing and grouting should range between 5°C and 25°C.

2.3 Cement

Only cement with a suitable fineness of grinding shall be used. The Blaine value should at least amount to 3200 cm^2/ g. The compatibility of cement, bentonite and water shall be verified.

In exceptional cases, special rapidly setting cements with a high degree of grinding fineness may be used to stop water seepage. The time span until the material starts to set should not exceed 20 minutes.

2.4 Bentonite or Clay Powder

In case of grouting with bentonite, non-activated bentonite or clay powder shall be used. The mix proportions, regarding the share of bentonite as well as that of water in the suspension, depend on the swelling properties of bentonite or clay powder. 90 % of the bentonite grain fraction should be smaller than 2 µ and the compatibility of cement and bentonite shall be closely observed.

2.5 Sand

Only fine sand with largely round grains and without organic components within a grading range between 0.1 and 1 mm may be used. The percentage of grains smaller than 0.1 mm must not exceed 10 %.

2.6 Additives

The use of grouting additives is subject to approval by the Engineer. Before works are started, the compatibility of additives with cement and bentonite as well as with the water used, shall be verified by laboratory tests.

Only technically acknowledged additives, which have been successfully employed for similar works and do not carry any harmful implications upon application, shall be proposed by the Contractor.

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2.7 Chemical Injections

Chemical injections may be executed with water glass or acrylic resin unless otherwise proposed by the Contractor. Water glass with 37° - 39° Blaine shall be used. Hardeners may be on an organic basis or may be soda lye with sodium aluminate. The gelling time must be variable between 1 minute and 2 hours.

2.8 Suspensions

With cement-bentonite suspensions or pure cement suspensions, the water/binder ratio should range between 0.6 and a maximum of 2. Suspensions with a larger water content are not admissible.

The cement-bentonite suspensions used should be largely stable, i.e. the degree of settling must not exceed 10 %.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

3.1 Mixing Plants

The site equipment shall include mixers and pumping equipment to allow for uninterrupted stirring of any grouting material (e.g. cement, bentonite, water glass or resin solution). Even in case of a power failure or any similar disturbance, a constant stirring of the injection material must be guaranteed.

The dosage of single components of the grout mix shall be measured by means of scales or volumetrically in a way to achieve an accuracy of 1 - 2 % in relation to the smallest portion of the mix. For the agitation of suspensions, colloidal mixers with a high rotation rate (1200 to 1500 rotations per minute) shall be used.

The duration of the mixing process must suit the respective grouting material but should at least be 2 minutes.

3.2 Pumping System

The injection pumps must be adjustable with respect to both pressure and flow rate. The use of pressure cylinders is not admissible. In case of piston pumps, equalising tanks shall be installed to avoid pressure surges during pump operation. The pumping rate should at least come to 60 l/min at a maximum pressure of 50 bar. It must moreover be possible to add sand or other fine inert material to the cement suspension.

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3.3 Measuring Facilities

Each mixing station shall be equipped with a pressure and flow rate recorder for each single pump. These devices shall serve to monitor the grouting process and to record operational data of each grout injection unit.

All pressure gauges used on site must be calibrated. The display range shall correspond to the pressures required and applied.

3.4 Injection Lines

A feeder line and a return line must be installed between each pump and the borehole. Thus the grouting material may circulate in the line system in case of failure and in case of any interruption of the grout injection process. A pressure gauge must be placed at the borehole mouth allowing for a direct reading of the pressure applied. Each pump must not inject more than one section of a borehole. In order to avoid sedimentation of grouting material and uncontrolled mixing or changes in the mix proportions within the line, injection lines with a diameter of 20 mm shall be used.

Furthermore, telephone communication between the borehole mouth and the pumping station should be operative at all times. The entire system shall be designed for an operation pressure of 50 bar (5 MPa).

Before starting grout injections or water pressure tests, the recorders installed in the mixing container and the pressure gauges located on the pumps and at the borehole mouth must be checked.

3.5 Packers

Once pressure is applied, the packers must be in tight contact with the borehole or grouting tube wall. The length of the packers shall be chosen in a way preventing dislocations during water tests or grout injections. The specified cross-section of water/grout flow must not be reduced at any location.

For grout injections or water pressure tests during drilling operation, single packers shall be employed. For grout injections and for water tests in completed boreholes twin packers shall be used.

All sealing elements must be available with appropriate diameter and in sufficient quantity. Using double packers, the injection length may be variable.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

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5. Workmanship

5.1 Injection Works

Grouting a ring or an array of boreholes shall be carried out adopting the following sequence:

If two rings of drill holes shall be injected, grouting will first be applied to the inner ring, before the outer ring will be grouted. At the first stage, only every second borehole will be grouted. Intermediate boreholes not yet grouted will be used to check the efficiency of the grout injection.

The injection pressure shall be selected according to the ground conditions. The pressures applied must never lead to ground fracturing. If faced with an accidental fracturing of the ground, the pressure employed for further grout injections shall be reduced to 80 % of the pressure which caused the fracturing.

The pumping rate in low-permeability ground shall amount to 50 –70 l/min, while for injections in strongly fissured ground a maximum pumping rate of 65 l/min shall be admissible.

5.2 Tube à Manchette Installation

Boreholes which have to be equipped with a casing will be equipped with perforated pipes with rubber sleeves arranged at a certain spacing (tube à manchette). The system and design of these pipes will be subject to the Engineer's approval.

The space between the borehole and the tube à manchette will be filled with cement suspension which, in the case of cased boreholes, must be applied when the casing tubes are extracted.

The composition of the cement suspension is to be suggested by the Contractor. The following information may serve as a guideline:

water: 884 l

bentonite: 75 kg

cement: 270 kg

The suitability of the mixture is to be verified on site and is to be approved by the Engineer.

Generally, the tubes à manchette shall be rinsed after each injection to keep them operable until the completion of the works. Following the completion of these works, the tubes à manchette are to be filled with cement-bentonite suspension.

5.3 Monitoring

A detailed log containing information on the grouting works executed shall be prepared separately for each single borehole and shall be submitted to the Engineer. The logs are to contain the following information:

- Indication of location
- Identification number of borehole

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- Injected section (sleeve - number)
- Date, hour, start and end of injection
- Pressure at start and end of injection
- Quantity of grouting material
- Type of grouting material
- Mix proportions

If different mix proportions shall be used within the same grouting section, these shall be indicated separately. The sequence of grout injections as well as the pressure characteristics will have to be recorded for each type of mix. The record tapes indicating pressure and flow rate measurements shall be enclosed in the log. Extraordinary events or disturbances must also be indicated.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

6.1 Suitability Test

Laboratory tests shall ensure that all requirements are met in the application of chemical injections as well as suspensions. The samples to be analyzed shall be prepared by the use of standard sand. The following characteristics shall be determined:

- Viscosity
- Settling characteristics
- Compressive strength
- Permeability
- Viscosity limit for injections (suspension viscosity is measured with a funnel, resin viscosity with a rotary cylinder viscometer)

Sample cubes of 50 x 50 x 50 [mm] shall be prepared and placed in water. The compressive strength shall be tested after 7 and after 28 days.

6.2 Quality Test

Upon injection of water glass or resin solutions, samples shall be taken from each mixing batch indicating hour, location of use, identification number of borehole, and position of sleeve within the borehole. In case of cement-bentonite suspensions, samples shall be taken from the mixing plant to be analyzed in the laboratory.

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6.3 Control of Workmanship

The efficiency of the injections shall be verified by water pressure tests carried out in intermediate boreholes. The results shall be compared with the results of water pressure tests carried out before the grouting operation started.

In case of uncertainty about the success of the grouting operation, additional confirmatory boreholes shall be drilled.

6.4 Water Pressure Tests

6.4.1 GENERAL

Water pressure tests are to be performed in rock. In soil they may be realised in exceptional cases.

Generally, water pressure tests are conducted at three pressure stages. The tests are to be extended over sections of 3 m or less, if necessary. In case of boreholes with single packers, the tests may proceed in drilling direction, in case of boreholes with double packers, the tests may be carried out in reverse direction following the completion of a borehole.

6.4.2 EXECUTION OF WATER PRESSURE TESTS

Installations for water pressure tests are to be designed for a maximum pressure of 25 bar. The pressure is measured with a pressure gauge. The water consumption is determined by use of a water meter. The water pressure applied is measured at the borehole mouth. Additionally, the following data are to be recorded at each test:

- Elevation of pressure gauge = borehole mouth
- Elevation of packer
- Pressure loss in pipe from borehole mouth to discharge through holes in sealing element (calibration of sealing element)

The pressure to be applied depends on the hydrostatic pressure prevailing in joints and voids. The pressure stages are determined on the basis of the maximum pressure, with the first stage amounting to a quarter and the second stage amounting to one half of the maximum pressure. The third pressure stage corresponds to the maximum pressure selected. On the falling side, in turn, half of the maximum pressure and at the last stage a quarter thereof are to be applied. Measurements may only be commenced after a state of equilibrium has been established, i.e. as soon as the pressure gauge indicates a steady pressure and the discharge of water is constant. At that point, the pressure has to be maintained for 5 minutes and the amount of water injected must be read from the water meter.

The results yielded by the water pressure tests shall be recorded in graphic form with all the characteristic data being included in the respective log. The graphic representation should be in the form of a pressure/flow rate diagram.

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7. Measurements

The quantity survey unit of the grouting measures shall be

- t (weight) for the materials,
- m (length) for the drilling of boreholes, differentiating between drilling inside the tunnel in all directions and drilling from the ground surface and graded in such steps as "up to 5 m, up to 10 m, up to 15 m, up to 30 m".
- h (time) for the ground injecting in phases, the time basis being the pump's operation time.
- piece for the delivery and appropriation of the whole equipment to the execution site and between the execution sites

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

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German Standards

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PR-00-5007
Interface Grouting

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of interface grouting measures for the prestressing of the final lining of the Diversion Tunnel of the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) joint installation of grouting hoses and waterproofing system

c) mixing of required grouting components (materials)

d) injection of annular space between shotcrete lining and waterproofing system at the specified pressure

e) quality control for material and workmanship.

The Scope of Work is defined for the Diversion Tunnel during construction of the final lining.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 GROUT HOSES

Synthetic pipes, with a nominal internal diameter of 15 mm and a wall thickness of approx. 3 mm, shall be provided at the interface between the shotcrete lining and the waterproofing membrane of the tunnel. The installation shall be carried out together with the installation of the waterproofing system.

The grout hoses are generally installed in rings at a uniform spacing along the tunnel.

1.3.2 MANCHETTES

The grout hoses are fitted with reinjectable outlet valves, termed manchettes, comprising 5 mm thick soft rubber sleeves, 200 mm long and covering groups of three 5 mm diameter holes drilled at intervals along the pipe. The manchettes are generally spaced at 3,000 mm centres and are fixed in position to prevent sliding.

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1.3.3 PVC JACKETS

To facilitate the distribution of grout into the interface, the grout hoses fitted with the manchettes are installed in a jacket of PVC sheet with a thickness of 250 microns and a circumference of 900 mm. The jackets have been carefully fixed to the prepared surface through metallic strips approximately spaced at 500 mm centres.

1.3.4 CONNECTION POINTS

The ends of the grout hoses, which shall stick out of the Diversion Tunnel's final lining concrete face, shall be provided with a 25 mm diameter I.S.O. or similar female threaded socket fitted with a screwed plug and installed flush with the concrete surface.

The Contractor shall provide suitable tools and equipment to make all connections necessary to these embedded sockets during interface grouting operations. Care shall be exercised at all times to avoid damage to the permanently embedded sockets.

The sockets shall be closed with caps once the interface grouting operation is finished.

1.3.5 GROUT BLOCKING RINGS

For the grout not to proceed too far from the points of injection, grout blocking rings shall be installed every 12 m. A grout blocking ring consists of a piece of geotextile fleece, which is not backed by any synthetic material. The geotextile fleece is folded to not less than four layers and fixed to the shotcrete surface around the circumference of the tunnel.

1.3.6 GROUTING COMPONENTS

The main components are:

- water
- cement

The individual components are specified in the Subchapter 2, **Materials**

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements, as well as the Engineer's instructions.

The Contractor shall provide his personnel with the know-how and equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way. All interface grouting operations on site shall be performed by skilled workmen under the direct and continuous guidance and supervision of foremen and engineers relying on extensive experience in this type of work.

Before commencing the interface grouting works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the

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grouting work stages, the selection of grouting material, as well as the injection pressures and rates to be applied.

Interface grouting shall only be commenced once contact grouting has been completed and once the specified concrete strength for the final lining has been attained.

2. Materials

2.1 General

The suitability of the individual materials for the respective ground and the grouting operation must be verified by testing.

2.2 Water

The water used for grouting works must not contain more than 1.5 ‰ of soluble substances. The percentage of sulfates must be below 1 ‰. Water polluted by organic substances is not suitable for the execution of grouting works. In order to determine chemical processes in the water, adequate water analyses shall be carried out prior to the works.

The water temperature during mixing and grouting shall range between 5°C and 25°C.

2.3 Cement

Ordinary Portland cement with a suitable fineness of grinding shall be used. The Blaine value shall at least amount to 3200 cm^2 / g. The quality strength of the cement (strength, hardening time) shall correspond with the working conditions required and the ultimately pressure required.

2.4 Suspensions

The water/binder ratio of the suspension shall range between 0.5 and 2.0. Suspensions with a larger water content are not admissible.

The suitable water/binder ratio in the different pressure stages shall be examined by trials.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

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3.1 Grout Mixer

A two-compartment high-speed colloidal mixer such as the Colcrete mixer or any equivalent shall be used for grout mixing. The grout shall be mixed in one compartment and discharged through strainers into a holding tank of suitable capacity. From the holding tank the grout shall pass through further strainers into the suction end of the grout pump. Provision shall be made to keep the grout in the holding tank continuously agitated by mechanical means.

The mixer(s) shall be of sufficient capacity to ensure that the grout pumps do not run dry at any time.

3.2 Pumping System

The grout shall be injected by means of an approved double-acting reciprocating pump or any other type of approved pump, equipped with interconnecting pipes and valves in a way permitting a stand-by pump and water supply equipment to be brought into immediate service as may be necessary to provide continuous injection of a hole or connection point. Grout pumps shall be capable of smoothly injecting grout at any pressure up to 30 bar. Air vessels shall be incorporated in the equipment arrangement to dampen surges in grouting pressure.

Pressure relief valves shall be incorporated in the system to avoid the possibility of injection at pressures in excess of that specified or instructed for the point being grouted.

The grouting equipment shall be such that the rate of delivery and/or pressure can be readily and precisely adjusted down to zero flow and that the grout consistency can be readily adjusted without causing any interruption of sufficient duration to allow the pumped grout to set.

For interface grouting through grout hoses, it is envisaged that the main grout mix is pumped with the aid of high-pressure pumps to a holding tank with mechanical agitation, forming a component of the local underground grouting unit. The capacity of the transport pumps shall be equal to twice the capacity of the underground grouting unit.

At the underground working point in the tunnel, for example, not less than three grouting pumps (plus stand-by pumps) each with a minimum capacity of one litre per second at 30 bar allowing good pressure control (such as Peroni pumps) shall be provided. A properly functioning pressure relief valve shall be fitted on each pump delivery to control and limit the grouting pressure.

For filling and pressurising the grout hoses and grout seals ahead of an interface grouting operation and for flushing the grout hoses after grouting a separate hydraulic pump (20 bar capability) with a capacity of five litres per second shall also be provided at each working location.

3.3 Injection Capacity at Working Point

Each grouting unit installed at the individual points of injection, including the mixing plant or the holding tank, the pump and the associated pipes shall be capable of delivering not less than 60 litres of liquid grout per minute at a pressure of 30 bar.

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For interface grouting operation, the delivery capability of the grouting unit provided at the working point shall not be less than 180 litres of liquid grout per minute at a pressure of 30 bar when utilising three injection pumps in parallel.

The actual quantity of grout required per minute shall be validated at the interface grouting trials to be carried out.

3.4 Water Tank

Each and every grouting unit employed on site shall include a water storage tank of adequate capacity to be used for a flushing of the pumps, pipes and grout hoses, etc.

3.5 Mobile Grouting Platforms

The use of mobile grouting platforms by the Contractor is envisaged for an efficient working performance in the tunnels. Only suitable mobile platforms shall be employed to move injection equipment into position in order to avoid damage to the finished surfaces of the concrete lined Diversion Tunnel. All mobile platforms shall be provided with suitable hauling and braking devices.

3.6 Grouting Communication

Where the various elements of a grouting unit are located in such positions that verbal communication at normal voice level between the pump and the hole or connection point to be grouted is not satisfactory, the Contractor shall install a verbal communication such as a telephone and shall operate and maintain the communication equipment to ensure efficient and satisfactory service at all times.

3.7 Measuring Facilities

Pressure gauges shall be fitted to the grout pump and to a point approximately one meter ahead of the grout hose connection point.

A pressure/time diagram recording plotter of approved make shall be installed at a position approved by the Engineer on the delivery pipe from each pump injecting grout.

A water meter of approved type, indicating quantities of half a litre, shall be installed in all supply mains to measure the mixing water.

A flow meter to measure the grout volume injected during interface grouting operations shall be installed in the pipework arrangement for each grouting unit.

The Contractor shall arrange for an adequate number of pressure gauges, pressure/time diagram recording plotters including charts, water meters and flow meters correctly calibrated to be available on site, preventing grouting operations to be held up at any time due to a lack of accurately calibrated instruments.

The pressure gauges shall have a range not exceeding twice the expected maximum pressure for a particular grouting stage and shall have an accuracy of plus / minus three per cent.

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Two certified pressure gauges together with calibration equipment by an approved authority for re-calibration purposes and one hundred per cent replacement stock of working pressure gauges shall be on hand at all times. The certificated pressure gauges shall not be used for grouting.

Working pressure gauges shall not be used for longer than two twelve hour shifts after which time they shall be cleaned and re-calibrated. All working gauges shall be clearly numbered for identification purposes.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

5.1 Grouting Works

The composition of the grout mixture for interface grouting operations shall be approved by the Engineer.

Interface grouting of a defined section of the works shall be carried out without interruption day and night until completed.

At the point of injection, one end of each segment of the grout hose ring shall be connected to one grouting pump. The other end of each segment shall be connected to the return flow manifold and shall lead to a holding tank. Each preset ring shall be equipped with stop valves and pressure gauges. Alternatively a four-way valve arrangement allowing control of the grouting operation from the pump may be approved for adoption.

Generally three preset rings in the tunnel shall be interconnected and grouted simultaneously, requiring a grouting unit of three working pumps. The preset rings shall be connected at alternate positions, in a way that every other ring is grouted clockwise or anticlockwise respectively.

The grouting operation shall commence at the first group of preset rings with full pump capacity. As the absorption of grout decreases, the injection pressure slowly increases. To prevent clogging of the preset rings in those sections of the pipe where there may be little or no flow, the stop valves at the return flow end of the preset ring shall be opened briefly to purge the line. This operation shall be repeated at ten minute intervals or at such intervals as on-going experience indicates to be adequate.

When the specified pressure is reached and no more grout is absorbed, the grouting pump shall be disconnected, flushed with water and connected to the other end of the preset ring, where the same procedure is applied in reverse direction of the preset ring. When the specified pressure is reached again and no more grout is absorbed, the grouting pump shall be disconnected and leapfrogged forward to be connected to the next grout hose.

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The grouted ring shall be flushed with water and the embedded sockets shall be closed off with permanent screw plugs. In case of satisfactory results of the interface grouting operation and if the preset grouting ring is not anticipated to be used again, final flushing with water will not be required.

Generally, the injection shall be judged to be satisfactory if the grout take on any ring drops to below one litre per minute at the specified pressure.

Generally the speed of grouting advance along the Diversion Tunnel should not exceed three to four metres per hour.

It is anticipated that the interface gap induced by the specified grout pressure will be in the order of 2 - 3 mm, equivalent to a convergence of 3 - 5 mm on the internal diameter of the Diversion Tunnel's final concrete lining. The Contractor shall plan his operations in the tunnel to cater for a total rate of grout injection of up to 8,000 litres of fluid mix per hour at the start of grouting when the pressures will be much less than the specified maximum.

In the event that the surrounding rock absorbs only a small quantity of grout and the specified pressure is likely to be attained rapidly, the injection rate shall be reduced to permit a dissipation of excess water to take place and to maintain the four metre speed of advance mentioned previously.

In the event that the grout travel is not sufficiently restricted due to leakage into fissures or through the final concrete lining and the pressure is unable to build up to the specified maximum or the anticipated convergence of the lining is not obtained, the injection of grout shall be stopped and the preset grout hose rings shall be flushed out. After a period of three hours or any other period determined by the Engineer, the preset rings shall be pressurised with water and the manchettes shall be cracked open to ensure that they will be reinjectable.

When directed by the Engineer within a period of 24 hours, the preset rings shall be reconnected and grout injection shall recommence.

This procedure shall be repeated as necessary until the specified pressure is maintained and/or the anticipated convergence is achieved.

In the event that interruption to the work is unavoidable through causes beyond the control of the Contractor, the grouting of the last preset ring shall be finished in the specified manner and flushed out.

After such an interruption the grouting shall be restarted approximately 10 metres ahead of the section previously injected and carried out in a backward direction with a single grout pump until the last completely injected preset ring has been reached. The remaining grouting pumps shall normally be used in the forward direction where this is practicable in the Diversion Tunnel.

Any significant leakage from the final concrete lining which is not self-sealing shall be by-passed and treated and the area shall be grouted again through flushed out preset rings until the specified pressure and/or convergence is attained.

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5.2 Grouting Procedure

Where shown on the drawings, interface grouting through grout hoses shall be carried out to prestress the rock surrounding the concrete lining and to prestress the final concrete lining in a way that internal water pressure shall not cause adverse cracking of the final concrete lining.

The grouting works shall be carried out making initial injections in every second ring. The remaining rings in between shall be used as back-up system. If satisfactory convergence of the final concrete lining is not obtained, the back-up rings shall be grouted as directed by the Engineer.

5.3 Monitoring

A detailed log containing information on the grouting works executed shall be prepared separately for each single pressure ring and shall be submitted to the Engineer. The log is to contain the following information:

- Reference number and location of grouted preset rings.
- Details of grout injections indicating pressures, grout consistencies, grout volumes injected, quantities of material injected and injection times throughout the period of injection.
- Details of grouting processes adopted, surface leaks, interconnections and reflux.
- Charts from the recording pressure gauges.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

6.1 Grouting Trials

6.1.1 PURPOSE OF TRIALS

The trials are designed to establish operational procedures for the interface grouting to ensure optimum prestressing of the linings in the Diversion Tunnel.

6.1.2 SCOPE OF TRIALS

It is intended that the trials will be carried out on seven 12-metre-long adjacent concrete bays approx. at km 7.3 in the Diversion Tunnel.

6.1.3 PROCEDURES

Before embarking on the trial grouting, the Contractor shall - in consultation with the Engineer - develop a detailed statement of the procedures to be followed during the grouting trials.

The trial grouting will provide the following information:

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(a) Suitability of grout and interface grouting arrangement

(b) Pressure required to initiate grout travel

(c) Rate of travel and how it may be controlled by injection procedures

(d) Grout take with respect to geological conditions

(e) Asymmetrical deformation of the lining and how this may be controlled

(f) Number of rings to be injected at any one time and pressures in individual rings

(g) Monitoring procedures

(h) Adequacy of acceptance criteria

The trials will be evaluated by the Engineer by means of instrumentation installed within the concrete lining and surrounding rock as well as by grout injection characteristics.

The results of this evaluation will be used to develop optimum operational procedures.

6.1.4 INSTRUMENTATION

A typical instrumentation layout is shown on proposal drawing PD-01-1008. Each instrumented cross-section will be in the centre of a 12 metre concrete bay. The scope of the instrumentation shown corresponds to the sections, subjected to the highest stresses. Other sections will be similar but will involve fewer instruments.

6.2 Quality Control of Works

In order to check the efficiency of the grouting measures, monitoring will be carried out at representative locations in the Diversion Tunnel. This monitoring will typically involve the following methods:

(a) Verification of available records

(b) Precise monitoring of convergence in vertical and horizontal axes during grouting of a section.

(c) Piezometer measurements at locations where such instruments have been installed, prior to concreting, to observe tunnel conditions.

(d) Extensometer measurements at locations where such instruments have been installed, prior to concreting, to observe tunnel conditions.

7. Measurements

The quantity survey unit of the grouting measures shall be

- m^3 (volume) for the suspension,
- h (time) for the injection in phases, the time basis being the pump's operation time.

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8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

European Standards

* * *

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PR-00-5008 Rev 1
Concrete Works Final Lining

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the final lining for the Diversion Tunnel at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) installation of formwork required

c) execution of concrete works

d) quality control for workmanship and material.

The Scope of Work is defined for the Diversion Tunnel during the construction of the final lining.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 FINAL LINING CONCRETE

For the concrete composition, Canadian standards shall mainly be applicable. A concrete with high abrasion resistance shall be produced. In addition to this, the following requirements shall be met:

- The release strength (= concrete strength at formwork removal) shall be 3 MPa, reached after 12 hours.
- The concrete composition shall be selected in such way that development of internal restraint stresses as a result of hydration will be minimized and the required release strength of 3 MPa will be reached within said 12 hours, without it being significantly exceeded.
- The concrete composition shall be suited to meet the respective seasonal conditions (summer, winter).
  Should this not be possible with one composition, two special compositions shall be developed.

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- The concrete composition shall consider the placing of concrete behind the horse-shoe shaped formwork. Especially the flow characteristics and the concrete's "bleeding" effect will have to be taken into account.

The concrete bay length is planned to be 12 m at a maximum. The final concrete lining will not be reinforced. The final lining will be prestressed with high-pressure grouting at the interface between the waterproofing membrane and the shotcrete lining.

1.3.2 FORMWORK

A formwork with a smooth surface shall be used. Special attention is to be paid to the sealing of joints and to the concreting windows. The shutter length (= formwork construction length) should be in the range of 12 m.

Both, formwork and formwork joints will have to be completely tight to prevent the leakage of grouting material. Both, formwork joints and formwork skin joints will have to be spaced at regular intervals.

Preference is given to steel formwork. Wooden formwork may not be exposed to the sun and to wind for excessive periods of time. The formwork should be fixed on a shutter which is designed to the requirements of the concreting procedure.

Within the formwork skin, windows and hoses for concreting behind the formwork have to be provided in sufficient number and in a way ensuring a sufficient filling of the concrete bay under all project conditions.

The formwork system in general is subject to the Engineer's approval.

1.3.3 JOINTS

All joints shall be butt joints and placed according to the drawings.

Due to the tunnel alignment and the straight course of the formwork, there will be an offset within the joints in the curves. This offset size should be minimized by readjusting the shutter and shall not exceed 77 mm (theoretical value) at a maximum.

1.3.4 CURING

Until the concrete is sufficiently hardened, it is to be protected against detrimental influences – for example excessive warming, drying out due to sun or wind, running water, chemical attack, frost.

1.3.5 CONTACT GROUTING

Following the concrete setting, there will be some porous cavities especially in the crown of the tunnel. These cavities will have to be filled with grout. For this task to be accomplished, hoses will be installed in the crown behind the final concrete lining, attached to the waterproofing membrane. Fittings will be provided at each end of the concrete bay.

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Along the hoses, rubber sleeves with grout flow openings will be installed at a mutual spacing of less than 3 m.

1.3.6 INTERFACE GROUTING

For a pre-stressing of the final concrete lining, high-pressure grouting at the interface of the waterproofing system and the shotcrete lining will be carried out. For this task, a separate specification is available.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the know-how and equipment necessary in accordance with the Specification and shall grant them access to the works to enable them carry out their work in a safe and proper way.

Before commencing the concrete works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

2. Materials

2.1 Aggregates

Aggregates shall be taken from a source approved by the Engineer. The mixture of the aggregates shall be uniform without gap grading. The gravel (coarse) fraction shall be of cubic crushed or rounded form.

Aggregates shall be hard, durable, non-porous and clean and shall not be chemically reactive. They shall not contain any deleterious material in sufficient quantity to adversely affect the strength at any age or the durability of the concrete or to cause corrosion of reinforcement.

The grading and the shape of the aggregates shall be such that a concrete can be produced with the specified proportions and consistency, which will readily work into position without segregation and without the use of excessive water and which can readily be compacted into a dense impervious mass.

The nominal maximum aggregate size shall be 16 mm. The gravel fraction of the aggregate shall not exhibit excessive fragmentation during delivery. The percentage of brittle grains shall be less than 5 %. The percentage of particles smaller than 0.06 mm, which can be washed away, shall not exceed 1 %.

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Sand and gravel shall be clean. Frozen aggregates shall not be used. The minimum permissible temperature shall be + 3°C. Should the aggregates be warmed using steam, special attention shall be paid to controlling the moisture content, particularly in the sand fraction.

All aggregates shall have a specific gravity of not less than 26 kN/m^3.

The grading curve shall comply with the curve determined during suitability tests. The deviation of the given specified gradation should not exceed the values listed below.

Table: Deviation from grain particle size

Grain Diameter	Admissible Deviation
0.06 mm	-/+ 1 %
0.25 mm	-/+ 1 %
1 mm	-/+ 2 %
4 mm	-/+ 3 %

2.2 Cement and Cementing Materials

It is of particular importance to use cement of uniform chemical composition and uniform fineness. Before commencement of delivery, the required characteristic values are to be agreed upon by the Engineer with the cement manufacturer. For the entire cement delivered, the manufacturer shall make the cement analyses and the standard test results available.

The cement shall be ordinary Portland cement, rapid hardening Portland cement or Portland pulverized fuel ash cement. The cement type shall be 20 according to the C.S.A. Standard 23.1-00.

In addition, the cement used should satisfy the following requirements:

(a) Initial setting time not less than three hours.

(b) Fineness: Not less than 340 m^2/kg; if content of pulverized fuel ash greater than 20 %, not less than 380 m^2/kg.

(c) Bleeding: not more than 20 cm^3 (Heidelberg Method); if content of pulverized fuel ash greater than 20 %, not more than 15 cm^3.

(d) Compressive strength after one day (24 h ± 1 h) on mortar cubes: not less than 9 N/mm^2

(e) The temperature of the cement at the time of use in the mixing plant must not be higher than 60°C.

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If cementing materials (like fly ash) are used, their suitability to meet the special requirements of the final concrete lining will have to be tested and the results will have to be approved by the Engineer.

2.3 Water

The water shall be clean and free of harmful matter in such quantities, as would affect the properties of concrete in the plastic or hardened state.

The water shall satisfy the requirements of potable water.

2.4 Admixtures

Admixtures added to the concrete, must not affect the concrete's hardening, strength and durability or cause corrosion of the reinforcement.

Chlorides or materials containing chlorides which promote steel corrosion may not be added to reinforced concrete or concrete which comes into contact with reinforced concrete. The prerequisite for the use of admixtures is a qualification test to be performed by the Contractor. The test results must be submitted to the Engineer.

2.5 Concrete

The concrete mix design should meet the following requirements (according to C.S.A 23. 1-00):

- concrete with high abrasion resistance and limited heat of hydration
- water / cement ratio ≤ 0.45
- aggregates size 0 mm to 16 mm
- recommended cement volume 300 kg / m^3
- required release strength 3 MPa after 12 hours
- required characteristic strength 35 MPa after 28 days
- air void content 3% to 6% at a maximum

2.6 Contact Grouting Material

The contact grouting material shall be a cement-water suspension with sufficient fluid characteristics to fill the porous cavities and annular space between the final concrete lining and the waterproofing membrane.

If other materials are used, they have to be consistent with the concrete. The consistency has to be demonstrated by test or by approved documents and the use of alternative materials has to be approved by the Engineer.

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3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

The design and construction of the formwork shutter has to be evaluated by approved documents (calculations and drawings) and a check of the shutter by a Professional Engineer. The results have to be certified by the Engineer.

4. Transport

All single components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

The concrete must not separate while being transported to the construction site and it shall be of the required workability at the location and time of placing.

5. Workmanship

5.1 General

Before starting the concrete works, the Contractor shall develop a concrete works program, which shall contain information on the

- type of concrete production, on site, ready mix
- distance of external plants to the site
- capacity of the mixing plants, additional plants for substitution (incl. distance to the site)
- testing procedure, suitability tests, quality control tests
- thermal development of the concrete during hardening
- schedule of concreting, simultaneous concreting on different sites
- concrete works procedure – use and preparation of formwork, cast in place procedure (progress, vibration, quality supervision)
- formwork replacement (concrete requirements)

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- curing procedure

The concrete works program has to be submitted to the Engineer for approval.

5.2 Formwork

The formwork must be thoroughly cleaned before use. Before concreting, appropriate shutter oil is to be applied in such a way that no concrete sticks to the formwork.

Any formwork support materials subject to rust or corrosion are to be removed upon striking of the formwork. Any reinforcement or support materials remaining in the concrete must be rust and corrosion-proof.

Particular care must be taken in the construction of formwork for the end face of the concrete bays to ensure that the shuttering is especially tight. Without exception, shuttering for end faces must be of smooth-planed boards with parallel, tongue-and-groove jointing; the forms must have a minimum thickness of 20 mm and must be of uniform width. Joints are to be so tight as to be unrecognisable, and the finished wall surface is to be perfectly smooth and even.

The formwork has to be erected and stabilized in such a way, that all stresses and strains caused by the concrete works can be covered. After erection and stabilization, the formwork will be surveyed for to its "correct" installation. The "correct" installation will be approved by the surveyor.

The construction element may only be stripped and the support may only be removed when the concrete has sufficiently hardened. The concrete has sufficiently hardened when the element is strong enough to support all loads, to which it is subjected when stripped, with the prescribed safety.

5.3 Concrete Works

5.3.1 CONCRETE PRODUCTION, SITE MIXING PLANT

The aggregates have to be stored on site in separate boxes for gravel, coarse sand and fine aggregates. They have to be protected against dryness, wetness and freezing. For the production of all types of concrete, the individual aggregate's components are to be measured by weight using automatic dosing equipment.

The cement and the additives shall be stored in such way that they will be protected against seasonal influences and that they will keep their original state of quality at the time of delivery. For the concrete production, the components are to be measured by weight, using automatic dosing equipment.

The concrete mixing plant is to be laid out for a separated and automatic batching of 3 different additives. To permit monitoring of the levels of additives added to the concrete mixture, a transparent gauge glass is to be foreseen.

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The concrete components (cement, aggregates, water and additives) must be measured with an accuracy of 3 %. The weight batching machines shall be carefully maintained and cleaned and provided with simple and convenient means of checking the weighing mechanisms plus they shall be checked when required by the Engineer.

The composition of each type of concrete to be mixed is to be posted at the mixing plant in a clearly legible form and must include the requirements of the given standards. The materials must be mixed in concrete mixers which are suitable for the pertinent concrete composition. The concrete mixer must be equipped with an electrical current indicator to facilitate regulation of the concrete's consistency. If the specific water content of the aggregates varies, the amount of wet material plus the amount of mixing water must always be selected in such a way, that the total amount of water remains constant.

The dimensions of the mixing plant have to be sufficient to deliver enough concrete to all relevant sites at any time of the concreting process. The concrete components and the concrete production have to be protected from extreme weather conditions (heat, rain). Mixing plants for sites located in cold weather areas, which may experience frost periods, are to be equipped with mixing water and aggregate heating systems.

A site laboratory, fully equipped to carry out all concrete and concrete component tests required, is to be set up and operated by experienced personnel. An expert in concrete technology and concrete production shall be in charge of this laboratory.

Test mixes are to be made for each type of concrete. The results are to be submitted to the Engineer. The mixes shall be approved by the Engineer and a trial mix shall be prepared under full-scale conditions, including workability tests and cube testing.

5.3.2 READY-MIXED CONCRETE

The entire ready-mixed concrete shall meet the requirements described in this Specification. In addition to this, the Contractor shall submit the name and address of the ready-mix Contractor to the Engineer for approval, giving all operation and plant details.

The details of the ready-mix Contractor shall include information on the plant, the equipment, the storage depots, as well as the transportation and quality systems. The Engineer shall have access to the ready-mix site for inspection at any time. The Engineer may reject the proposed ready-mix Contractor and may cancel an approval at any time, if the quality of the concrete or the documentation of the quality control is not satisfactory in the opinion of the Engineer.

All testing of the mixed concrete shall be executed on site.

The Contractor shall ensure that the supplier keeps records of all the required tests and the quality control for mixing and transportation.

The concrete shall be delivered to the site in truck mixers or agitators which are continuously in operation. Each batch delivered must be accompanied by a certificate containing the following information:

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- Name of supplier
- Type and grade of concrete
- Mix code number
- Time and date of mixing
- Temperature of mixing
- Additives
- Cement type
- Cement content
- Water cement ratio or quantity of added water
- Time of arrival of truck on site
- Time of end of discharge
- Registration number of truck
- Delivery certificate number

The certificates shall be available to the Engineer for quality supervision.

Any addition of water and admixtures to the concrete after the concrete has been discharged from the mixing plant shall not be accepted.

5.3.3 CONCRETING PROCEDURE

The concrete workability shall remain satisfactory until placing and compaction is finished. This shall at a minimum be 3 hours at 25°C upon arrival on site, this shall also be true for hot weather periods.

During cold weather and frost periods, the concrete shall be placed at a specified minimum temperature because of the lower hardening rate and the danger of permanent impairment of defined concrete properties. With ambient temperatures of +5°C to –3°C, the concrete temperature upon placing must not fall below +5°C. With ambient temperatures below –3°C, the concrete temperature must not fall below +10°C.

During hardening, the concrete temperature may not exceed 50°C.

Before the concrete is placed, all formwork elements and surfaces to come into contact with the concrete shall be cleaned from dust, mud and other impurities. The concrete shall not be placed in standing water unless this has been specified or approved.

During placing, suitable means shall be provided to prevent premature hardening of the concrete put in contact with hot surfaces.

When placing concrete in layers, if no construction joints are foreseen, the placing may only be interrupted for a period of time during which the concrete does not set, so that a good and even connection is possible between the two layers of concrete. The concrete shall be placed in layers of such depth that the new layer will be readily and properly mixed with the previous layer below by the use of vibrators. The difference in height of the layer's level on the right hand sidewall and the left hand sidewall of the final lining may not exceed 1 m.

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Concreting shall begin in the bottom parts of the sidewalls and shall finish in the crown. Normally the concrete shall be pressed into the formwork. If the formwork is filled by gravity flow, the concrete's height of fall shall not exceed 1 m.

The type and number of vibrators shall be approved by the Engineer and shall consider the mass and quality of concrete to be compacted and the type of formwork.

The formwork shall be released, when the final concrete lining meets its release strength, measured in the crown by suitable means of measurement.

5.3.4 CURING

The curing of the final lining surface will start immediately after the formwork is released.

When water curing is applied, chill shocks are to be avoided (as could occur when cool water comes into contact with warm concrete surfaces) due to the resulting danger of peeling or scaling. The quality of water used for curing shall be the same as that used for concrete mixing. If liquid membranes are used, they must not affect the normal setting reaction of cement. Compounds incorporating reflective, white or light-coloured pigments shall be used.

The methods of preventing the concrete from prematurely drying are to be submitted to the Engineer for approval before use.

The concrete must be cured during the first four days.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

During the entire period of construction, the Contractor will have to verify the material properties and qualities as defined by the Specifications and Standards.

In addition to the tests and investigations contained in the Specifications and Standards, all other tests deemed necessary by the Engineer are to be performed.

Records are to be kept of all test results and submitted to the Engineer. The Contractor shall grant the Engineer full access to and use of the laboratory and shall produce on demand the records of all tests carried out.

6.1 Suitability Tests

6.1.1 CONCRETE COMPONENTS

No aggregates shall be delivered to the site without satisfactory initial sampling and testing. The sample of fine aggregate shall be 25kg in weight and that of the coarse aggregate shall be 50kg in weight.

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The Contractor's attention is drawn to the need to maintain a consistent aggregate quality and he will be expected to undertake adequate testing to ensure that the quality does not vary significantly (reference is made to Subchapter 6.2, **Quality Control Tests**).

All components have to be certificated for their origin and quality. The suitability of the components used has to be approved by the Contractor's concrete expert and by the Engineer.

6.1.2 CONCRETE

In order to verify the suitability of the concrete compositions for the respective task, tests at the site or the mixing plant have to be carried out for both designed concrete compositions (winter and summer composition). The following items have to be tested using three samples per item under the mentioned conditions:

- Bulk density
- Air void content (= 3% to 6 %, maximum)
- Consistency immediately after mixing and one hour later (= class F3; DIN 1045-2)
- Release strength after 12 hours (= 3 MPa)
- Characteristic strength after 28 days (= 35 MPa)
- Characteristic strength after 90 days

6.2 Quality Control Tests

6.2.1 AGGREGATES

The following tests have to be carried out with a frequency of "each delivery"

- grading analyses
- wet analyses
- moisture content, for sand
- organic impurities
- visual inspections of aggregate type, granulometric composition, aggregate condition, particle shape, detrimental components (e.g. coal, humic substances, brittle grains, etc.)

The moisture content of the sand is to be checked in addition once a week.

Chloride and sulphate tests have to be carried out once each 4 months and in case of suspected change.

The tests are to be carried out in accordance with DIN EN 12620.

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6.2.2 CEMENT AND CEMENTING MATERIALS

The following tests have to be carried out every 4 months:

- compressive strength
- specific surface
- chemical analysis.

Certificates issued by the supplier shall be tested per storage vessel.

The tests are to be conducted in accordance with the German DIN EN 196 Standard and the requirements of Subchapter 2, MaterialsMaterialsMaterials.

6.2.3 ADMIXTURES

The certificates issued by the supplier have to be checked at each delivery to the site.

6.2.4 CONCRETE

Fresh concrete has to be tested according to the criteria listed below:

testing item	testing frequency	testing procedure	testing moment
consistency	once for every batch on site	acc. to German DIN EN 12350 Standard	before placing of concrete
water / cement ratio	once for every batch on site	by visual inspection	before placing of concrete
unit weight	once for every batch on site	by visual inspection	before placing of concrete
bulk density	three times per concrete bay	acc. to German DIN EN 12350 Standard	during concreting
air void content	three times per concrete bay	acc. to German DIN EN 12350 Standard	during concreting

Hardened concrete has to be tested according to the criteria listed below:

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testing item	testing frequency	testing procedure	testing moment
compressive strength	three times per concrete bay at the crown	with penetration test or pendulum hammer	after 12 h (release strength)
compressive strength	three cubes or cylinders per concrete bay	acc. to German DIN EN 12390 Standard	after 28 days (characteristic strength)
compressive strength	three cubes or cylinders per concrete bay	acc. to German DIN EN 12390 Standard	after 90 days (characteristic strength)
air void content	three times per concrete bay	acc. to German DIN EN 12390 Standard	after 7 days (abrasion resistance)

The testing procedure and interpretation of results is described in the above mentioned references. The limit values of the individual tests are specified in Subchapter 2, MaterialsMaterialsMaterials and Subchapter 6.1, **Suitability Tests**.

6.2.5 CONCRETE WORKS

The minimum radius of the cross-section shall be the design radius. Smaller radii are to be avoided.

If faced with a smaller radius, the following measures will have to be taken:

origin	extension	consequence	check	measures
Local "breakdown" of formwork	limited in size	increase of concrete lining thickness	sufficient thick-ness of concrete lining and sufficient flow volume of cross section	grinding of bulges
	whole concrete bay			if maximum flow can not be achieved, breakdown and reconstruction of concrete bay
wrong alignment of formwork	whole concrete bay	increase / decrease of concrete lining thickness	sufficient thick-ness of concrete lining	if maximum flow can not be achieved, breakdown and reconstruction of concrete bay in any other case, smoothening of the surface as described

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				below.

The minimum thickness of the final concrete lining shall be the design thickness. Any reduction in thickness shall be avoided. Any increase in thickness shall be limited to the design thickness + 10 cm. The space, available for the placing of the final concrete lining has to be proven by survey of the shotcrete lining surface.

Should the required limits not be met (thinner final lining), the area in question should be re-excavated and re-supported. Should the limits be exceeded, the difference between the allowable and the measured thickness shall be compensated by additional shotcrete.

The survey results of the shotcrete surface, as well as the measures to be taken when the limits are exceeded are - in any case - subject to Engineer's approval.

The final concrete lining surface shall be smooth and flat. Wedges and bulges are to be avoided, or smoothened by grinding. Unevenness shall not exceed 4 degrees (angle of gradient) in all directions.

7. Measurements

The quantity survey unit of the concrete for the final lining shall be m^3.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

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8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

CSA 23.1-00:	Concrete materials and method of concrete construction
CSA 23.2-00:	Methods of test for concrete
CSA 23.3-94:	Design of concrete structures

European / German Standards

DIN EN 196	Methods of testing cement
DIN EN 197-1	Cement Part 1: Composition, specifications and conformity criteria for common cements
DIN EN 206	Concrete Part 1: Specification, performance, production and conformity
DIN 1045-1:	Concrete, reinforced and prestressed concrete structures Part 1: Design
DIN 1045-2:	Concrete, reinforced and prestressed concrete structures Part 2: Concrete specification, properties, production and conformity application rules for DIN EN 206-1
DIN 1045-3:	Concrete, reinforced and prestressed concrete structures. Part 3: Execution of structures
DIN EN 12620	Aggregates for mortar and concrete
DIN EN 12350	Testing methods for fresh concrete
DIN EN 12390	Testing methods for hard concrete

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PR-00-5009 Rev 1
Concrete Works Invert Segment

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the invert segment as part of the final tunnel lining for the Diversion Tunnel at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) installation of a plant on site for the prefabrication of the invert segment with the entire equipment required for production and testing

c) production of invert segments, storage and delivery on site

d) installation of invert segments on site

e) quality control for workmanship and materials.

The Scope of Work is defined for the Diversion Tunnel during the construction of the final lining.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 INVERT SEGMENT CONCRETE

For the concrete composition, Canadian standards shall mainly be applicable. A concrete with high abrasion resistance shall be produced.

The invert segments will be prefabricated in a plant on site. The dimensions of the prefabricated invert segments have been documented in the corresponding drawings.

1.3.2 FORMWORK

Sufficient formwork moulds will have to be supplied for the production of the prefabricated invert segment. Steel formwork with a smooth surface shall be used. The formwork moulds shall be equipped with enough vibrators for concrete compacting.

Both, formwork and formwork joints will have to be completely tight to prevent leakage of grouting material. Both, formwork joints and formwork skin joints will have to be spaced at regular intervals.

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The formwork is be thoroughly cleaned before use.

Any formwork support material subject to rust or corrosion is to be removed upon striking of the formwork. Any reinforcement or support material, remaining in the concrete and coming into contact with atmospheric humidity is to be rust and corrosion-proof.

All proposed shuttering details are to be submitted for approval by the Engineer.

The formwork system in general is subject to the Engineer's approval.

1.3.3 JOINTS

All joints are to be butt joints and placed according to the drawings.

Due to the tunnel alignment and the straight course of the invert segment, there will be an offset within the joints in the curves. The offset size should be minimized readjustment and shall not exceed the maximum theoretical value.

1.3.4 CURING

Until the concrete is sufficiently hardened, it is to be protected against detrimental influences – for example excessive warming, drying out due to sun or wind, running water, chemical attack, frost.

1.3.5 PROTECTION SHEET

In order to protect the waterproofing membrane system against damage, a geotextile with an area weight of $\geq$ 750 g / m^2 shall be laid upon the waterproofing membrane prior to the installation of the precast invert segments.

1.3.6 MORTAR BEDDING

The precast invert segments shall be embedded in a mortar bed. The mortar bed shall be provided before the invert segments are installed. The mortar bed shall stabilize the invert segment in its exact position. The thickness shall depend on the surrounding conditions, but shall not exceed 5 cm.

1.3.7 CONTACT GROUTING

Upon installation of the invert segment, there might be a few porous cavities in the mortar bed, caused by the installation procedure. These cavities will have to be filled with grout. For this task to be accomplished, three holes with a diameter of 50 mm are provided in every invert segment.

1.3.8 INTERFACE GROUTING

For a pre-stressing of the final concrete lining, high-pressure grouting at the interface of the waterproofing system and the shotcrete lining will be carried out. For this task, a separate specification is available.

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1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the know-how and equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way.

Before commencing the concrete works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

2. Materials

2.1 Aggregates

Aggregates shall be taken from a source approved by the Engineer. The mixture of the aggregates shall be uniform without gap grading. The gravel (coarse) fraction shall be of cubic crushed or rounded form.

Aggregates shall be hard, durable, non-porous and clean and shall not be chemically reactive. They shall not contain any deleterious material in sufficient quantity to adversely affect the strength at any age or the durability of the concrete or to cause corrosion of reinforcement.

The grading and the shape of the aggregates shall be such that a concrete can be produced with the specified proportions and consistency, which will readily work into position without segregation and without the use of excessive water and which can readily be compacted into a dense impervious mass.

The nominal maximum aggregate size shall be 16 mm. The gravel fraction of the aggregate shall not exhibit excessive fragmentation during delivery. The percentage of brittle grains shall be less than 5 %. The percentage of particles smaller than 0.06 mm, which can be washed away, shall not exceed 1 %.

Sand and gravel shall be clean. Frozen aggregates shall not be used. The minimum permissible temperature shall be + 3°C. Should the aggregates be warmed using steam, special attention shall be paid to controlling the moisture content, particularly in the sand fraction.

All aggregates shall have a specific gravity of not less than 26 kN/m^3.

The grading curve shall comply with the curve determined during suitability tests. The deviation of the given specified gradation should not exceed the values listed below.

Table: Deviation from grain particle size

Grain Diameter	Admissible Deviation

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0.06 mm	-/+ 1 %
0.25 mm	-/+ 1 %
1 mm	-/+ 2 %
4 mm	-/+ 3 %

2.2 Cement and Cementing Materials

It is of particular importance to use cement of uniform chemical composition and uniform fineness. Before commencement of delivery, the required characteristic values are to be agreed upon by the Engineer with the cement manufacturer. For the entire cement delivered, the manufacturer shall make the cement analyses and the standard tests results available.

Cement shall be Ordinary Portland Cement, Rapid Hardening Portland Cement or Portland Pulverized Fuel Ash Cement. The cement type shall be 20 according to the C.S.A. Standard 23.1-00.

In addition, the cement used should satisfy the following requirements:

(a) Initial setting time not less than three hours.

(b) Fineness: Not less than 340 m^2/kg; if content of pulverized-fuel ash greater than 20 %, not less than 380 m^2/kg.

(c) Bleeding: not more than 20 cm^3 (Heidelberg Method); if content of pulverized fuel ash greater than 20 %, not more than 15 cm^3.

(d) Compressive strength after one day (24 h ± 1 h) on mortar cubes: not less than 9 N/mm^2

(e) The temperature of the cement at the time of use in the mixing plant must not be higher than 60°C.

If cementing materials (like fly ash) are used, their suitability to meet the special requirements of the final concrete lining will have to be tested and the results will have to be approved by the Engineer.

2.3 Water

The water shall be clean and free of harmful matter in such quantities, as would affect the properties of concrete in the plastic or hardened state.

The water shall satisfy the requirements of potable water.

2.4 Admixtures

Admixtures added to the concrete, must not affect the concrete's hardening, strength and durability or cause corrosion of the reinforcement.

Chlorides or materials containing chlorides which promote steel corrosion may not be added to reinforced concrete or concrete which comes into contact with reinforced concrete. The

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prerequisite for the use of admixtures is a qualification test to be performed by the Contractor. The test results must be submitted to the Engineer.

2.5 Concrete

The concrete mix design should meet the following requirements (according to C.S.A 23. 1-00):

- concrete with high abrasion resistance
- water / cement ratio ≤ 0.45
- aggregates size 0 mm to 16 mm
- recommended cement volume 300 kg / m^3
- required characteristic strength 35 MPa after 28 days
- air void content 3% to 6% at a maximum

2.6 Reinforcement

The reinforcement steel used, shall be ribbed steel, grade 500 R or 500 W according to C.S.A. Standard 23.1-00.

In order to improve the composite action and to limit the crack formation, small-diameter reinforcement bars with a small spacing shall be used.

The concrete cover shall be sufficient in accordance with the invert segment requirements and in compliance with the design. The sufficient concrete cover shall be ensured by concrete spacers, fixed to the reinforcement in sufficient number.

2.7 Mortar

The mortar for the mortar bedding shall be composed of one part of cement and three parts of sand. The cement shall fulfill the above mentioned requirements. The sand shall consist of naturally occurring sand, of crushed rock or of gravel or a combination thereof. The sand shall be clean, hard and free of impurities. It shall comply with the above mentioned concrete aggregate requirements.

Mortar plasticizer, if used, shall be subject to acceptance by the Engineer and shall be used in the proportions and manner recommended by the manufacturer.

The water content of mortar shall be just sufficient to ensure a dense mortar with adequate workability, when trowelled or worked into place. Mortar that has begun to harden shall not be used in any part of the works.

All materials shall be accurately gauged by gauge boxes and mechanically mixed and used within 30 minutes of first mixing. Retempering of mortar will not be permitted. Gauge boxes and mixers shall be kept clean.

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2.8 Contact Grouting Material

The contact grouting material shall be a cement-water suspension with sufficient fluid characteristics to fill the porous cavities and annular space between the invert segment and the mortar bedding.

If other materials are used, they have to be consistent with the concrete. The consistency has to be demonstrated by tests or approved documents and the use of alternative materials has to be approved by the Engineer.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

The design and construction of the formwork moulds is to be evaluated by approved documents (calculations and drawings) and the moulds are to be checked by a Professional Engineer. The results are to be certificated by the Engineer.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

The concrete must not separate while being transported to the construction site and it shall be of the required workability at the location and time of placing.

The precast invert segments have to be loaded, unloaded and carried on site in such a way, that they and especially their wedges are protected against damage at every time and that these procedures will not cause loading conditions, which are not covered by the calculations and the design.

5. Workmanship

5.1 General

Before starting the concreting works, the Contractor shall develop a concrete works program, which shall contain information on the

- type of concrete production, on site, ready mix
- distance of external plants to the site

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- capacity of the mixing plants, additional plants for substitution (incl. distance to the site)
- testing procedure, suitability tests, quality control tests
- thermal development of the concrete during hardening
- schedule of concreting, simultaneous concreting
- concrete works procedure – use and preparation of formwork, cast in place procedure (progress, vibration, quality supervision)
- formwork replacement (concrete requirements)
- curing procedure

The concrete works program has to be submitted to the Engineer for approval.

5.2 Formwork

The formwork has to be erected and stabilized in such a way that all stresses and strains caused by the concrete works can be covered.

Special attention is to be paid to the sealing of joints and the concreting of windows. The concrete surface must be smooth, free of voids and pores. Any formwork use more than once must be approved by the Engineer.

The construction element may only be stripped and the support may only be removed when the concrete has sufficiently hardened. The concrete has sufficiently hardened when the element is strong enough to support all loads, to which it is subjected when stripped, with the prescribed safety.

Before concreting, appropriate shutter oil is to be applied to ensure that no concrete will stick to the formwork.

Generally, the formwork system (incl. skin) is subject to the Engineer's approval.

5.3 Concrete Works

5.3.1 CONCRETE PRODUCTION, SITE MIXING PLANT

The aggregates have to be stored on site in separate boxes for gravel, coarse sand and fine aggregates. They have to be protected against dryness, wetness and freezing. For the production of all types of concrete the individual aggregate components are to be measured by weight using automatic dosing equipment.

The cement and the additives shall be stored in such way that they will be protected against seasonal influences and that they will keep their original state of quality at the time of delivery. For the concrete production, the components are to be measured by weight, using automatic dosing equipment.

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The concrete mixing plant is to be laid out for a separated and automatic batching of 3 different additives. To permit monitoring of the levels of additives added to the concrete mixture, a transparent gauge glass is to be foreseen.

The concrete components (cement, aggregates, water and additives) must be measured with an accuracy of 3 %. The weight batching machines shall be carefully maintained and cleaned and provided with simple and convenient means of checking the weighing mechanisms plus they shall be checked when required by the Engineer.

The composition of each type of concrete to be mixed is to be posted at the mixing plant in a clearly legible form and must include the requirements of the given standards. The materials must be mixed in concrete mixers which are suitable for the pertinent concrete composition. The concrete mixer must be equipped with an electrical current indicator to facilitate regulation of the concrete's consistency. If the specific water content of the aggregates varies, the amount of wet material plus the amount of mixing water must always be selected in such a way, that the total amount of water remains constant.

The dimensions of the mixing plant have to be sufficient to deliver enough concrete to all relevant sites at any time of the concreting process. All concrete components and the concrete production have to be protected from extreme weather conditions (heat, rain). Mixing plants for sites located in cold weather areas, which may experience frost periods, are to be equipped with mixing water and aggregate heating systems.

A site laboratory, fully equipped to carry out all concrete and concrete component tests required, is to be set up and operated by experienced personnel. An expert in concrete technology and concrete production shall be in charge of this laboratory.

Test mixes are to be made for each type of concrete. The results are to be submitted to the Engineer. The mixes shall be approved by the Engineer and a trial mix shall be prepared under full-scale conditions, including workability tests and cube testing.

5.3.2 READY-MIXED CONCRETE

The entire ready-mixed concrete shall meet the requirements described in this Specification. In addition to this, the Contractor shall submit the name and address of the ready-mix Contractor to the Engineer for approval, giving all operation and plant details.

The details of the ready-mix Contractor shall include information on the plant, the equipment, the storage depots, as well as the transportation and quality systems. The Engineer shall have access to the ready-mix site for inspection at any time. The Engineer may reject the proposed ready-mix Contractor and may cancel an approval at any time, if the quality of the concrete or the documentation of the quality control is not satisfactory in the opinion of the Engineer.

All testing preparation and testing of the mixed concrete shall be executed on site.

The Contractor shall ensure that the supplier keeps records of all the required tests and the quality control for mixing and transportation.

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The concrete shall be delivered to the site in truck mixers or agitators which are continuously in operation. Each batch delivered must be accompanied by a certificate containing the following information:

- Name of supplier
- Type and grade of concrete
- Mix code number
- Time and date of mixing
- Temperature of mixing
- Additives
- Cement type
- Cement content
- Water cement ratio or quantity of added water
- Time of arrival of truck on site
- Time of end of discharge
- Registration number of truck
- Delivery certificate number

The certificates shall be available to the Engineer for quality supervision.

Any addition of water and admixtures to the concrete after the concrete has been discharged form the mixing plant shall not be accepted.

5.3.3 CONCRETING PROCEDURE

The concreting procedure will start once the required reinforcement has been arranged and fixed against displacement during concreting. The formwork and the reinforcement arrangement will have to be checked for compliance with the requirements of the Contractor's Quality Management System. The approval has to be recorded and made available for the Engineer's quality supervision.

The concrete workability shall remain satisfactory until placing and compaction is finished. This shall at a minimum be 3 hours at 25°C upon arrival on site, this shall also be true for hot weather periods.

During cold weather and frost periods the concrete shall be placed at a specified minimum temperature because of the lower hardening rate and the danger of permanent impairment of defined concrete properties. With ambient temperatures of +5°C to –3°C, the concrete temperature upon placing must not fall below +5°C. With ambient temperatures below –3°C, the concrete temperature must not fall below +10°C.

During hardening, the concrete temperature may not exceed 50°C.

Before the concrete is placed, all formwork elements and surfaces to come into contact with the concrete shall be cleaned from dust, mud and other impurities. The concrete shall not be placed in standing water unless this has been specified or approved.

During placing, suitable means shall be provided to prevent premature hardening of the concrete put in contact with hot surfaces.

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When placing concrete in layers, if no construction joints are foreseen, the placing may only be interrupted for such a period of time during which the concrete does not set, so that a good and even connection is possible between the two layers of concrete. The concrete shall be placed in level layers of such depth that the new layer will be readily and properly mixed with the previous layer below by the use of internal vibrators.

The type and number of vibrators shall be approved by the Engineer and shall consider the mass of concrete to be compacted, the density of reinforcement, and the type of formwork.

The formwork shall be released, when the invert segments meet the required strength. The required strength shall be calculated and the corresponding period shall be verified by suitability tests.

5.3.4 CURING

The invert segment will be kept in the formwork until the required release strength for the formwork is reached. The curing measures for the surface, which is not covered by formwork, have to be started immediately after concreting is finished.

When water curing is applied, chill shocks are to be avoided (as could occur when cool water comes into contact with warm concrete surfaces) due to the resulting danger of peeling, or scaling. The quality of water used for curing shall be the same as that used for concrete mixing. If liquid membranes are used, they must not affect the normal setting reaction of cement. Compounds incorporating reflective, white or light-coloured pigments shall be used.

The concrete has to be cured until the formwork is released.

5.3.5 STORAGE

The prefabricated invert segments are to be stored in a way protecting them against any kind of damage. To minimize internal stress and strain conditions during storage, they have to be supported by wooden line bearers, arranged in the third points of the curved part.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

During the entire period of construction, the Contractor will have to verify the material properties and qualities as defined by the Specifications and Standards.

In addition to the tests and investigations contained in the Specifications and Standards, all other tests deemed necessary by the Engineer are to be performed.

Records are to be kept of all test results and submitted to the Engineer. The Contractor shall grant the Engineer full access to and use of the laboratory and shall produce on demand the records of all tests carried out.

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6.1 Suitability Tests

6.1.1 CONCRETE COMPONENTS

No aggregates shall be delivered to the site without satisfactory initial sampling and testing. The sample of fine aggregate shall be 25kg in weight and that of the coarse aggregate shall be 50kg in weight.

The Contractor's attention is drawn to the need to maintain a consistent aggregate quality and he will be expected to undertake adequate testing to ensure that the quality does not vary significantly (reference is made to Subchapter 6.2, Quality Control TestsQuality Control TestsQuality Control Tests).

All components have to be certificated for their origin and quality. The suitability of the components used has to be approved by the Contractor’s concrete expert and by the Engineer.

6.1.2 CONCRETE

In order to verify the suitability of the concrete compositions for the respective tasks, tests at the site or at the mixing plant have to be carried out for both designed concrete compositions (winter and summer composition). The following items have to be tested using three samples per item under the mentioned conditions:

- Bulk density
- Air void content (= 3% to 6 %, maximum)
- Consistency immediately after mixing and one hour later (= class F3; DIN 1045-2)
- Characteristic strength after 28 days (= 35 MPa)

6.1.3 MOMENT OF FORMWORK RELEASE

The required concrete strength has to be calculated, considering all loading conditions of the invert segment during the hardening period.

The moment of formwork release has to be determined by concrete strength tests after 3 days, 7 days and 28 days. The tests have to be carried out using three samples per test. The required strength and the corresponding moment have to be analyzed by interpretation of the test results.

6.2 Quality Control Tests

6.2.1 AGGREGATES

The following tests have to be carried out with a frequency of “each delivery”

- grading analyses
- wet analyses
- moisture content, for sand

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- organic impurities
- visual inspection of aggregate type, granulometric composition, aggregate condition, particle shape, detrimental components (e.g. coal, humic substances, brittle grains, etc.)

The moisture content of the sand is to be checked in addition once a week.

Chloride and sulphate tests have to be carried out once each 4 months and in case of suspected change.

The tests are to be carried out in accordance with DIN EN 12620.

6.2.2 CEMENT AND CEMENTING MATERIALS

The following tests have to be carried out every 4 months:

- compressive strength
- specific surface
- chemical analysis.

Certificates issued by the supplier shall be tested per storage vessel.

The tests are to be conducted in accordance with the German DIN EN 196 Standard and the requirements of Subchapter 2, MaterialsMaterialsMaterials.

6.2.3 ADMIXTURES

The certificates issued by the supplier have to be checked at each delivery to the site.

6.2.4 CONCRETE

Fresh concrete has to be tested according to the criteria listed below:

testing item	testing frequency	testing procedure	testing moment
consistency	once for every batch on site	acc. to German DIN EN 12350 Standard	before placing of concrete
water / cement ratio	once for every batch on site	by visual inspection	before placing of concrete
unit weight	once for every batch on site	by visual inspection	before placing of concrete
bulk density	three times per invert segment	acc. to German DIN EN 12350 Standard	during concreting
air void content	three times per invert segment	acc. to German DIN EN 12350 Standard	during concreting

Hardened concrete has to be tested according to the criteria listed below:

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testing item	testing frequency	testing procedure	testing moment
compressive strength	three cubes or cylinders each 10th invert segment	acc. to German DIN EN 12390 Standard	after 28 days (characteristic strength)
compressive strength	three cubes or cylinders each 10th invert segment	acc. to German DIN EN 12390 Standard	after 90 days (characteristic strength)
air void content	three times per invert segment	acc. to German DIN EN 12390 Standard	after 7 days (abrasion resistance)

The testing procedure and interpretation of results is described in the above mentioned references. The limit values of the individual tests are specified in Subchapter 2, MaterialsMaterialsMaterials and Subchapter 6.1, Suitability TestsSuitability TestsSuitability Tests.

6.2.5 CONCRETE WORKS

The minimum thickness of the final concrete lining shall be the design thickness. Any reduction in thickness shall be avoided. Any increase in thickness shall be limited to the design thickness + 10 cm. Tolerances in extension, length, width, shall not exceed 10% of the original (design) dimensions.

Should the required limits not be met (thinner invert segment), the related segment will have to be built a second time.

The final lining surface of the installed segments shall be smooth and flat. Wedges and burrs are to be avoided, or smoothened by grinding. Unevenness shall not exceed 4 degrees (angle of gradient) in all directions.

7. Measurements

The quantity survey units may be described as follows

- concrete for invert segment = m^3
- reinforcement = ton
- mortar for mortar bedding = m^2
- protective sheet = m^2

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8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

CSA 23.1-00:	Concrete materials and method of concrete construction
CSA 23.2-00:	Methods of test for concrete
CSA 23.3-94:	Design of concrete structures

European / German Standards

DIN EN 196	Methods of testing cement
DIN EN 197-1	Cement Part 1: Composition, specifications and conformity criteria for common cements;
DIN EN 206	Concrete Part 1: Specification, performance, production and conformity
DIN 1045-1:	Concrete, reinforced and prestressed concrete structures Part 1: Design

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DIN 1045-2:	Concrete, reinforced and prestressed concrete structures Part 2: Concrete Specification, properties, production and conformity application rules for DIN EN 206-1
DIN 1045-3:	Concrete, reinforced and prestressed concrete structures . Part 3: Execution of structures
DIN EN 12620	Aggregates for mortar and concrete
DIN EN 12350	Testing methods for fresh concrete
DIN EN 12390	Testing methods for hard concrete

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PR-00-5010
Concrete Works Intake, Outlet Structures

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the concrete works for the intake and outlet structures at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the equipment required to the site

b) installation of required formwork

c) execution of concrete works

d) quality control for workmanship and material.

The Scope of Work is defined for the concreting of the intake and outlet structures.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 OUTLET STRUCTURE

The outlet structure shall be built in a watertight manner concerning both concrete composition and construction.

In addition to these requirements, the concrete composition shall meet the C.S.A. requirements for resistance against thawing and freezing.

1.3.2 INTAKE STRUCTURE

The intake structure shall be built in a watertight manner concerning both concrete composition and construction.

In addition to these requirements, the concrete composition shall meet the C.S.A. requirements for resistance against thawing and freezing, as well as the requirements for resistance against severe sulphate attack.

1.3.3 CONCRETE SUBBASE

The concrete subbase is a layer of lean concrete, arranged beneath the invert of the structure. It serves the task of leveling the excavated underground surface and of allowing an exact and

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proper arrangement of the required reinforcement. It moreover ensures a continuous bedding of the structure's invert.

The thickness of the subbase concrete shall not exceed 10 cm on average.

1.3.4 CONCRETE FILL

The concrete fill is a lean concrete layer, placed on the bottom of the canal to protect the Rochester Shale surface and to level out the invert of the canal. The minimum thickness of the concrete fill shall be 5 cm.

1.3.5 1ST STAGE INVERT CONCRETE

The 1st stage invert concrete is part of the final structure and shall be watertight. It shall be installed immediately after excavation. It shall take on the loads caused by the installation and the launching of the Tunnel Boring Machine (TBM). The 1st stage invert concrete shall be reinforced concrete in accordance with the design requirements.

1.3.6 2ND STAGE INVERT CONCRETE

The 2nd stage invert concrete serves the completion of the invert within the shaft structure to the final invert level. The 2nd stage invert concrete shall meet the requirements with respect to surface evenness and smoothness stipulated by the flow criteria. The 2nd stage invert concrete shall be watertight and shall consist of reinforced concrete in accordance with the design requirements.

1.3.7 CAST-IN-PLACE CONCRETE

Cast-in-place concrete specifies the other parts of the structure (shaft walls, linings of cross-sections) which are not described above. It will be placed upon completion of the excavation and support period of the Diversion Tunnel. The cast-in-place concrete shall meet the requirements with respect to surface evenness and smoothness stipulated by the flow criteria. The cast-in-place concrete shall be watertight and shall consist of reinforced concrete in accordance with the design requirements.

1.3.8 FORMWORK

Formwork with a smooth surface shall be used. Special attention is to be paid to the sealing of joints and concreting windows. The shutter length (= formwork construction length) should be in the range of 5 m.

Both, formwork and formwork joints will have to be completely tight to prevent the leakage of grout material. Both formwork joints and formwork skin joints will have to be spaced at regular intervals.

Preference is given to steel formwork. Wooden formwork may not be exposed to the sun and to wind for excessive periods of time. The formwork shall be fixed on a shutter which is designed to the requirements of the concreting procedure.

Within the formwork skin, windows and hoses for concreting behind the formwork shall be provided in sufficient number and in a way ensuring a sufficient filling of the concrete bay under all project conditions.

The formwork system in general is subject to the Engineer's approval.

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1.3.9 JOINTS

All joints shall be butt joints and placed according to the drawings. Every joint, expansion joint and construction joint shall be sealed with a corresponding joint tape in compliance with the Specification for the waterproofing system.

1.3.10 CURING

Until the concrete is sufficiently hardened, it is to be protected against detrimental influences – for example excessive warming, drying out due to sun or wind, running water, chemical attack.

1.3.11 CONTACT GROUTING

Upon setting of the concrete, there will be a few porous cavities especially in the crown of the tunnel. In order to ensure a homogenous bedding of the structure, these cavities will have to be filled with grout.

For this task to be accomplished, holes shall be arranged in the crown area's concrete lining.

1.3.12 COMPRESSIBLE MATERIAL LAYER

In order to limit the total final loads exerted on the structures by eliminating the loadings caused by long-term underground pressure rearrangement, a layer of compressible material, with a thickness of 10 cm, shall be foreseen between the structure's backside and the excavation surface.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the know-how and equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way.

Before commencing the concrete works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

2. Materials

2.1 Aggregates

Aggregates shall be taken from a source approved by the Engineer. The mixture of the aggregates shall be uniform without gap grading. The gravel (coarse) fraction shall be of cubic crushed or rounded form.

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Aggregates shall be hard, durable, non-porous and clean and shall not be chemically reactive. They shall not contain any deleterious material in sufficient quantity to adversely affect the strength at any age or the durability of the concrete or to cause corrosion of reinforcement.

The grading and the shape of the aggregates shall be such that a concrete can be produced with the specified proportions and consistency, which will readily work into position without segregation and without the use of excessive water and which can readily be compacted into a dense impervious mass.

The nominal maximum aggregate size shall be 32 mm. The gravel fraction of the aggregate shall not exhibit excessive fragmentation during delivery. The percentage of brittle grains shall be less than 5 %. The percentage of particles smaller than 0.06 mm, which can be washed away, shall not exceed 1 %.

Sand and gravel shall be clean. Frozen aggregates shall not be used. The minimum permissible temperature shall be + 3°C. Should the aggregates be warmed using steam, special attention shall be paid to controlling the moisture content, particularly in the sand fraction.

All aggregates shall have a specific gravity of not less than 26 kN/m^3.

The grading curve shall comply with the curve determined during suitability tests. The deviation of the given specified gradation shall not exceed the values listed below.

Table: Deviation from grain particle size

Grain Diameter	Admissible Deviation
0.06 mm	-/+ 1 %
0.25 mm	-/+ 1 %
1 mm	-/+ 2 %
4 mm	-/+ 3 %

2.2 Cement and Cementing Materials

It is of particular importance to use cement of uniform chemical composition and uniform fineness. Before commencement of delivery, the required characteristic values are to be agreed upon by the Engineer with the cement manufacturer. For the entire cement delivered, the manufacturer shall make the cement analyses and the standard test results available.

The cement shall be ordinary Portland cement, rapid hardening Portland cement or Portland pulverized fuel ash cement. The cement type shall be 20 according to the C.S.A. Standard 23.1-00.

In addition, the cement used shall satisfy the following requirements:

(a) Initial setting time not less than three hours.

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(b) Fineness: Not less than 340 m^2/kg; if content of pulverized fuel ash greater than 20 %, not less than 380 m^2/kg.

(c) Bleeding: not more than 20 cm^3 (Heidelberg Method); if content of pulverized fuel ash greater than 20 %, not more than 15 cm^3.

(d) Compressive strength after one day (24 h ± 1 h) on mortar cubes: not less than 9 N/mm^2

(e) The temperature of the cement at the time of use in the mixing plant must not be higher than 60°C.

If cementing materials (like fly ash or slag) are used, the suitability to meet the special requirements of the final concrete lining will have to be tested and approved by the Engineer.

2.3 Water

The water shall be clean and free of harmful matter in such quantities, as would affect the properties of concrete in the plastic or hardened state.

The water shall satisfy the requirements of potable water.

2.4 Admixtures

Admixtures added to the concrete, must not affect the concrete's hardening, strength and durability or cause corrosion of the reinforcement.

Chlorides or materials containing chlorides which promote steel corrosion may not be added to reinforced concrete or concrete which comes into contact with reinforced concrete. The prerequisite for the use of admixtures is a qualification test to be performed by the Contractor. The test results must be submitted to the Engineer.

2.5 Structural Concrete Composition

The concrete mix design shall meet the C.S.A 23. 1-00 requirements of a freezing and thawing restricted concrete. The concrete mix used for the intake structure shall furthermore fulfill the requirements of a sulphate-resistant concrete. And in addition, the following requirements shall be met:

- aggregates size 0 mm to 32 mm
- recommended cement volume 270 kg / m^3 (maximum)
- recommended cementing material (slag) volume 50 kg / m^3 (minimum)

or

- recommended "blended cement" volume 320 kg / m^3
- water / cement ratio ≤ 0.45
- water reducer and / or plasticizers are recommended
- required characteristic strength 35 MPa after 28 days (= long-term strength)

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- the concrete will have to meet the water infiltration test requirements according to DIN EN 12390 for watertight structures. That means the water infiltration depth, tested with the mentioned method, shall not exceed 30 mm.

2.6 Lean Concrete Composition

The lean concrete composition shall meet the requirements of a grade N concrete, C.S.A. 23.1-00. Its characteristic strength shall be 10 MPa.

2.7 Reinforcement

The reinforcement steel used shall be ribbed steel, grade 500 R or 500 W according to C.S.A. Standard 23.1-00.

In order to improve the composite action and to limit the crack formation, small-diameter reinforcement bars with a small spacing shall be used.

2.8 Contact Grouting Material

The contact grouting material shall be a cement-water suspension with sufficient fluid characteristics to fill the porous cavities and annular space between the final concrete lining and the waterproofing membrane.

If other material is used, they will have to be consistent with the concrete. The consistency has to be demonstrated by test or approved documents and the use of alternative materials has to be approved by the Engineer.

2.9 Compressible Material Layer

The layer shall be stiff enough to cover the stress and strain caused by concrete placement without deformation. At the same time, the layer shall be smooth and flexible enough to transform the long-term underground pressure into deformation so that the structure will not be strained by this kind of loading throughout the facility's design life time.

For that task, polystyrol material with an original thickness of 10 cm will be used. The layer will be installed at the excavated wall surface of the pit before concreting.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

The design and construction of the formwork moulds is to be evaluated by approved documents (calculations and drawings) and the moulds are to be checked by a Professional Engineer. The results are to be certificated by the Engineer.

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4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

The concrete must not separate while being transported to the construction site and it shall be of the required workability at the location and time of placing.

5. Workmanship

5.1 General

Before starting the concreting works, the Contractor shall develop a concrete works program, which shall contain information on the

- type of concrete production, on site, ready mix
- distance of external plants to the site
- capacity of the mixing plants, additional plants for substitution (incl. distance to the site)
- testing procedure, suitability tests, quality control tests
- thermal development of the concrete during hardening
- schedule of concreting, simultaneous concreting on different sites
- concrete works procedure – use and preparation of formwork, cast-in-place procedure (progress, vibrating, quality supervision)
- formwork replacement (concrete requirements)
- curing

The concrete works programme has to be submitted to the Engineer for approval.

5.2 Formwork

The formwork must be thoroughly cleaned before use. Before concreting, appropriate shutter oil is to be applied to ensure that no concrete will stick to the formwork.

Any formwork support material subject to rust or corrosion is to be removed upon striking of the formwork. Any reinforcement or support material, remaining in the concrete is to be rust and corrosion-proof.

Particular care must be taken in the construction of formwork for the end face of the concrete bays to ensure that the shuttering is especially tight. Without exception, shuttering for end faces must be of smooth-planed boards with parallel, tongue-and-groove jointing; the forms must have a minimum thickness of 20 mm and must be of uniform width. Joints are to be so tight as to be unrecognisable, and the finished wall surface is to be perfectly smooth and even.

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The formwork has to be erected and stabilized in such a way, that all stresses and strains caused by the concrete works can be covered. After erection and stabilization, the formwork will be checked and evaluated for its "correct" installation.

The construction elements may only be stripped and the support may only be removed when the concrete has sufficiently hardened. The concrete has sufficiently hardened when the element is strong enough to support all loads, to which it is subjected when stripped, with the prescribed safety.

5.3 Reinforcement

The reinforcement shall - in an approved manner - be stored above ground and shall be protected against aggressive elements. It shall be cut and bent in accordance with the corresponding standards. The tying wire shall be made of soft annealed mild steel with such diameter that all connections required shall be carried out with sufficient stiffness.

The reinforcement arrangement has to be designed, installed and connected in such a way that it is stiff enough to stand without additional support and to minimize deformations and displacements while concreting.

The concrete cover shall be sufficient in accordance with the structural requirements and in compliance with the design. A sufficient concrete cover shall be ensured by concrete spacers, fixed to the reinforcement in sufficient number.

5.4 Concrete Works

5.4.1 CONCRETE PRODUCTION, SITE MIXING PLANT

The aggregates have to be stored on site in separate boxes for gravel, coarse sand and fine aggregates. They have to be protected against dryness, wetness and freezing. For the production of all types of concrete, the individual aggregate components are to be measured by weight using automatic dosing equipment.

The cement and the additives shall be stored in such a way that they will be protected against seasonal influences and that they will keep their original state of quality at the time of delivery. For the concrete production, the components are to be measured by weight, using automatic dosing equipment.

The concrete mixing plant is to be laid out for a separated and automatic batching of 3 different additives. To permit monitoring of the levels of additives added to the concrete mixture, a transparent gauge glass is to be foreseen.

The concrete components (cement, aggregates, water and additives) must be measured with an accuracy of 3 %. The weight batching machines shall be carefully maintained and cleaned and provided with simple and convenient means of checking the weighing mechanisms plus they shall be checked when required by the Engineer.

The composition of each type of concrete to be mixed is to be posted at the mixing plant in a clearly legible form and must include the requirements of the given standards. The materials must be mixed in concrete mixers which are suitable for the pertinent concrete composition. The

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concrete mixer must be equipped with an electrical current indicator to facilitate regulation of the concrete's consistency. If the specific water content of the aggregates varies, the amount of wet material used plus the amount of mixing water must always be selected in such a way, that the total amount of water remains constant.

The dimensions of the mixing plant have to be sufficient to deliver enough concrete to all relevant sites at any time of the concreting process. All concrete components and the concrete production have to be protected against extreme weather conditions (heat, rain). Mixing plants for sites located in cold weather areas, which may experience frost periods, are to be equipped with mixing water and aggregate heating systems.

A site laboratory, fully equipped to carry out all concrete and concrete component tests required, is to be set up and operated by experienced personnel. An expert in concrete technology and concrete production shall be in charge of this laboratory.

Test mixes are to be made for each type of concrete. The results are to be submitted to the Engineer. The mixes shall be approved by the Engineer and a trial mix shall be prepared under full-scale conditions, including workability tests and cube testing.

5.4.2 READY-MIXED CONCRETE

The entire ready-mixed concrete shall meet the requirements described in this Specification. In addition to this, the Contractor shall submit the name and address of the ready-mix Contractor to the Engineer for approval, stating all the operation and plant details.

The details of the ready-mix Contractor shall include information on the plant, the equipment, the storage depots, as well as the transportation and quality systems. The Engineer shall have access to the ready-mix site for inspection at any time. The Engineer may reject the proposed ready-mix Contractor and may cancel an approval at any time, if the quality of the concrete or the documentation of the quality control is not satisfactory in the opinion of the Engineer.

The concrete shall in all respects comply with DIN standards, except where amended in this Specification.

All testing of the mixed concrete shall be executed on site.

The Contractor shall ensure that the supplier keeps records of all the required tests and the quality control for mixing and transportation.

The concrete shall be delivered to the site in truck mixers or agitators which are continuously in operation. Each batch delivered must be accompanied by a certificate containing the following information:

- Name of supplier
- Type and grade of concrete
- Mix code number
- Time and date of mixing
- Temperature of mixing
- Additives
- Cement type
- Cement content
- Water cement ratio or quantity of added water

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- Time of arrival of truck on site
- Time of end of discharge
- Registration number of truck
- Delivery certificate number

The certificates shall be available to the Engineer for quality supervision.

Any addition of water and admixtures to the concrete after the concrete has been discharged form the mixing plant shall not be accepted.

5.4.3 CONCRETING PROCEDURE

The workability of the concrete shall remain satisfactory until placing and compaction is finished. This shall at a minimum be for 3 hours at 25°C upon arrival on site; this shall also be true for hot weather periods.

During cold weather and frost periods the concrete shall be placed at a specified minimum temperature because of the lower hardening rate and the danger of permanent impairment of defined concrete properties. With ambient temperatures of +5°C to –3°C, the concrete temperature upon placing must not fall below +5°C. With ambient temperatures below –3°C, the concrete temperature must not fall below +10°C.

During hardening, the concrete temperature may not exceed 50°C.

Before the concrete is placed, all formwork elements and surfaces to come into contact with the concrete shall be cleaned from dust, mud and other impurities. The concrete shall not be placed in standing water unless this has been specified or approved.

During placing, suitable means shall be provided to prevent premature hardening of the concrete put in contact with hot surfaces.

When placing concrete in layers, if no construction joints are foreseen, the placing may only be interrupted for a period of time during which the concrete does not set, so that a good and even connection is possible between the two layers of concrete. The concrete shall be placed in level layers of such depth that each layer will be readily and properly mixed with the previous layer below by the use of internal vibrators. The difference in height of the layer's level on the right hand sidewall and the left hand sidewall of the final lining may not exceed 1 m.

Concreting shall begin in the bottom parts of the sidewalls and shall finish in the crown. Normally the concrete shall be pressed into the formwork. If the formwork is filled by gravity flow, the concrete's height of fall shall not exceed 1 m.

The type and number of vibrators shall be approved by the Engineer and shall consider the mass and quality of concrete to be compacted and the type of formwork.

The formwork shall be released, when the final concrete lining meets its release strength, measured in the crown by suitable means of measurement.

5.4.4 CURING

The curing of the final lining surface will start immediately after the formwork is released.

When water curing is applied, chill shocks are to be avoided (as could occur when cool water comes into contact with warm concrete surfaces) due to the resulting danger of peeling or

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scaling. The quality of water used for curing shall be the same as that used for concrete mixing. If liquid membranes are used, they must not affect the normal setting reaction of cement. Compounds incorporating reflective, white or light-coloured pigments shall be used.

The methods of preventing the concrete from prematurely drying are to be submitted to the Engineer for approval before use.

The concrete must be cured during the first four days.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

During the entire period of construction, the Contractor will have to verify the material properties and qualities as defined by the Specifications and Standards.

In addition to the tests and investigations contained in the Specifications and Standards, all other tests deemed necessary by the Engineer are to be performed.

Records are to be kept of all test results and submitted to the Engineer. The Contractor shall grant the Engineer full access to and use of the laboratory and shall produce on demand the records of all tests carried out.

6.1 Suitability Tests

6.1.1 CONCRETE COMPONENTS

No aggregates shall be delivered to the site without satisfactory initial sampling and testing. The sample of fine aggregate shall be 25 kg in weight and that of the coarse aggregate shall be 50 kg in weight.

The Contractor's attention is drawn to the need to maintain a consistent aggregate quality and he will be expected to undertake adequate testing to ensure that the quality does not vary significantly (reference is made to Subchapter 6.2, Quality Control Tests).

All components have to be certificated for their origin and quality. The suitability of the components used has to be approved by the Contractor’s concrete expert and by the Engineer.

6.1.2 CONCRETE

In order to verify the suitability of the concrete compositions for the respective tasks, tests at the site or at the mixing plant have to be carried out for both designed concrete compositions (winter and summer composition). The following items have to be tested using three samples per item under the mentioned conditions:

- Bulk density
- Air void content (= 3 % to 6 %, maximum)
- Consistency immediately after mixing and one hour later (= class F3; DIN 1045-2)

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- Release strength after design time for formwork removal
- Characteristic strength after 28 days (= 35 MPa)

6.2 Quality Control Tests

6.2.1 AGGREGATES

The following tests have to be carried out with a frequency of "each delivery"

- grading analyses
- wet analyses
- moisture content, for sand
- organic impurities
- visual inspection of aggregate type, granulometric composition, aggregate condition, particle shape, detrimental components (e.g. coal, humic substances, brittle grains, etc.)

The moisture content of the sand has to be checked in addition once a week.

Chloride and sulphate tests have to be carried out once every 4 months and in case of suspected change.

The tests are to be carried out in accordance with DIN EN 12620.

6.2.2 CEMENT AND CEMENTING MATERIALS

The following tests have to be carried out every 4 months:

- compressive strength
- specific surface
- chemical analysis.

Certificates issued by the supplier shall be tested per storage vessel.

The tests are to be conducted in accordance with the German DIN EN 196 Standard and the requirements of Subchapter 2, Materials.

6.2.3 ADMIXTURES

The certificates issued by the supplier have to be checked at each delivery to the site.

6.2.4 CONCRETE

Fresh concrete has to be tested according to the criteria listed below:

testing item	testing frequency	testing procedure	testing moment
consistency	once for every batch on site	acc. to German DIN EN 12350 Standard	before placing of concrete
water / cement	once for every batch on	by visual inspection	before placing of

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ratio	site		concrete
unit weight	once for every batch on site	by visual inspection	before placing of concrete
bulk density	three times per concrete bay	acc. to German DIN EN 12350 Standard	during concreting
air void content	three times per concrete bay	acc. to German DIN EN 12350 Standard	during concreting

Hardened concrete has to be tested according to the criteria listed below:

testing item	**testing frequency**	**testing procedure**	**testing moment**
compressive strength	three times per concrete section	with penetration test or pendulum hammer	after 12 h (release strength)
compressive strength	three cubes or cylinders per concrete bay	acc. to German DIN EN 12390 Standard	after 28 days (characteristic strength)
water infiltration	three times per concrete section	acc. to German DIN EN 12390 Standard	
air void content	three times per concrete bay	acc. to German DIN EN 12390 Standard	after 7 days (abrasion resistance)

The testing procedure and interpretation of the results is described in the above mentioned references. The limit values of the individual tests are specified in Subchapter 2, Materials and Subchapter 6.1, Suitability Tests.

6.2.5 CONCRETE WORKS

The minimum dimensions of the structures shall be the designed dimensions. Smaller dimensions are to be avoided.

If faced with smaller dimensions, the following measures will have to be taken:

origin	**Extension**	**consequence**	**Check**	**measures**
local "breakdown" of formwork	limited in size	increase of structural concrete thickness	sufficient thick-ness of concrete structure and sufficient flow volume of cross section	grinding of bulges
	whole concrete section			if maximum flow can not be achieved, breakdown and reconstruction of concrete section

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origin	Extension	consequence	Check	measures
wrong alignment of formwork	whole concrete section	increase / decrease of structural concrete thickness	sufficient thick-ness of concrete structure	if maximum flow can not be achieved, breakdown and reconstruction of concrete section in any other case, smoothening of the surface as described below.

The minimum thickness of the concrete structures shall be the design thickness. Any reduction in thickness shall be avoided. Any increase in thickness shall be limited to the design thickness + 10 cm. The space available for the placing of the final concrete lining has to be proven by survey of the shotcrete lining surface.

Should the required limits not be met (thinner lining), the area in question should be re-excavated and re-supported. Should the limits be exceeded, the difference between the allowable and the measured thickness shall be compensated by additional shotcrete.

The survey results of the shotcrete surface, as well as the measures to be taken when the limits are exceeded are – in any case – subject to the Engineer's approval.

The surface of the concrete structure shall be smooth and flat. Wedges and bulges are to be avoided, or to be smoothened by grinding. Unevenness shall not exceed 4 degrees (angle of gradient) in all directions.

7. Measurements

The quantity survey unit of the concrete shall be m^3, the quantity survey unit of the reinforcement shall be ton.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

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8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

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9. Applicable Regulations

9.1 Standards

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DIN EN 206	Concrete Part 1: Specification, performance, production and conformity
DIN 1045-1:	Concrete, reinforced and prestressed concrete structures Part 1: Design
DIN 1045-2:	Concrete, reinforced and prestressed concrete structures Part 2: Concrete Specification, properties, production and conformity Application rules for DIN EN 206-1
DIN 1045-3:	Concrete, reinforced and prestressed concrete structures. Part 3: Execution of structures
DIN EN 12620	Aggregates for mortar and concrete
DIN EN 12350	Testing methods for fresh concrete

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DIN EN 12390	Testing methods for hard concrete

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PR-00-5011, Rev 1
Waterproofing System

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of the waterproofing system in the Diversion Tunnel of the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) installation of components required

c) quality control for material and workmanship.

The Scope of Work is defined for the installation of the final lining for the Diversion Tunnel.

1.3 Basic Requirements

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1.3.1 GENERAL

A dual layer waterproofing system shall be installed in tunnel sections, where the swelling potential of the rock mass may affect the stability of the tunnel, In all other tunnel sections, a single layer waterproofing system is envisaged (Fig. 1 and Fig. 2).

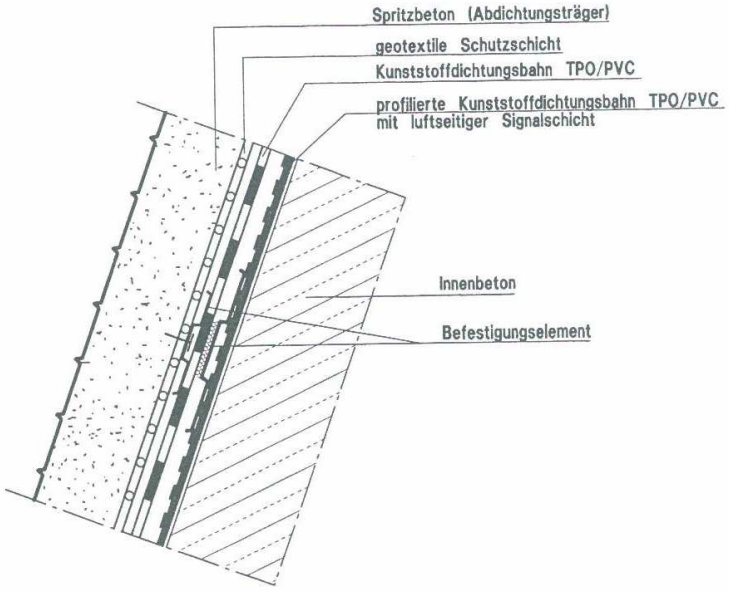

Fig. 1: Dual layer waterproofing system

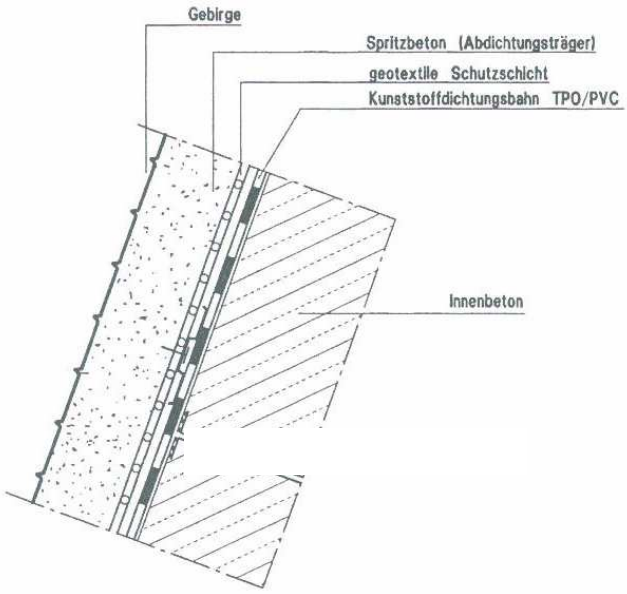

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Fig. 2: Single layer waterproofing system

1.3.2 SHOTCRETE SURFACE

The basis for the waterproofing system must be constructed in such a way that - taking the material properties into account without any overstress and/or damage being caused - the protective sheet and the loosely installed plastic waterproofing membrane may fit to the shotcrete base as snugly as possibly. In particular:

- all wedges and edges shall be smoothed. The ratio between diameter and depth of local "inaccuracies" shall not be smaller than 10 : 1. The minimum radius shall exceed 20 cm.
- all protruding iron parts shall be removed
- all iron parts, which can not be removed (e. g. heads of rock dowels) shall be covered with shotcrete with a minimum thickness of 3 cm.
- all inflowing water shall be collected and drained off.

1.3.3 REGULATING SHOTCRETE

To meet the shotcrete surface requirements, a thin shotcrete layer, is to be installed where required - independent of the excavation and support procedure. The mechanical properties and the thickness of the so-called regulating shotcrete are to be adapted to the fastening elements (discs) used for the waterproofing membrane and the protective sheet.

1.3.4 GEOTEXTILE FLEECE

To prevent the waterproofing membrane from being damaged when it is pressed against the shotcrete surface, a protective sheet must be provided between the waterproofing membrane and the shotcrete surface.

This sheet should be a geotextile, patched with a thin membrane on one side.

1.3.5 WATERPROOFING MEMBRANE

The waterproofing membrane shall consist of Polyvinylchloride (PVC) or Polyolefin (TPO/FPO).

The materials used must all be permanently resistant to all kinds of external influences and must not be harmed by the usual deformations of structures due to shrinkage, temperature change, or ground movement. The materials used for waterproofing must be compatible with each other and with all other materials they might come into contact with.

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1.3.6 JOINT SEALING

In every outside joint of the intake and outlet structure joint tapes shall be placed. The functions of these joint tapes are to seal the joints against liquid inflow and to prevent seepage through the joints.

Depending on the function and location, the following types of joints are distinguished:

Tunnel Final Lining Joint

Within the final lining joint area the waterproofing membrane will be protected against damage by an additional membrane strip fixed on the membrane by welding. The joint will be sealed against grouting inflow by a kind of geotextile fixed on the front face of the previous concrete bay.

Construction Joints

The construction joints of the intake and outlet structure are sealed with joint tapes (water stops). Injection hoses, installed in the joints to grout the joint surface shall support the waterproofing effect. The injection hoses should be constructed and arranged in such way, that joint grouting will be possible throughout the Diversion Tunnel's design life time.

Expansion Joints

Expansion joints are sealed with joint tapes, which are suited to keep the joint tight independent of the joint movement. Additional injection hoses shall be installed in the expansion joints.

1.3.7 SLEEVES

To penetrate the waterproofing membrane with hoses for interface grouting and for other devices to be installed outside the waterproofing membrane, special, pre-fabricated sleeves will be provided. These sleeves will be welded on the waterproofing membrane and will surround the hoses in such a way that the location of the membrane penetration is as waterproof as the surrounding waterproofing system.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications, the Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way.

Before commencing the waterproofing works, the Contractor shall propose a concept for these works. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

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2. Materials

2.1 Geotextile Fleece

The protective sheet consists of a geotextile, patched with a thin membrane on one side facing the waterproofing membrane.

The geotextile satisfy have the following minimum requirements:

• Material	Polypropylene (PP) or Polyethylene (PE-HD)
• Product identification	Manufacturer, thickness, type, production date
• Product appearance	Mechanically woven fleece
• Area weight Test Method: EN 965	$\geq$600 g/m^2, -/+ 5 %
• Melting flow (for PE-HD only) Test Method: DIN ISO 1133	Tolerable deviation: $\leq$ 10 %
• Thickness under a pressure of 2 kPa Test Method: EN 964-1	$\leq$ 10 mm
• Thickness under a pressure of 20 kPa Test Method: : EN 964-1	$\geq$ 4 mm
• Tensile breaking force	$\geq$ 25 kN/m
Elongation at break (tension) Test Method: EN ISO 12 219	$\geq$ 50 %
• Perforation force Test Method: EN ISO 12 236	$\geq$ 8 kN and $\leq$ 20 kN
• Elongation at perforation Test Method: EN ISO 12 236	$\geq$ 50 %
• Storage in salt water (10 % NaCl) at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tensile strength $\leq$ 25 % Reduction in tensile elongation $\leq$ 25 %
• Storage in sulfuric acid (5%) at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tensile strength $\leq$ 25 % Reduction in tensile elongation $\leq$ 25 %

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• Storage in caulk water (saturated with $Ca(OH)_2$) at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tensile strength $\leq$ 25 % Reduction in tensile elongation $\leq$ 25 %
• Fire resistance	Non flammable

The patched backing membrane shall satisfy the following minimum requirements:

• Material	Polyolefin (FPO or TPO)
• Product identification	Manufacturer, thickness, type, production date
• Product appearance	No blisters, cracks, nests or holes
• Thickness	Minimum 0.3 mm
• Materials	Polyolefin (FPO or TPO)
• Tensile breaking force	$\geq$ 25 kN/m
• Elongation at break	$\geq$ 300 %
• Fire resistance	Non flammable

2.2 Waterproofing Membrane

The waterproofing membrane shall satisfy the following minimum requirements

• Material	Polyolefines (FPO or TPO)
• Product identification	Manufacturer, thickness, type, production date
• Product appearance	No blisters, cracks, or nests, full areal bond between signal layer and membrane
• Straight deviation and evenness Test Method: DIN 16 726, 5.2	Deviation from straight $\leq$ 50 mm Evenness $\leq$ 10 mm
• Single membrane thickness Dual membrane thickness	3.0 mm (mean), -/+ 5 % 2.0 mm + 1.5 mm (mean), -/+ 5 %
• Thickness signaling layer	$\leq$ 0.2 mm
• Density Test Method: DIN 53 479	Tolerable deviation: + 0,03, -0,003 g/cm^3

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• Melting flow Test Method: DIN ISO 1133	Tolerable deviation: $\leq$ 10 %
• Breaking strength (tear)	$>$ 15 N/mm^2
Elongation at break (tear) Test Method: DIN 16 726, 5.6.1	$>$ 500 %
• Module of Elasticity between 1 and 2 % elongation Test Method: DIN 16 726, 5.6.2	$<$ 100 N/mm^2
• Multiaxial tension (bulge test) Test Method: DIN 53 861	Tolerable deviation: $>$ 50 % of 1,0 m dia. sample
• Shear test for welded seams Test Method: DVS 2226-2	Break outside seam, shear strength factor $\geq$ 0.9
• Peel test for welded seams Test Method: DVS 2226-3	Peel resistance $\geq$ 0.8 * thickness * tension stress [N/mm^2]
• Resistance against water pressure Test Method: DIN 16 726, 5.11	No leakage at pressure of 30 bar over 72 hours
• Perforation Test Method: DIN 16 726, 5.12	No perforation for test tool of 500 g weight falling from 750 mm
• Storage at 100° C for 1 hour Test Method: DIN 16 726, 5.13.1	Change of dimensions $\leq$ -/+ 2 % No blister formation
• Storage in water at 80° C for 70 days Test Method: DIN 16 726, 5.13.3	Reduction in tensile strength $\leq$ 20 %
• Storage in water at 50° C for 8 months Test Method: SIA-V 280, test 13	Reduction in tear strength $\leq$ 20 % Reduction in tear elongation $\leq$ 20 %
• Storage in salt water (10 % NaCl) at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tear strength $\leq$ 20 % Reduction in tear elongation $\leq$ 20 %
• Storage in sulfuric acid (5%) at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tear strength $\leq$ 20 % Reduction in tear elongation $\leq$ 20 %
• Storage in caulk water (saturated with $Ca(OH)_2$)	Reduction in tear strength $\leq$ 20 %

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	at 23° C for 28 days Test Method: DIN 16 726, 5.18	Reduction in tear elongation $\leq$ 20 %
•	Fire resistance	Non flammable

The inner layer of dual membranes shall have dimples with 2 – 3 mm diameter, 0.5 mm high spacing 20 mm approx. to provide a space between the two membranes for vacuum testing.

2.3 Joint Tapes

2.3.1 JOINT TAPES FOR CONSTRUCTION JOINTS, EXPANSION JOINTS

The joint tapes (water stops) for the waterproofing of construction and expansion joints shall be manufactured from non-reclaimed, durable, weldable plasticized PVC of a oil- and bitumen-resistant material quality, using softening agents with a polymer molecular structure.

The minimum material requirements shall be as follows:

• ultimate tensile strength	at + 23°C (acc. to EN ISO 527)	> 10 N/mm²
• elongation at break	at + 23°C (acc. to EN ISO 527) at - 20°C (acc. to EN ISO 527)	> 350 % > 200 %
• minimum thickness, construction joints: minimum thickness, expansion joints:		3.5 mm 4 mm

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

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5. Workmanship

5.1 Tunnel

Before starting the waterproofing works in the tunnel, the shotcrete surface of the initial lining shall be reviewed for its suitability for the works anticipated. The requirements, described in chapter 1 indicate the criteria of suitability.

5.1.1 REGULATING SHOTCRETE

At locations at which the required surface condition has not been met, regulating shotcrete must be applied. The following minimum requirements shall be met:

1. Adequacy of mechanical properties
2. Minimum thickness 30 mm
3. The ratio of diameter to the height of local "inaccuracies" due to excavation must be at least 10:1
4. Filletings with a minimum radius of 0.20 m
5. Care is to be taken that all rebound is removed, especially in the invert.

5.1.2 GEOTEXTILE FLEECE

Before installing the geotextile fleece as a protective sheet, the regulating shotcrete must be checked by the Contractor of the waterproofing system works and acceptance must be stated in written form.

The protective sheet is delivered and installed onto the surface of the regulating shotcrete in strips fixed by fastening elements (discs). Depending on the weight of the protective sheet, 3 discs per m^2 should be positioned at the tunnel roof, while 2 discs per m^2 should be sufficient at the sidewalls and the invert.

The overlapping of the strips should not be smaller than 100 mm.

5.1.3 WATERPROOFING MEMBRANE

The waterproofing membrane is delivered in rolled strips. The strips are welded onto the above mentioned discs (Fig. 3). Dual membrane elements are delivered with prefabricated seams. Only the minimum amount of seems required for installation shall be produced on site (Fig. 4).

The connection between the waterproofing membrane and the fastening elements must be inferior in strength to the connection between the individual strips of waterproofing membrane. If subjected to extremely high stresses, the waterproofing membrane should break loose from the fastening elements, preventing damage being done to the membrane itself.

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The strips are connected by welding with flat-face fillet welds; solid seams are not permitted in the standard case. Controllable double seams (Fig. 5) are provided at each joint. The control space of the double seam must be at least 10 mm wide, but must not exceed 20 mm. T-joints as well as repair works may be carried out as solid seams of at least 30 mm. Cross-joints shall be avoided. Welding has to be carried out in accordance with the temperature range specific for the material used. Seams must not be welded at temperatures below + 5°C, unless special measures are taken, which are approved by the Engineer.

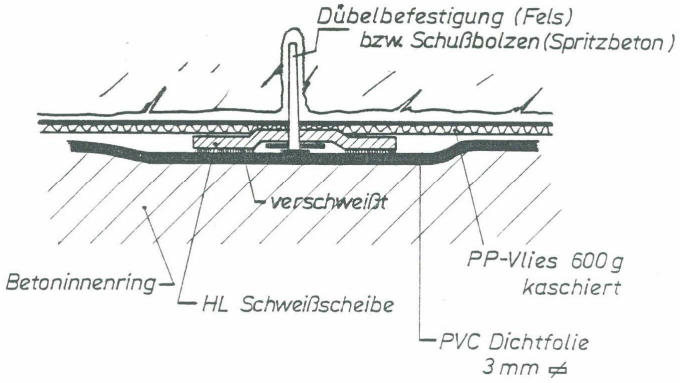

Fig. 3: Installation of the single layer waterproofing system

In the tunnel invert, where the precast invert concrete segment is laid ahead of the final lining vault, the installed waterproofing system segment (geotextile and waterproofing membrane) has to be covered with suitable measures, to prevent damage (reference is made to the corresponding drawing no. PD-01-1020).

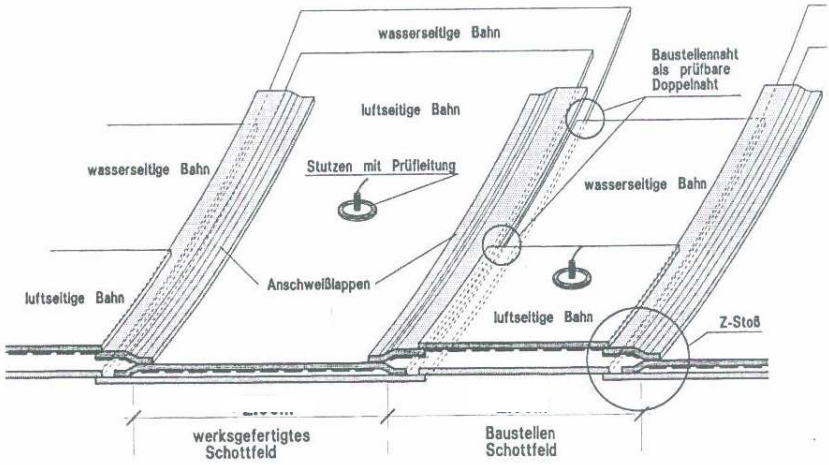

Fig. 4: Connection of dual layer waterproofing membrane

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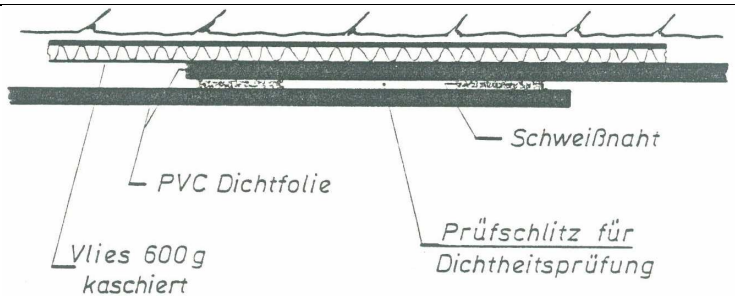

Fig. 5: Controllable double seam

5.1.4 SLEEVES

Waterproofing membrane strips with welded sleeves shall be prefabricated and delivered to the site. The hoses shall carefully be inserted into the sleeves, following the manufacturer's order.

The hoses and sleeves shall be fixed and protected in such a way that no moving, cracking or other damage will occur during concreting.

Pre-fabricated sleeves shall be provided to penetrate the waterproofing membrane with grouting hoses and for other devices to be installed through the waterproofing membrane. These sleeves shall be welded on the waterproofing membrane and will surround grouting hoses and such devices in such a way, that the location of the membrane penetration is waterproof (Fig. 6 and 7).

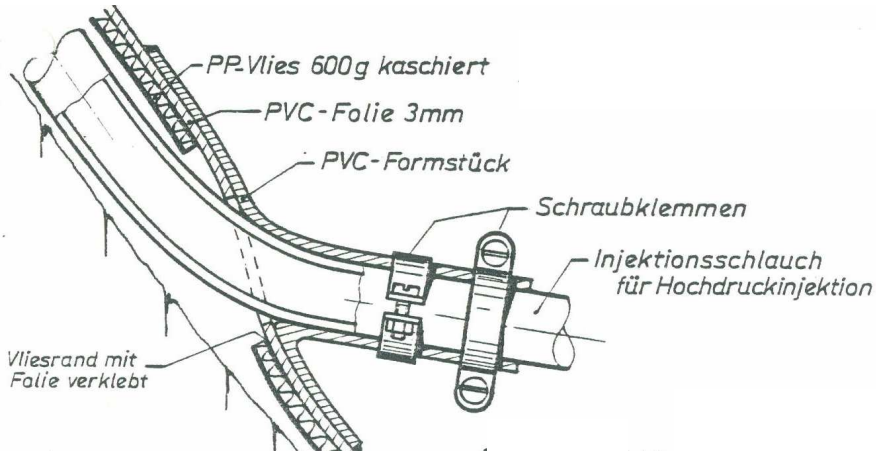

Fig. 6: Sleeve for grouting hose

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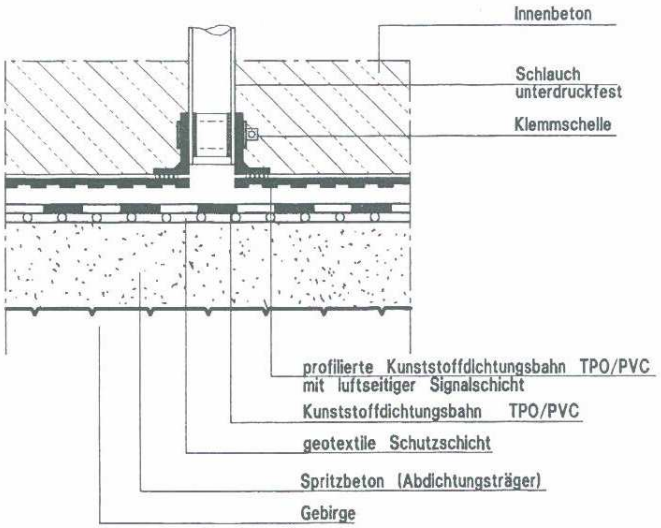

Fig. 7: Sleeve for testing of dual layer membrane system

5.2 Intake, Outlet Structure

Considering the width of the structure, the required joint tapes shall be located within the joint as close as possible to the outside face of the concrete structure. They shall be installed and fixed in such way that no moving, bending or any other kind of damage will occur during concreting. The injection hoses shall be installed in such way that the joints can be sealed against water from the inside and the outside over the entire length. The grouting procedure shall be possible to be repeated at any time throughout the lifetime of the structures.

Required field connections shall be welded by experienced personnel according to the manufacturer's or the Employer's instructions.

At the interfaces to the tunnel structure, the intake /outlet structures are sealed with joint tapes, which are welded on the waterproofing membrane on the Diversion Tunnel side and inserted in the structural concrete of the intake and outlet structure.

6. Quality Control

6.1 Suitability Tests

Suitability tests as specified in section 1 must be carried out by the manufacturer for all components of the waterproofing system. The test procedure and the material performance have to be certified by an officially approved checking organisation.

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6.2 Testing During Production

During production of plastic components of the waterproofing system, tests have to be performed, which cover the following requirements and are documented by the manufacturer at specified intervals and the checking organisation at 6 month intervals.

6.2.1 GEOTEXTILE FLEECE WITH BACKING MEMBRANE

• Material	Each delivery
• Product identification	Each delivery
• Product appearance	Each delivery
• Area weight	Every 1000 m^2
• Thickness	Every 1000 m^2
• Tensile breaking force	Daily or every 4000 m^2
Elongation at break (tension)	Daily or every 4000 m^2
• Perforation force	Daily or every 4000 m^2

6.2.2 WATERPROOFING MEMBRANE

• Material	Continuously or each delivery
• Product identification	Continuously or each delivery
• Product appearance	Continuously or each delivery
• Density	daily
• Melting flow	daily
• Membrane thickness	Continuously or 2 * each shift
• Thickness of signaling layer	Continuously or 2 * each shift
• Breaking strength (tear)	daily
Elongation at break (tear)	daily
• Shear test for prefabricated seams	daily
• Peel test for prefabricated seams	daily
• Storage at 100° C for 1 hour	daily

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6.3 Testing on Site

6.3.1 GEOTEXTILE FLEECE

The product sheets containing test results for items specified in 3.2.1 shall be checked on site for each delivery. Only fleece materials, which do meet the specified requirements may be installed in the tunnel.

6.3.2 WATERPROOFING MEMBRANE

The product sheets containing test results for items specified in 3.2.2 shall be checked on site for each delivery. Only membrane materials, which do meet the specified requirements may be installed in the tunnel.

Dual layer membrane systems shall be tested by connection of the test hoses to a vacuum system. Each compartment is to be tested before concreting of the final lining (Fig. 8). Initially - 0.7 bar of vacuum pressure shall be applied until after 10 minutes - 0.5 bar testing pressure is installed. The pressure shall be recorded for 15 minutes. The test is considered as passed, if the pressure drop after 10 minutes does not exceed 20 % (= 0.1 bar) of the applied test pressure. Repair before concreting is carried out with additional layers of membrane welded on to the damaged areas.

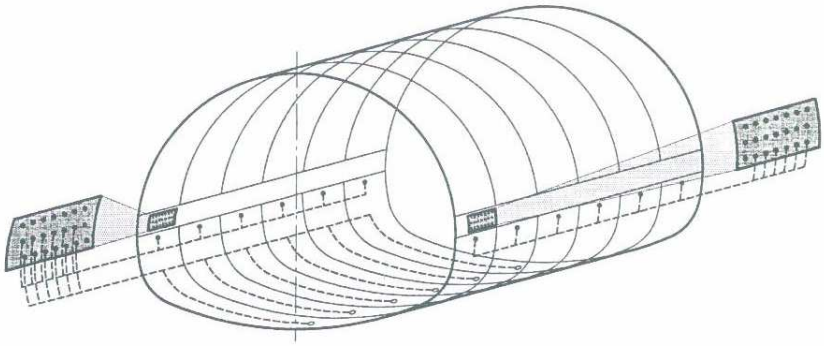

Fig. 8: Testing of compartments

Single layer membrane systems shall be visually inspected and the inspection documented, before concrete is placed.

The double seams of the waterproofing membrane produced on site are to be tested with compressed air of 2.0 to 2.5 bar. In the test, the pressure is applied at one end of the test section and measured at the other end. The test is considered as passed, if the pressure drop after 10 minutes does not exceed 20 % of the applied test pressure.

T-joints, repair seams and sleeves for penetration through the membrane shall be tested with a vacuum bell jar applying a low pressure of 0.2 bar over 10 minutes.

Tests and QA/QC inspections have to be carried out and documented accordingly.

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6.4 Joint Tapes

The Contractor shall furnish the Employer with copies of the manufacturer's test certificates for the water stops to be supplied.

7. Measurements

The quantity survey unit of the waterproofing system components (geotextile and membrane) shall be m^2. The quantity survey unit of the joint tapes shall be m.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design, the documentation and with the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

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European / German Standards

DIN EN 918	Fasteners; terminology; spelling of terms; abbreviations
DIN EN 964:	Geotextiles and geotextile-related products: determination of thickness at specified pressures
DIN EN 965 (ISO 9864)	Geotextiles and geotextile-related products: determination of mass per unit area
DIN 4102	Fire behaviour of building materials and elements - classification of building materials
DIN16726	Plastic roofing felt and waterproofing sheet – testing
ISO 527	Plastics: tensile test
ISO 10319	Geotextiles and geotextile-related products: wide – width tensile test
SIA 280	Plastic waterproofing membrane sheets: requirements and material testing methods

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PR-00-5012
Drainage Measures

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of drainage measures in the Diversion Tunnel of the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) installation of drainage measures

c) quality control for material and workmanship.

The Scope of Work is defined for the excavation and support procedure to be adopted for the Diversion Tunnel.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

In general, two types of measures may be distinguished with respect to drainage:

- Drainage of water seeping into the tunnel through the initial lining or the tunnel face
- Treatment of water from the surrounding rock mass to increase rock mass stability and limit rock mass permeability

Subsequently, the respective components shall be described:

1.3.1 DRAINAGE MATS

Drainage mats are geotextiles with a watertight surface on the front side and a permeable medium on the back side. They will be fixed to the shotcrete of the initial lining in case of extensive water inflow through the shotcrete lining.

1.3.2 DRAINAGE PIPES

Drainage pipes are flexible plastic pipes, with a diameter between 1" and 2". They are used to drain the inflow of water at certain locations of the shotcrete lining. Several pipes can be interconnected with pipe fittings to create one "collection pipe".

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1.3.3 INVERT DRAINAGE

The water of all these drainage systems is collected in a pit, located in the precast concrete invert segment. This pit offers sufficient space to retain the incoming water and drain it to the collection tank.

1.3.4 PUMP SUMPS

In a downhill tunnel excavation, pumps sumps are to be installed approx. every 30 m on both sides of the excavation in the vicinity of the tunnel face to collect and remove the water coming from the excavated and supported tunnel area.

These pump sumps shall have a diameter of not less than 800 mm and a depth of not less than 1 m. The walls should be covered with precast concrete elements or with shotcrete. The bottom shall feature a pumping pit and shall be covered with shotcrete. The pumps shall remove the water by pipes, fixed to the sidewalls, to the portal areas or to nearby collection points.

1.3.5 COLLECTION TANK

At the lowest point of the tunnel, a tank with sufficient volume shall be installed to retain the water collected in the tunnel. The tank shall be equipped with two pumps (redundant system) to avoid flooding. The tank can be excavated beneath the invert and supported with a reinforced shotcrete lining or installed as a mobile basin.

During the downhill excavation and while approaching the lowest point of the tunnel, a mobile collection tank shall be attached to the tunnel boring machine behind the gantry, for the water from the tunnel backside and the excavation area to be collected and pumped out.

1.3.6 SETTLING TANK

The water collected in the tunnel might on the one hand be mixed with suspended sediments and settleable particles and might on the other hand be polluted with liquids like oil etc.. And it might be alkaline in composition due to the cement components contained in the shotcrete.

In view of these facts and in response to the environmental requirements, a settling tank with a light oil separator, and - depending on the ph-value - with a neutralization facility shall be installed. The settling tank shall be constructed in such a way that the environmental requirements for the water to be conveyed into any existing watercourse can be fulfilled.

The settling tank can be constructed as an earth basin, supported by reinforced shotcrete or as a precast steel basin. The light oil separator shall be installed at the basin's intake, the neutralisation facility at the basin's outlet.

The intended neutralisation process, with sulphuric acid or carbonic acid, shall be submitted to the Engineer for approval. Neutralisation with hydrochloric acid shall be avoided, due to the health risk and the danger to the environment.

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1.3.7 WATER TREATMENT OF SURROUNDING ROCK MASS

To reduce the permeability of the surrounding rock mass, the area in the vicinity of the tunnel is sealed by grouting. Details regarding this procedure are presented in the corresponding Specification "Underground Grouting".

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, the General Technical Specification, the detailed Technical Specification and the Engineer's instructions.

2. Materials

Reference is made to Item 1.4 – Definitions. The material depends on the manufacturer and the construction method.

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected within regular inspection periods.

The pumps, the necessary pumping pipes, as well as all other components previously mentioned, will have to be sufficient in dimension to safely remove the local water inflow.

At the entrance of the settling tank, a measuring unit shall be installed to quantify the amount of water.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

The Contractor shall present an organisation chart and a time schedule to the Engineer for approval, giving due consideration to all conditions accompanying the execution of the works.

All components will have to be installed with such care that the success of the measures is guaranteed at any time.

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6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

The quality of the measures taken has to be controlled by permanent visual inspection. The quality of the water released into the watercourse has to be monitored at regular intervals in accordance with the relevant environmental requirements.

7. Measurements

The quantity survey units of the individual components shall be:

Drainage mats	m^2 of mats installed
Drainage pipes	m length of pipes installed
Invert drainage	m of drainage installed and operating satisfactorily
Pump sumps	piece of pump sump(s) installed
Settling tank	piece of settling tank(s) installed incl. all additional components
Installation of equipment	1 piece
Timeframe per measure:	day of operation

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The Works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

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9. Applicable Regulations

9.1 Standards

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PR-00-5013 Rev 1
Tunnel Excavation and Support

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of tunnel excavation and support works in the Diversion Tunnel at the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used for the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all the components and the entire equipment required to the site

b) excavation of required tunnel cavity by drilling and blasting or mechanical excavation

c) mucking and storage of excavated material

d) installation of required support measures

e) quality control for material and workmanship.

The Scope of Work is defined for the Diversion Tunnel at the tunnel connection area to the outlet and the intake structure during the excavation and support period.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 EXCAVATION AND SUPPORT TYPES

The excavation and support works have to be carried out, in compliance with the excavation and support type documentation. This documentation states the allowable excavation volume per round, i.e. the span and the cross-section area of the next excavation step and type, as well as the extent and location of the required support measures.

The excavation and support types have been designed based upon the rock mass description and the rock mass behaviour description.

The application of the different excavation and support types at the works is to be determined on site by experienced personnel and by arrangement with the Engineer, taking into account the local geology, verified by visual inspection and documentation, as well as the deformation of the excavated and supported tunnel area, verified by geotechnical measurements and monitoring.

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1.3.2 EXCAVATION AND SUPPORT OF TUNNEL ENTRANCE / EXIT AREA

At the tunnel entrance and exit area, the tunnel cross-section is changing from square shape at the intake / outlet interface to circular shape within a stretch of 20 m. This tunnel stretch will be excavated by drilling and blasting adopting the principles of the New Austrian Tunnelling Method (NATM).

1.3.3 MINED TUNNEL PORTAL

For the mined tunnel portal at the intake / outlet, a special excavation and support technique is intended to be employed, taking the cross-section form and the "starting procedure" into account. For this procedure to be adopted, the entire edge of the excavation cross-section is supported with reinforced shotcrete. To limit the excessive breakout of rock mass, caused by blasting, rock dowels with a minimum length of 6 m shall be installed horizontally on top of the crown of the tunnel.

The excavation, by blasting, shall be done in several steps and for the support of the excavation surface, reinforced shotcrete and rock dowels shall be installed immediately after excavation.

1.3.4 DRILLING AND BLASTING

Tunnel excavations involving drilling and blasting shall only be carried out by experienced, well trained personnel. At an early stage, in advance of the proposed use of explosives, the Contractor shall inform the Engineer, third parties, statutory authorities and services which have an interest in the project or are likely to be affected by the blasting operations, of the general nature of the operation. The Contractor shall – in due time (at a minimum a fortnight) – subsequently notify the Engineer and all others listed above of the intended use of explosives.

With this notification, the Contractor will submit to the Engineer's approval a detailed method statement considering all aspects of the intended use.

1.3.5 MECHANICAL EXCAVATION, TUNNEL BORING MACHINE

The circular Diversion Tunnel will be excavated with a tunnel boring machine (TBM). In response to the rock mass conditions, a so-called "gripper machine" will be installed.

The tunnel boring machine shall be designed and constructed in such a way that

- horizontal and vertical alignment requirements are met
- the differing conditions of the surrounding rock mass, e.g. rock strength and rock mass strength, parting plane structure can be governed
- the minimum clearance necessary will be achieved for the proper construction of the works and the overbreak will be limited to a minimum
- provisions will be made to resist rotation of the tunnel boring machine
- all materials used will be fire resistant.
- an effective fire-fighting system will be installed on the machine

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- adequate access will be granted to all areas of the TBM where work, including maintenance, may have to be carried out

In the design and manufacturing of the TBM it must be ensured that no contamination of excavated material will take place. Material contaminated during the excavation process shall be handled by the Contractor.

Further detailed specifications are described in Subchapter 3, Equipment and Subchapter 5, Workmanship.

1.3.6 MUCKING

The excavated rock material will be mucked out by a belt conveyor, installed at the sidewall of the tunnel.

1.3.7 MATERIAL DEPOSIT

The excavated material will be deposited as required by the Owner. It will be placed in layers of approximately 0.5 m and compacted according to the storage requirements.

On the designated storage area, a temporary deposit for contaminated materials will be installed. The temporary deposit shall cover a volume of 60,000 m^3 at a maximum (complying with a 15 workday excavation progress).

To meet this requirement, the storage area shall cover a base area of approx. 100 m x 200 m. The material shall be stored in such a way that the slopes will be stable under normal weather conditions. The temporary deposit is sealed against the underground with an impermeable base and surrounded by peripheral ditches and drains to capture any runoff. The runoff will be collected in a separate settlement basin and suitably treated prior to discharge into the water treatment plant of the temporary tunnel drainage.

1.3.8 SUPPORT INSTALLATION

Depending on the defined support types (see above) the respective support measures shall be implemented as described in the corresponding drawings. The support elements which comprise

- reinforced shotcrete
- steel H-beams and steel U-profiles
- rock dowels

are listed in the corresponding Specifications. For the installation of the support elements, a differentiation is made between an area within the TBM, right behind the cutter, and an area behind the TBM. The installation of the support elements will interrupt or even govern the TBM advance.

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1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

The Contractor shall provide his personnel with the equipment necessary in accordance with the Specification and shall grant them access to the works to carry out their work in a safe and proper way.

Before commencing the works, the Contractor shall propose a concept to the Engineer for approval. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

2. Materials

2.1 Explosives

The mandatory requirements of the Owner will be considered. In addition to that the following items are obligatory as well.

Only licensed explosives and detonators shall be used. Explosives and detonators shall be stored in separate vessels, which shall be protected against damage and misuse. The storage volume on site shall not exceed the needs of two days.

The explosives and detonators used shall be safe in handling until the intended time of use. Explosives shall only be handled and used by the Contractor's duly authorised personnel. The names and qualifications shall be submitted to the Engineer in writing prior to any possible use of explosives.

All statutory requirements for the storage and use of explosives have to be considered. The Contractor shall give notice about the use and storage of explosives to the Engineer and all security services and responsible authorities for approval. This information shall contain

- the volume and type of explosives and detonators stored on site
- the type, construction and location of the different storage vessels
- the authorised personnel with name and qualification
- the shot-firer's name and qualification
- the design of the used blasting system with information about the specific volume of explosives (g explosives / m^3 excavation) and the number and firing sequence of the detonators.

2.2 Support Elements

The material and handling of the support elements listed above is described in the corresponding Specifications. Reference is made to the

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- "Technical Specification Shotcrete"
- "Technical Specification Reinforcement"
- "Technical Specification Rock Dowels"
- "Technical Specification Steel Ribs"

3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected and maintained within regular inspection and maintenance periods.

3.1 General Construction Plants

For excavation by drilling and blasting, within the tunnel entrance / exit areas the Contractor will use a driller for the boreholes and the rock dowel installation and a shotcrete installation plant depending on the method applied (wet or dry shotcrete).

For general delivery and transportation services within the tunnel, trains will be used. A train station will be installed in the lowest part of the tunnel.

A list of construction plants intended to be used and a concept of transportation will be submitted to the Engineer for approval.

3.2 Tunnel Boring Machine (TBM)

In addition to the general definitions (reference is made to Subchapter 1.3.5, Mechanical Excavation, Tunnel Boring Machine) the TBM shall satisfy the following requirements:

- Installation of steel ribs, shotcrete and rock dowels immediately behind the cutter head.
- Installation of steel ribs, wire mesh, shotcrete and rock dowels from the working platform between the TBM and the gantry, providing ring closure after approximately 40 m.
- Installation of shotcrete and rock dowels from the TBM gantry.
- Arrangement of gripper system in such a way that the support measures to be installed behind the cutter hand will not be obstructed by the position of the grippers.
- Provision of steering and gripper system suitable for hard rock and deformable soft rock.
- Provision of probing facility suitable to drill at least 15 m ahead of the excavation face, without interruption of the TBM advance cycle.
- Provision of access facility in the front of the cutter head for maintenance and other works.
- TBM operation, unimpaired by a damp and wet working environment.

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- Maintenance of cutting tools possible at all times from the rear side or the front side of the cutter head.

3.3 Belt Conveyor

The belt conveyor has to be designed and constructed in such a way that:

- the excavated rock material can be mucked out in the required volume and with the required progress without any interruption of the TBM advance for mucking
- the excavated material will be transported in a safe way and the working personnel will be protected against any kind of incident / accident
- an emergency stop is possible at any time
- the conveyor is protected against misuse

A detailed specification, including an installation plan will be given to the Engineer for approval.

3.4 Tunnel Ventilation

Ventilation ducting shall be non-combustible.

Atmospheric tests shall be carried out continuously to determine the concentrations of the following contaminants and to ensure that the oxygen content of the atmosphere is at least 20 %.

- Carbon dioxide
- Carbon monoxide
- Hydrogen sulphide
- Methane
- Sulphur dioxide
- Nitrogen oxides
- Oil vapour
- Silica dust

The exposure of any person to silica dust shall not exceed internationally recognised limits, which are approved by the Engineer.

In case of changes in the work procedures or changes in ground conditions, the reference dust measurements shall be checked with traditional documentation measurements.

The procedures for corrective actions shall be described in the emergency plan.

Recirculation of cleaned air will not be accepted.

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4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

5.1 Drilling and Blasting

Boreholes intended to be charged with explosives for blasting shall be drilled in strict accordance with the agreed pattern in spacing, direction and depth.

No borehole shall be charged until completion of all drilling operations at the face.

Blasting operations shall be carried out only under the direction of an experienced operator and explosives shall only be handled by shot-firers. The Contractor will appoint one competent person to be responsible for the security of explosives.

Blasting shall be carried out carefully so as to avoid the loosening or shattering of rock beyond the required line of excavation. All loose or shattered rock shall be removed by scaling down or other means before personnel will be permitted to restart operation after blasting.

If required, the neighbourhood of the blasting location has to be protected against "flying" rock pieces.

To extract the explosive gases, a minimum fresh air ventilation of 15 minutes is obligatory before the personnel is permitted to resume operations on site.

Notices of blasting operations shall be posted on site. Before each firing, the responsible shot-firer shall give audible warning, clear the area and take measures to prevent personnel from entering the danger area.

No person shall be allowed to approach the face and no face operation shall commence until the authorised person in charge of the operation has given permission.

The results of blasting shall be monitored closely and where appropriate changes of the blasting operation shall be proposed for agreement of the Engineer.

5.2 TBM Operation

5.2.1 INFORMATION TO BE PROVIDED

As part of this Proposal an outline specification of the TBM intended for use is provided.

In addition to full mechanical and electrical details, an assessment of maximum, average, and intended progress rates is to be provided, supported by records from existing machines of the same type under similar ground conditions. The name of the proposed TBM manufacturer shall be stated with information on his experience, production capacity, etc.

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5.2.2 INSPECTION OF FACILITIES

The Contractor is to allow the Engineer full inspection of the machine facilities during fabrication or adaptation, testing, installation and commissioning.

5.2.3 MACHINE MAINTENANCE

The Contractor shall provide the Engineer with a proposed machine maintenance schedule, including a list of maintained spare parts and available periods for assessment and acceptance. Details outlining the cooperation and the split responsibilities between the TBM manufacturer and the Contractor shall be given.

Use of the machine shall not commence until the maintenance schedule is agreed.

5.2.4 PERSONNEL TRAINING

Evidence shall be produced to the Engineer that

- the senior personnel has had previous experience regarding the operation of similar TBMs under similar ground conditions
- the operating personnel has had previous TBM experience or has undergone training in day to day machine use, steering and operation
- the entire personnel has been trained in emergency procedures

5.2.5 WORKING ENVIRONMENT

The TBM shall be designed in such a way that working conditions during operation and maintenance fulfil the health and safety requirements. Care shall be taken regarding working postures, accessibility, quality of air and noise level.

5.3 Installation of Support Elements

In advance of every excavation and support step, the intended excavation and support type for the execution has to be determined in writing by the Contractor's Representative and agreed by the Engineer. The record's shall contain but shall not be limited to such facts as:

- Excavation area (from chainage to chainage)
- Determined excavation and support type (according to described types)
- Length of unsupported excavation area (round length)
- Specifications of the individual support elements, like thickness of shotcrete lining, kind of reinforcement, kind and length of steel ribs, number, arrangement, type and length of rock dowels
- Place of support installation, right behind the cutter head, between TBM and gantry, behind the gantry
- Additional measures like dewatering measures, grouting measures, etc.

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- Measurement installation, type, location, arrangement

The works shall be carried out in compliance with this record. The decision regarding the excavation and support type to be applied will have to be evaluated at every excavation round and will have to be adapted to the local geological and geomechanical conditions of the surrounding rock mass.

The support elements will have to be installed in such a way that they are effective with respect to their required use.

Sufficient quantities of every individual support element will have to be stored on site, to react to unforeseen events, caused by unforeseen rock mass behaviour.

In addition to the designed support elements, liner plates and timber struts in sufficient number and dimension will have to be stored on site.

For reasons of personnel safety, the work site has to be kept safe at any time and as long as necessary for the personnel to be evacuated.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

6.1 Quality Test

All materials and components have to be tested with respect to their specific use. Records of the testing shall be produced and submitted to the Engineer for approval. If necessary, adaptations of materials and components have to be made.

Quality tests of all delivered materials have to be carried out regularly. The equipment has to be inspected and maintained periodically to prevent failure during operation.

6.2 Control of Workmanship

The works have to be guided and supervised by experienced personnel. The excavation and support works shall be recorded for every shift. The records shall contain, but shall not be limited to the following information:

- Number of workmen within the team
- Name of foreman
- Sequence and duration of working steps (excavation, installation of support elements, etc.)
- Tunnel chainage at the beginning and the end of the shift.
- Progress of work
- Special events like unforeseen overbreak, unforeseen deformations, unforeseen water inflow etc. and corrective action
- Additional works like dewatering, grouting, etc.

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- Inspections by the Engineer or the Owner's representatives
- Other events like failure of any kind of equipment, incidents /accidents, problems encountered with material delivery, etc.

7. Measurements

The quantity survey unit for excavation shall be m^3 of excavated material.

8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works which are to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the site Book that the works have been executed in accordance with the design and the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

European Standards

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9.2 Guidelines

CEN TC 151 WG4 N8:	Tunnelling machines, road headers, continuous miners and impact rippers, safety requirements; Rev. 13 May 1994
CEN TC 151 WG4 N7	Construction equipment and building material machines - safety in manufacture - tunnelling machines; Rev. 10 July 1994
CEN TC 151 WG4 N22	Tunnelling machines, horizontal thrustboring machines, lining erection equipment, safety requirements; Rev. 10 July 1994

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PR-00-5014
Dewatering System Excavation and Support

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1. Introduction

1.1 Subject of Technical Specification

This Technical Specification (TS) shall define the requirements for the execution and commissioning of excavation and support works for the Dewatering System in the Diversion Tunnel of the Niagara Tunnel Facility Project.

1.2 Range of Technical Specification Application

This TS is a bid and contract document used in the execution and commissioning of the works referred to in Item 1.1.

The provisions contained in this Specification refer to the working methods to be adopted for the:

a) delivery of all components and the entire equipment required to the site

b) drilling of required boreholes

c) mucking and disposal of excavated material

d) installation of required support measures

e) installation of facilities at the surface

f) quality control for workmanship and material.

The Scope of Work is defined for the Diversion Tunnel at the connection area of the tunnel with the outlet and the intake structure during the excavation and support period.

1.3 Definitions

The basic definitions given in this TS are in conformity with the relevant standards in force.

1.3.1 DEWATERING SHAFTS

For the dewatering of the Diversion Tunnel, five shafts will be provided at the low point of the tunnel. The shafts will be running from the surface to the crown of the tunnel. Their length will be approximately 129 m and their inside diameter will be 750 mm. Coated steel pipes will be used as casing. For the dewatering procedure, pumps with flexible hoses will be installed in the individual shafts. The water collected in the Diversion Tunnel will be pumped via the shafts into a water collection sump, with a diameter of 3,050 mm, which will be located next to the shaft top structure. From there the water will flow through a HDPE pipe, with a diameter of 1,000 mm, to Canal 2. Details are given in the corresponding Drawing.

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1.3.2 SHAFT TOP STRUCTURE

At the shaft tops, the steel pipes are founded with rectangular concrete slabs, flexibly bedded on the ground. These pipes are covered with blind flanges, equipped with a vent with screen. Details are given in the corresponding Drawings.

1.3.3 PUMP SUMP

At the bottom of the Diversion Tunnel, a 2.0 m x 2.0 m x 2.0 m pump sump will be installed. To accommodate this pump sump, the tunnel will be deepened, covering an area 6.0 m in length x 4.0 m in width. The invert will be made of cast-in-place, reinforced concrete with a minimum thickness of the required final lining thickness.

The pump sump will be covered with a fixed and perforated cover construction, which can be removed.

1.3.4 SHAFT EXCAVATION OVERBURDEN

The overburden material is described as soil. Therefore the shaft excavation in this layer will be done from the surface. The excavated hole, will be covered with a casing pipe, which will be advanced simultaneous to the drilling. The excavation diameter will be 1,050 mm. The casing pipe will be removed while filling the annulus between the final steel pipe and the borehole surface with cement-sand grout.

1.3.5 SHAFT EXCAVATION ROCK MASS

In the hard rock area, the shafts will be excavated adopting the raise-boring method. With this method, a pilot hole is drilled from the surface or the top end. At the low point of the borehole in the tunnel cross-section, a reamer with the required excavation diameter is connected to the drill rod and the excavation is done by pulling the rotating reamer back to the surface. The excavated material which falls into the tunnel can then be mucked out.

1.3.6 FINAL CASING

The final casing will be made of coated steel pipes with a wall thickness between 8 mm and 30 mm. The inside diameter will be 750 mm. The steel pipes will be coated on the interior and the exterior in compliance with the surrounding conditions. At defined distances, steel spacers will be provided at the pipe outside to keep the pipe string centric and to transfer the vertical loads to the surrounding rock mass.

The coating material requirements are specified below.

1.4 General Work Requirements

The Contractor shall be responsible for the quality of material and workmanship and for their conformity with the Design Documentation, other corresponding Specifications and Method Statements and the Engineer's instructions.

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The Contractor shall provide his personnel with the entire equipment necessary in accordance with the Specification and shall grant them access to the works to enable them to carry out their work in a safe and proper way.

Before commencing the works, the Contractor shall propose a concept to the Engineer for approval. The concept shall comprise the equipment envisaged, the scope of work and the work stages.

2. Materials

2.1 Steel

The steel of the pipes shall be a high-quality steel in accordance with the C.S.A. Standards. Its characteristic yield strength shall not be lower than 240 MPa.

The spacers shall be of the same quality as the pipes and shall be factory-welded onto the pipe segment.

2.2 Coating

The installed steel pipes will be coated

On the exterior: with a 3-layer polyethylene (PE) coating

On the interior: with a fusion-bonded epoxy coating

The coatings will generally be factory-applied, yet the coating at the welded segment joints will be completed on site.

2.3 Annular Grouting Material

The annular grouting material shall be made of sand, cement and water, using approximately two parts of sand, one part of cement and one part of water. The detailed composition shall be adjusted by trials.

2.4 Concrete

The concrete for the concrete slab at the top of the shafts shall be a grade C-2 quality according to the C.S.A. Standard A23.1-00.

The concrete for the pump sump shall be of the same quality and specification as the concrete for the invert segment. Reference is made to the corresponding "concrete works, invert segment" Specification.

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3. Equipment

The works may be performed using any type of equipment approved by the Engineer.

The entire equipment must have a valid quality control certificate and is to be inspected and maintained within regular inspection and maintenance periods.

3.1 Overburden Excavation

For the overburden excavation, standardized equipment for shaft excavation of this diameter will be used.

3.2 Raise Boring Equipment

The equipment will comprise the following components (example):

Machine:	Tamrock Rhino 1000DC. Weight: 14,000 kg (with crawler 18,000 kg). Height: 5,450 mm (with beams 5,800 mm)
Stabilizers:	11"-12¼" integral stabilizers
Drill rods:	10", 1.52 meter long (high strength)
Pilot bit:	11" – 12 ¼" tricone roller bit (Sandvik or Baker Hughes)
Reamer head:	Sandvik CRH 3, weight (total): 2,600 kg
Cutters:	Sandvik CMR-41 and CMR-52

3.3 Pipe Installation

For the pipe installation, standardized equipment for this kind of pipe installation will be used.

4. Transport

All components shall be transported by suitable means of transport and in accordance with industrial safety and road traffic regulations to avoid any damage.

5. Workmanship

5.1 Drilling and Casing in Overburden

The drilling and casing of the borehole will be carried out simultaneously from the surface. Because of the water sensitivity of the surrounding soil material, water-base mud will have to be avoided.

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The casing will be removed, while filling the annulus with the sand-cement-grout composition.

5.2 Raise Boring

5.2.1 SET-UP

1. An unarmored concrete slab, 5 m x 4 m x 0.25 m (length x width x height) is cast on an air-cleaned and well-leveled rock surface. The clearance height above the concrete slab shall be >6.5 m.
2. Two foundation beams are placed and positioned on the concrete slab. Each beam is held by twelve anchor bolts, diameter 20 mm - 25 mm with a length of 1600 mm, grouted into solid rock.
3. The raise borer is mounted on the beams and erected. The initial drilling direction is adjusted in one direction with the help of adjustable spanners and in the other direction with the help of shims placed between the foundation beams and the concrete slab.
4. A water re-circulation basin of 50 m^3 at a minimum, is built adjacent (within 30 meters) to the drill site with double 4" steel pipes connecting the basin with the raise boring rig.
5. Before starting the pilot hole drilling, the initial drilling direction is controlled and all anchor bolts are tightened.

5.2.2 PILOT HOLE DRILLING

1. The pilot hole drilling commences slowly and carefully with low load and rotation.
2. Upon completion of the first stabilizer, the initial drilling direction is controlled by Skanska and the Client (in special occasions) and adjustments are made - if necessary.
3. The pilot hole drilling continues, by adding one stabilizer to each other, carefully until the whole stabilizer package has been drilled into the rock.
4. The pilot hole drilling continues with normal load and rotation by adding one drill rod after another. Rock samples, coming up with the flush water, can regularly be taken for tests or inspections. If fractures or significant changes of the rock conditions are recognized, the thrust and rotation of the pilot bit is adjusted in line with our experience. If the flush water disappears, grouting may be necessary. (In case of Directional Drilling: values from the directional drilling tool are continuously displayed on a laptop computer in the operator's cabin, and saved on disc.)
5. Once the pilot hole has reached its final depth, the deviation from the theoretical point of break through will be measured.

5.2.3 CHANGING OF DRILL BIT FROM PILOT BIT TO REAMER HEAD

1. After breakthrough, the pilot bit will be dismantled and the reamer head will be connected.
2. The reamer will be taken down to the lower tunnel and put in the right position to be mounted.

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3. Once put in the right position, the threads will be connected and fully torqued. At this point, the reamer must be locked, for example with the help of the machinery available inside the tunnel.

5.2.4 UP-REAMING TO FINAL RAISE BORE DIAMETER

1. The reaming phase commences from the bottom upwards, first carefully until the reamer head has full contact with the rock surface and then at normal load and rotation. The thrust and rotation will be adjusted, from time to time, in line with the experience acquired and the rock conditions encountered.
2. The cuttings produced by reaming will consist of fine material. The material will fall down through the shaft and pile up at the bottom where mucking is carried out.
3. When the reamer head will have reached the machine, it will be secured with chains and the machine will be de-mobilized. The reamer head will then easily be lifted out of the hole with a crane or a similar device.

5.3 Pipe Installation

The pipe string will be composed of prefabricated segments welded together on site. The steel thickness requires the welding method to be adopted. The welded joints shall have the same bearing capacity as the regular pipe walls. At the joints, the coating is completed on site.

The pipe string will be installed from the surface connecting the pipe segments and driving the string into the borehole all the way to the bottom.

After installation of the pipe string, the annular space will be grouted with the required grout composition. At last the pipes will be covered with blind flanges and the shaft top construction will be completed.

6. Quality Control

All components must have a valid quality certificate and a valid permission for the intended use.

6.1 Quality Test

All materials and components have to be tested for their specific use. Records of the testing shall be produced and submitted to the Engineer for approval. If necessary, adaptations of materials and components have to be made.

Quality tests of all delivered materials have to be carried out regularly. The equipment has to be inspected and maintained periodically to prevent failure during operation.

6.2 Control of Workmanship – General

All kinds of specified works have to be controlled and supervised for their adequacy according to the design and other method statements and specifications. The works shall be recorded daily,

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furnishing information on progress, name of responsible people, number of workmen, used equipment, unforeseen events, etc.

6.3 Control of Workmanship – Raise Boring

6.3.1 RECORDS

1. For all works, a diary shall be kept on a day to day basis, describing activities, progress, notes, etc..
2. In addition, a drill record shall be produced when drilling. This record shall document the drilling characteristics for each drill rod, including such information as rod no., type of drilling (pilot hole or reaming), date (year, month, day), start time (hour, minute), stop time (hour, minute), load (metric tones), penetration (meter per hour), accumulated bored length (meter) incl. average length (value of directional drilling tool)

All records will be available to the Engineer's checking and approval.

6.3.2 CONTROL PROCEDURES

Prior to commencement of drilling works

The position and the alignment of the raise borer is controlled and documented in the diary. The tightening of all anchor bolts, holding the raise borer, is controlled.

During performance of drilling works

Upon completion of the first stabilizer, the initial drilling direction is controlled and documented in the diary (adjusted - if necessary). All drilling parameters (load, RPM, etc.) are continuously controlled (by the operator) and adjusted to the actual drilling situation. The parameters for each drill rod are to be noted down in the drill record. The rock cuttings are collected by the operator for visual inspection or test.

Upon completion of drilling works for pilot hole

Upon completion of the drilling works for the pilot hole, the final position and the length of the pilot hole will be measured and the results will be added to the diary.

6.4 Control of Workmanship – Annular Grouting

The success achieved by annular grouting has to be evaluated by recording the grout volume, the grouting pressure, and the grouting time. The values obtained have to be compared with the values calculated based on theoretical conditions.

7. Measurements

The quantity survey unit of the excavation shall be m^3 excavated material. The quantity survey unit of the installed pipes shall be m.

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8. Acceptance

8.1 Conformity of Work with Design and Technical Specification

The works shall be carried out in accordance with the design, the Technical Specification(s) and the written instructions of the Engineer.

8.2 Acceptance of Works To Be Removed or Covered

8.2.1 DOCUMENTS AND DATA

The acceptance of works to be removed or covered shall be based upon:

- a written statement by the Engineer entered into the Site Book that the works have been executed in accordance with the design and with the Technical Specification(s),
- other written statements by the Engineer commenting on the execution of the works.

8.2.2 SCOPE OF WORKS

The scope of works to be removed or covered shall be determined by written statements of the Engineer and by other documents confirmed by the Engineer.

9. Applicable Regulations

9.1 Standards

Canadian Standards

European Standards

* * *

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Appendix 1.1(vv)
Owner’s Mandatory Requirements

Appendix 1.1(vv) - Owner's Mandatory Requirements

1. GENERAL

1.1 Introduction

1. The Mandatory Requirements cover the minimum requirements for the design, instrumentation, construction, testing, commissioning and other requirements necessary for the performance of the Work. These requirements are the minimum acceptable requirements for the Work. The Contractor shall develop additional requirements and Specifications as necessary to perform the Work.

2. These requirements shall be used in conjunction with the Summary of Work, Concept Drawings, Geotechnical Report (GR) and other information as provided by the Owner to perform the Work.

3. The GR provides a summary of geotechnical information obtained during various investigation phases of the work. This information is to be used in preparation of the final design and augmented with information from additional investigations as required by the Contractor for the final design.

1.2 Operating Environment

1. The tunnel and all ancillary equipment required for its safe operation shall be capable of adequate operation under all weather and river conditions.

1.3 Water Surface Elevations

1. Water surface elevations defined in Appendix 1.1(sss) shall be used in the design of the Tunnel Facility Project as appropriate.

1.4 Water Level Gauges

1. The water level gauges for measuring the intake and outlet canal water levels are as shown on the Concept Drawings.

2. These gauge locations shall be used in conjunction with the hydraulic design levels defined in Appendix 1.1(aa) for determining the GFA of the tunnel.

1.5 Design and Service Life

1. The primary elements of the Niagara Tunnel Facility Project are required to be designed and constructed for a service life of 90 years with no tunnel outages during such 90-yr life. Elements not specifically required to be designed to a 90-yr service life shall be designed to applicable and appropriate codes, guidelines and standards that are commensurate with their intended purpose.

2. The following elements shall be designed and constructed to a 90-yr service life:

(a) tunnel lining system, including

(i) reinforced concrete lining

(ii) annular grout

(iii) impermeable liner if used

(iv) gaskets and/or any other water control features incorporated in the Work

(b) intake structure

(c) outlet structure.

3. Assessment of 90-Yr Service Life

(a) **Loading –** The tunnel lining system and intake and outlet structures shall be designed for all short- and long-term prescribed time-dependent loading and deformations. The 90-yr service life shall be deemed to have been met by demonstrating compliance with the long-term time-dependent loading and deformations prescribed in Section 8.3 of this Appendix.

(b) **Loading and Deformation –** Compressible annular grout, if proposed, and compressible materials at the intake and outlet structures shall be designed to accommodate all short- and long-term time dependent loading and deformation as prescribed in Section 8.3. Confined compressive testing of annular grout mixes with a confining pressure equivalent to the applied pressure shall be performed to determine the compressive strength of the grout at the calculated long-term (90-yr) deformation. The 90-yr service life shall be deemed to have been met by demonstrating through testing that the measured compressive strength of the grout at a strain equivalent to the 90-yr deformation assumed for the design is greater than the ultimate design strength (f_c') of the grout.

(c) **Sulphate Attack –** The cement for the annular grout and reinforced concrete lining shall be designed to resist the effects of sulphate attack. Accelerated tests shall be performed on the annular grout and lining concrete mixes. The 90-yr service life shall be deemed to have been met by demonstrating through testing that the mixes are resistant to sulphate attack derived from the highest values of sulphate concentrations for the groundwater in contact or potentially in contact with the tunnel lining or annular grout over a 90-yr period.

(d) **Corrosion from Chloride Penetration –** The tunnel lining system shall be designed to be resistant to corrosion from chloride penetration. The 90-yr service life shall be deemed to have been met by demonstrating that the time taken to reach the corrosion threshold at the reinforcing steel, based on chloride diffusion rates for the concrete and chloride levels present in the

groundwater in contact or potentially in contact with the tunnel lining or annular grout , exceeds 90 years. Tests to derive chloride diffusion rates used to demonstrate compliance with 90-yr service life shall be in accordance with test methods in accordance with the Nordtest Method, NT Build 443 (Approved 1995-11), Nordic Innovations Centre, or as otherwise approved by the Owner.

(e) **Abrasion –** Concrete in water passages shall be designed to be resistant to the abrasive action of water flow, entrained ice and debris. For this purpose, concrete in water passages shall be dense, have a low water/cement ratio and be of sufficient strength. Precedents in projects of similar conditions shall be used to establish the required concrete material properties and to assess compliance with the 90-yr service life.

1.6 Safety by Design

1. Design methods consistent with the 'Safety by Design' approach shall be used.

1.7 Equipment Isolation and Interlocks

1. All equipment that can instantaneously release dangerous amounts of energy to personnel maintaining the equipment shall be fitted with adequate isolation devices and lockout mechanism as required by the Owner.

2. Electrical breakers must be lockable in open and closed positions and must have visible contacts (Visibreak). Valves must be lockable in open and closed positions.

3. All safeguarding devices (interlocks) that signal equipment to stop shall comply with the appropriate Canadian Standards Association, American National Standards Institute, International Organization for Standardization or European Norm. The Contractor shall provide documentation to the Owner certifying that all such safeguarding devices have been manufactured and installed in accordance with manufacture's instructions and that the protective devices have been manufactured or modified to meet current applicable standards.

4. For all other safeguarding devices, the Contractor shall provide documentation to the Owner certifying that the protective element is installed in accordance with the manufacturer's instructions and current applicable standards.

1.8 Dam Safety

1. The outlet closure gate equipment will be tested for operation by the Owner at a minimum once yearly after Final Completion Date. For this purpose, the gate equipment shall be capable of being operated over any partial range within its full range of operation.

1.9 Condition Surveys

1. Pre-construction and post-construction condition surveys shall be undertaken by the Owner of all buildings and infrastructure including any active recorded drinking water wells within 300 m of the construction works, including but not limited to the INCW, the PGS station and dykes, and third party properties. Independent consultants, qualified in this work, will carry out the condition surveys. The Contractor shall review and accept the results of these surveys. These surveys will be used to determine the impact, if any, of the performance of the Work on the surveyed buildings and infrastructure.

2. ENVIRONMENTAL PROTECTION

2.1 General

1. As they relate to the performance of the Work, the Contractor shall be responsible for

   (a) compliance with the EA and the EA Approval, and for fulfilling all associated EA Approval conditions; and

   (b) compliance with Department of Fisheries and Oceans Authorization 5250-43.

2. All necessary Approvals shall be in place prior to undertaking the relevant element of Work.

2.2 Minimum Requirements

1. The Woodlands Reserve Area and meadow identified on the Concept Drawings shall be protected with fencing paid for and installed by the Contractor. Trespassing within these areas by Contractor Personnel is not permitted.

2. Trees to be cut shall be flagged and shall only be cut after approval by the Owner.

3. On-Site burning shall not be allowed.

4. Tree clearing and grubbing shall not occur between May 1 and June 15 to avoid the main bird nesting and raising period, unless approved by the Owner.

5. The Contractor shall demonstrate, through testing, that the areas where the "contaminants" (as defined under the *Environmental Protection Act* (Ontario)) were stored have been remediated to meet the soil, groundwater and sediment standards of Regulation 153/04, Environmental Protection Act (Ontario), for non-potable groundwater criteria for industrial land use sites, as more particularly set out in Table 3 of MOE publication entitled "Soil, Groundwater and Sediment Standards for Use Under Part XV.I of the *Environmental Protection Act* (Ontario)."

6. If fuelling facilities are required on Site, there shall be only one such fuel facility located at the outlet work area. The fuel tanks shall be stored above ground on a

concrete pad and shall comply with Technical Standards and Safety Authority Liquid Fuels Handling Code.

7. Sewage holding tank(s) shall be installed to average the flow rates prior to sewage disposal into the City of Niagara Falls sanitary sewer.

8. The Contractor shall take all necessary measures to ensure that hourly equivalent sound levels from construction activities are met at sensitive receptors in accordance with MOE Publication NPC 205, unless written exceptions have otherwise been obtained.

9. Construction equipment and trucks shall meet the requirements of MOE Publications NPC 115 and 118. They shall be measured at a distance of 7 m (15 m for tracked drills and heavy trucks) according to the standards and procedures prescribed in MOE Publication NPC 103 to confirm their compliance. Measurements shall take place before the equipment is used and annually thereafter. For new equipment where manufacturer's data are available, the first measurement may be waived.

10. Blasting

    (a) All blasting shall be undertaken in compliance with NPC 119 as applicable unless exceptions obtained.

    (b) The Contractor shall establish standard blast warning codes.

    (c) Notice of blasting shall be placed in local newspapers. The Contractor shall develop and submit a protocol for informing immediately affected residents, Niagara Parks Commission, Niagara Helicopters, OPG, Hydro One, Niagara Falls Bridge Commission, City of Niagara Falls and Town of Niagara-on-the-Lake of the blasting schedule.

    (d) Monitoring of all ground vibrations shall be undertaken during all blasting, with special emphasis on the INCW structure, the PGS dyke and the PGS generating station. The peak particle velocity shall be monitored at all structures with the peak ground acceleration also monitored at the downstream toe of the PGS dyke at its closest proximity to the outlet canal excavation. The Contractor shall make his own assessment of the effects on blasting on structures and establish appropriate limits; however, the limits defined in the following table shall not be exceeded.

    Limits on Blast Vibrations

Measurement	**Limit**
Peak Partical Velocity (at structure)	<30 mm/s
Acceleration, 2/3 Peak Value (at toe of PGS dyke)	0.04 g

    (e) All blasting material shall be stored in a designated magazine building which shall be securely locked at all times. A weekly audit of blasting material shall

be made and reconciled with blasting materials actually used at the Site. The Contractor shall notify the Owner immediately of any missing blasting material.

(f) The Contractor shall comply with DFO Authorization 5250-43 issued under Section 32 of the Fisheries Act for underwater blasting.

3. DISPOSAL OF EXCAVATED MATERIAL

1. The Contractor shall provide a temporary storage pad in the main construction facilities area for holding any excavated material suspected of being contaminated (including formations containing benzene, toluene, ethyl-benzene and xylene). Such materials will be stored until the results of chemical testing are available to determine how the material is to be managed and disposed of to the Approval of the Governmental Authorities having jurisdiction. The storage pad shall have an impermeable base and shall be surrounded by peripheral drains/ditches to capture any runoff. The runoff shall be suitably treated prior to discharge. The storage pad shall be of sufficient size to hold a minimum of 15 working days of excavated material.

2. Where a surge pile or stockpile is provided at the outlet area, including the stockpile at the designated disposal area, any runoff from the surge pile or stockpile shall be directed to a Contractor-supplied water treatment facility that has Approvals prior to discharge into any watercourse.

3. Methods of depositing of material in the stockpile shall ensure good compaction with side slopes, such that the surface provides sufficient slope for drainage at all times, and any ponding of water on the surface does not be occur. The stockpile shall be designed and constructed to be permanently stable on the underlying foundation material with side slopes not steeper than two horizontal to one vertical.

4. At completion of the Work, the Contractor shall ensure that the surface of the stockpile is generally level, such that the difference in elevation over any part of the stockpile shall not exceed 1 m, and the surface shall be graded smooth and crowned sufficiently so as to drain to the edges of the stockpile. The toe of the stockpile shall not encroach on any elevation lower than 180 m, unless approved in writing by the Owner, and shall be no closer than the distance specified on the Concept Drawings to the edge of the existing canals. Stock piles will be revegetated to reduce long-term erosion.

5. The Contractor shall ensure that its stockpiling operations at the disposal area does not cause damage, or limit the Owner's access, to the existing transmission line that is located on the southern edge of the stockpile area. The toe of the stockpile shall be no closer than 5 m from any part of the structure of the towers, or of the location in plan of the overhead lines.

6. The Contractor is required to sample excavated material to determine if contaminants have been introduced by the Contractor during the course of the work. Any material

found to be contaminated shall be segregated and treated by the Contractor prior to being delivered to the disposal site.

7. Excavated rock suitable for aggregate production shall be disposed off-site in accordance with Applicable Laws and in a manner to facilitate its use as aggregate.

8. No excavated material shall be spilled into a watercourse.

4. TUNNEL, INTAKE AND OUTLET ALIGNMENT

4.1 Tunnel Alignment

4.1.1 Alignment Constraints

1. The alignment of the tunnel shall satisfy the following requirements:

   (a) the submerged intake of the tunnel shall be located beneath Gate 1 of the INCW at the location and orientation indicated on the Concept Drawings

   (b) the outlet structure of the tunnel shall be located on the northwest side of the SAB2 Canal at the location and at the azimuth indicated on the Concept Drawings

   (c) the horizontal alignment of the tunnel shall remain within the subsurface right of way as indicated on the Concept Drawings. The vertical alignment indicated on the Concept Drawings was the basis for the EA Approval. Deviation from this vertical alignment, indicated on the Concept Drawings, may require an amendment to the EA. The Contractor shall be responsible for obtaining such an amendment.

   (d) the tunnel alignment shall not preclude future construction of a similarly designed tunnel with an intake beneath Gate 4 of the INCW and an outlet structure parallel and located south of the new tunnel outlet structure

   (e) the tunnel alignment shall be such as not to cause a material change in the in-situ stress regime at the existing tunnels or the Toronto Power Generation Station wheel pit as determined by numerical analyses such as PHASE2 or equivalent

   (f) a dewatering station shall be provided at the low point of the tunnel. The shafts shall be located on the Owner's land east of the buried St. Davids Gorge.

5. INSTRUMENTATION

5.1 Purpose

1. Instrumentation during tunnel construction shall be installed and monitored until Final Completion by the Contractor, as required, to

   (a) monitor movements of existing structures and buildings affected by the Work to ensure their protection, structural integrity and safety

   (b) monitor the tunnel and response of adjacent rock at a single section to be selected by the Owner during construction, filling and commissioning

   (c) monitor response of initial lining to the imposed rock loading at locations as required on the basis of observations during tunneling

   (d) monitor groundwater piezometers around the tunnel.

2. Standpipe tunnel piezometers to monitor the tunnel piezometric during tunnel operation.

5.2 Instrument Type

1. Surface movement monitoring point (SMMP)-A surface movement monitoring point is a marker fixed to a surface, and used for the measurement of the vertical and horizontal movements of that surface. SMMP shall be permanent pins on structures or grouted rods in rock. Survey equipment (theodolite, level, electronic distance measuring device, tape extensometer), shall be capable of measuring vertical and horizontal movements of the SMMPs to ±1 mm.

2. Multiple Point Borehole Extensometers (MPBE)-A multiple point borehole extensometer is a device installed in boreholes for monitoring the changing distance between more than two points along the axis of the borehole. The MPBE shall be of the vibrating wire type and shall be capable of determining the relative position of each anchor to the surface installation with a repeatability of ±0.1 mm.

3. Groundwater Piezometer-A groundwater piezometer is a device that is sealed within the ground so that it responds only to groundwater pressures around itself. Piezometers shall be of the vibrating wire type and shall be capable of measuring the head of water at the piezometer tip to a repeatability of ±0.1 m.

5.3 Minimum Instrumentation Requirements

5.3.1. Surface Movement Monitoring

1. Install SMMP on masonry or buildings prior to commencing any excavation. Buildings shall include, but not be limited to, INCW structure Bays 1 to 5 and the INCW control and maintenance buildings.

2. Install a series of SMMPs on the INCW structure on Bays 1 to 3 above the intake excavation with a spacing of no more than 5 m.

3. Install SMMPs at the pier nose of Piers 1 and 2.

4. Install a plumbline at the pier nose of Piers 1 and 2 extending to rock level. The plumbline shall have measuring tables at least three locations.

5.3.2. Excavation Monitoring

1. Install a permanent array of a minimum of one MPBE on each vertical or near vertical rock cut at the intake and outlet structures at approximately the midpoint that shall have, as a minimum, monitoring positions (anchors) at 20, 10, 5 and 2 m from the wall of the excavation. Electrical leads shall be in watertight conduits leading to a lockable watertight box located at the deck level.

2. Monitor tunnel convergence following installation of the primary lining by tape extensometer or survey methods repeatable to ±1 mm as required, dependent on response to imposed rock loads. Number and locations of monitored sections shall be agreed with the Owner.

5.3.3. Instrumented Tunnel Section

1. The following instrumentation shall be installed at one section of the tunnel as selected by the Owner:

   (a) install a permanent array of a minimum of eight MPBEs that shall have, as a minimum, monitoring positions (anchors) at 25, 10, 5, 2 and 1 m radially from the inside surface of the tunnel lining. Installation shall be completed and the initial readings taken before the tunnel face advances more than 25 m beyond the array. This array of MPBE shall be capable of being monitored remotely from the surface during the initial filling and operation of the tunnel.

   (b) install a permanent array of a minimum of six piezometers around the exterior of the tunnel lining and one on the interior of the lining at the tunnel invert. The array of piezometers shall be capable of being remotely monitored from the surface during the initial filling and operation of the tunnel.

   (c) electrical leads for MPBEs and piezometers shall be in watertight conduits, adequately fixed to the tunnel crown and extending up one of the dewatering shafts leading to a lockable watertight box located at the top of the shaft.

5.3.4. Tunnel Standpipe Piezometers

1. Tunnel piezometric levels shall be measured at two locations along the alignment of the tunnel at approximate Chainages 30+00 and 90+00 m. Each location shall consist of two standpipe piezometers, 2 to 20 m apart, extending through the tunnel lining at

the tunnel crown to the ground surface. Final locations shall be agreed with the Owner prior to installation.

2. Piezometer holes shall be cased with a corrosion resistant casing with a minimum 95 mm inside diameter. The annular gap between the rock and the casing shall be grouted to prevent groundwater migration between the different rock formations.

3. Detailing of the piezometer fitting at the tunnel crown shall ensure that the velocity head is not measured and that degradation of the adjacent tunnel lining or fitting does not occur. The fitting shall be corrosion resistant.

4. The piezometer shall be embedded in concrete at the surface with adequate detailing to prevent problems of ground movement due to frost heave. A watertight, lockable cap shall be provided.

5. Arrangement of piezometers shall be consistent with flow verification requirements.

6. STRUCTURES AND EXCAVATIONS

6.1 General

1. The Contractor shall establish all design parameters, load cases and load combinations as required by Applicable Laws, codes, standards and guidelines, this Agreement and as necessary for the design and construction of structures fit for their intended purpose, robust, reliable and maintainable, with adequate safety factors and detailed to deal with all conditions throughout their required 90-yr service life. Normal, unusual and extreme conditions of loading shall be considered in determination of the design loads.

6.2 Stability

1. Stability of the structures shall be checked using the limit equilibrium method using guidelines outlined by the United States Bureau of Reclamation or the Corps of Engineers. Load cases shall be developed in the most critical combinations and adequate factors of safety against sliding, uplift, overturning, including base stresses, provided.

2. Passive pressures due to backfill shall not be considered.

3. The weight of rock in a mobilized wedge above the structure shall only be considered in the calculation of uplift stability.

4. Cohesion at the concrete rock interface shall not be assumed.

5. Rock anchors shall not be used to provide the required stability of gravity structures.

6. The stability of the excavations shall be evaluated and provision shall be made in the design for rock support to be installed as identified in the stability evaluation. The

evaluation and design of the excavation shall take into consideration the requirements for

(a) the stability of the INCW

(b) permanent stability conditions of the vertical faces.

7. Permanent rock support systems, where required, shall be provided with suitable corrosion protection.

6.3 Effects on Existing Structures

1. The Contractor shall investigate the effects of tunnel construction on existing structures, including, but not necessarily limited to,

   (a) the effects of deformation on equipment operation including the INCW gates

   (b) the effects on structural strength and integrity

   (c) the effects on structural stability.

6.4 Excavation

1. The sides of the intake channel and outlet canal excavations shall be line drilled and controlled blasting techniques employed to ensure that the rock beyond the excavation limits is not damaged or destabilized by the blasting operation. Any damaged rock shall be removed and backfilled with concrete adequately tied back to sound rock to produce the requisite excavation lines.

2. Due to the need for blasting at close proximity to the INCW, preset rock reinforcement may be required to be provided prior to excavating for the intake to secure the integrity of the foundation of the control structure.

3. During excavation, methods shall be employed to prevent damage to existing structures and buildings and to prevent detrimental effects to the operation of existing equipment. Blasting velocities shall be carefully controlled and monitored to ensure adequate control.

4. Any exposed shaly rocks or shale layers which are susceptible to deterioration upon exposure to wetting and drying cycles and large temperature differences shall be immediately protected by shotcrete.

6.4.1. Outlet Canal Rock Plug Removal

1. The outlet gate shall be closed and under balanced water conditions during rock plug removal.

2. Excavated material shall be removed from the PGS canal prior to the PGS canal being brought back into operation.

3. A sounding survey of the PGS canal shall be performed before and after removal of the rock plug to verify that no excavated material remains within the PGS canal and the results submitted to the Owner.

4. No material shall be allowed to be carried down the PGS canal during and after removal of the rock plug.

6.5 Intake Structure, Intake Channel and Intake Approach and Accelerating Walls

1. The location and dimensional geometry of the intake channel and intake approach wall are fixed as defined on the Concept Drawings as adjusted for final tunnel slope and diameter. The alignment and dimensional geometry of the ice accelerating wall is generally as shown on the Concept Drawings. The intake channel, ice accelerating and approach walls shall be designed and constructed to convey water smoothly into the intake structure and shall provide satisfactory performance for both open water and ice conditions.

2. The intake structure location, internal dimensional geometry, and transition from the shape at the entrance to the circular shape of the tunnel are fixed as defined on the Concept Drawings. Adjustment to the geometry for tunnel diameter or tunnel slope shall be as indicated on the Concept Drawings.

3. The intake and outlet structures shall be designed and detailed with an appropriate compressible material or other means to accommodate a minimum of 100-mm movement due to time-dependent deformations of the rock.

4. Suitable venting shall be provided at the intake behind the sectional gate to permit aeration of the tunnel during filling and dewatering. Vent sizing shall be such as to limit noise levels during filling and dewatering to the relevant noise restrictions.

5. A cover shall be provided over the top of the sectional service gate openings in the intake structure to avoid the possibility of ice being drawn into the structure. The cover shall be of ample mass to prevent dislodgement and shall be detailed to prevent seizing of the cover after prolonged submergence. Appropriate lifting devices shall be provided on the covers to enable the sectional service gate follower to engage and lift the gate slot cover.

6. The intake approach wall shall be blended into the existing SAB2 intake wall.

7. The accelerating and intake approach walls shall be adequately capped with concrete.

8. The Contractor shall

   (a) provide the facility for bubbling along the river side of the cofferdam in the event that ice starts to form along the cofferdam or sticks to its walls;

   (b) design and construct the cofferdam to minimize impact on flow at the INCW; and

(c) remove the existing ice accelerating wall and construct the new wall prior to construction of the cofferdam at the intake.

6.6 Dewatering System Shafts

1. Each shaft shall be circular, with a minimum internal diameter of 1.05 m in overburden and 0.915 m in rock to accommodate the Owner's pumping equipment and arrangement. The shafts shall be located on the centreline of the tunnel so that the pumps can be positioned over the tunnel invert. One sump shall be provided at the invert below one of the dewatering shaft locations such that a submersible pump can be positioned below the tunnel invert to achieve the required operating submergence in the final stage of dewatering.

2. The shafts shall be capped for normal operation of the tunnel and the cap shall be protected from pressure surges with air vents.

3. The dewatering shafts shall be lined in the overburden section with a corrosion resistant sleeve.

4. The rock portion of the dewatering shafts shall also be lined with a corrosion resistant sleeve and the annulus between rock and sleeve grouted to prevent groundwater migration between different rock formations.

5. A sump shall be provided at the invert of the tunnel to allow the suction inlet of one pump to be lowered into the sump to provide the necessary operating submergence.

6.7 Demolition of Dewatering Structure

1. Means and methods used in demolition of the dewatering structure shall be such as to minimize impact on the operation of the PGS. Construction activities shall be coordinated with the Owner as indicated in Appendix 1.1(sss), Section 3.1(c).

2. The piers shall be removed flush with the sill. Abutment piers shall be retained; however, any loose sections of concrete shall be removed or tied back to sound rock.

3. Demolished materials shall be removed from the PGS canal. A sounding survey as required by Section 6.4.1.3) shall be performed. No demolished material shall be allowed to be carried down into any of the other existing canals.

4. The relocated waterline shall be constructed to the same standards and details as the existing waterline running over the dewatering structure. The waterline shall either be relocated to run across the PGS canal at the downstream deck of the PGS or near its existing location by means of a pipe bridge. The waterline shall be relocated and in operation prior to the start of demolition of the dewatering structure. The commissioning procedure shall minimize disruption of water supply. Commissioning shall be coordinated with the Owner.

7. INTAKE SECTIONAL SERVICE AND OUTLET CLOSURE GATES, HOISTS AND GUIDES

7.1 General

7.1.1. Intake and Sectional Service Gate

1. A sectional service gate shall be provided to isolate the tunnel from the upper Niagara River GIP at the INCW to facilitate dewatering by OPG. The service gate shall be installed under conditions of no flow when there is a requirement to dewater the tunnel. The top gate section shall be fitted with a manually actuated, non-hydraulic, equalizing valve to allow for equalizing the water pressure across the gate. The gate shall be removed under balanced head conditions once the tunnel is filled.

2. The sectional service gate shall be designed to be installed using mobile cranes situated on the INCW. Mobile crane loads shall be limited to the specified bridge capacity. Outriggers may be situated on the extended piers during lifting; however, outrigger loads shall not cause distress to the structure. Service gate sections shall be sized to match the mobile crane equipment at the required reach and arrangement.

3. The sectional service gate follower shall provide a means to engage and disengage from the gate or slot cover with control from the surface.

4. Removable gate extensions shall be provided to allow for installation of the gates from the surface using the gate follower. The structure to extend the guides shall be rigid enough for this purpose and be designed for gate jamming. The structure shall be fabricated in sections to allow for installation and removal to an off-site storage location. Suitable platforms shall be provided at the top of each guide extension to allow for personnel to guide the gates into place. Suitable handrails shall be provided. The structure may be installed with the use of divers; however, underwater work shall be limited and shall not require divers to manipulate heavy structures underwater.

7.1.2. Outlet Closure Gate

1. The gate shall be capable of safely opening and closing against head and flow conditions, and when closed, withstanding the hydrostatic pressure imposed by the maximum water level in the outlet canal while the tunnel is dewatered.

2. The gate shall be raised and lowered by a dedicated, fixed hoist mounted on a steel structure above the gate location. The hoist shall be designed to maintain the gate in the raised position without dogging. The gate shall have the capability of being dogged in the open position to permit hoist maintenance.

3. The gate shall be articulated and allow the top section to be lifted enabling watering up of the tunnel.

4. Capability for installation and removal of a sectional service gate using a mobile crane operating from the wall of the outlet structure in the future shall be provided for in the layout and design of the structure.

7.2 Design Requirements

7.2.1. Loads and Load Combinations

1. The Contractor shall establish all design parameters, load cases and load combinations as required by Applicable Laws, codes, standards and guidelines and as indicated herein necessary for the design and construction of the gates, hoist and guides fit for their intended purpose, robust, reliable and maintainable, with adequate safety factors and detailed to deal with all conditions throughout its required design life. Normal, unusual and extreme conditions of loading shall be considered in determination of the design loads.

2. In particular, the following loads shall be considered in conjunction with other loads developed for the design of the gates, guides and hoist

   (a) hydrodynamic loading with the gate descending or ascending at applicable design speed for any position of the gate and including the effects of the maximum transient head in the tunnel during gate closure

   (b) structure weight

   (c) roller, seal, bearing bar and static and dynamic spring friction forces

   (d) impact loads of 30%

   (e) lateral loads of 30% of maximum loads acting normal to roller path

   (f) impact loads of 100% on lifting points and dogging devices

   (g) lateral loads acting in the plane of the bearing path generated by gate or steel sectional service gate flexure

   (h) loads due to wire rope hoists developing motor rated torque

   (i) loads caused by a jammed gate at any point in the guides, with locked rotor or motor stall torque, whichever is greater, 100% hoist efficiency and the force being applied to one lift point.

7.2.2. Materials

1. All sealing surfaces shall be stainless steel.

2. Gate roller paths shall be stainless steel.

7.2.3. Gate Hoist

1. The outlet closure gate fixed hoists shall be of the wire rope type and shall be designed to meet the following requirements:

   (a) each gate hoist shall be located in a weather-tight housing on the steel superstructure of the outlet structure

   (b) each hoist shall be equipped with sufficient protection (*e.g.*, limit switches, interlock) to prevent damage to the gate, the outlet structure and the hoist structure

   (c) control of each hoist shall be both local and remote

   (d) each hoist shall be capable of lowering the gate at the maximum speed allowable based on minimizing transient pressures in the tunnel

   (e) a fail-safe braking system shall be installed on each hoist for emergency controlled unpowered lowering of the gate

   (f) the hoist shall comprise two drums, driven through separate drive trains by a common double ended electric motor

   (g) the gate shall be held in the raised position by electrically operated brakes on the input shafts of each gear reducer

   (h) the gate speed for unpowered lowering shall be controlled by centrifugal fan brakes on the high speed shafts of each gear reducer

   (i) the following maximum hoist speeds shall be used

(i)	Raising	0.16 m/min
(ii)	Lowering (Powered)	0.16 m/min
(iii)	Lowering (Unpowered)	0.31 m/min

7.2.4. Gate and Hoist Structural Components

1. For consistency with usual design practice, the working stress design method shall be applied, and AISC Specification for Structural Steel Buildings (ASD) and CSA Standard B167 shall be used.

2. Allowable stresses shall be based on those defined in AISC. A 3-mm allowance shall be made for corrosion. Design stresses for Normal Loading Conditions shall not exceed 90% of those permitted by AISC. For Extreme Loading Conditions allowable stresses may be increased by 33% provided they do not exceed 80% of the yield stress of the material. For hoist design, CSA Standard B167 should be referenced instead of AISC, but otherwise the same restrictions on allowable stresses shall apply.

3. Bolted connections shall be designed using high strength bolts in friction type connections, in accordance with AISC, except that design stresses shall not exceed 90% of those permitted by AISC.

4. Bolted connections must be watertight and shall have bolts at a suitable pitch. Seal welds shall not be used on bolted connections.

5. Maximum deflection of the gates under normal loading conditions shall be limited to 1/800 of the span between main rollers or bearing bars or one half allowable seal flexure at the seals, whichever is less.

6. All welded connections subject to immersion shall be seal welded.

7. Sufficient weight shall be provided in each gate and gate section so that it shall close readily under its own weight during normal hydraulic conditions. The lowering force shall exceed the resistance to lowering, based on static friction coefficients, by a minimum of 25%.

7.2.5. Mechanical Components

1. For normal conditions, design stresses shall not exceed those permitted by CMAA Specification 70, AISE Technical Report No. 6, and AGMA Standard 420.04.

2. For Extreme conditions, design stresses shall not exceed 80% of the elastic limit of the material.

3. The load on wire ropes shall not exceed 20% of the minimum breaking strength of the rope.

4. Main rollers shall be designed in accordance with the criteria outlined in ASCE Paper 3000 "Fixed Wheel Gates for Penstock Intakes" or approved equivalent. The exception shall be that the 'Critical Stress' obtained from the formula on Page 755 of ASCE Paper 3000 shall be multiplied by 0.30 for normal loading conditions and by 0.45 for extreme loading conditions to achieve suitable factors of safety.

5. The roller axles shall be designed in accordance with ASCE Paper 3000. The design of flat and crowned rollers and their supports shall take into consideration the rated radial load acting on the roller and an axial load equivalent to 30% of the radial load acting at the outer rim of the roller and the roller path.

6. The maximum shear stress (in MPa) in rollers and roller paths shall not exceed 2.40 times the minimum BHN of the softer material or 620 MPa, whichever is less.

7. The maximum compressive stress (in MPa) in rollers and roller paths shall not exceed 6.90 times the minimum BHN of the softer material or 1700 MPa, whichever is less.

8. The roller face shall have a surface hardness of 255 to 280 BHN. The minimum roller path hardness shall be at least 50 BHN greater than the minimum roller face hardness.

9. Crowned rollers shall use anti-friction bearings.

7.2.6. Gate Controls, Heating & Electrical

1. The hoist control shall automatically detect and compensate for any creeping of the gate toward the closed position.

2. A slack rope switch shall be furnished that detects rope slacking in the event that the gate hoist closes, but the gate hangs up.

3. Gate, hoist and guides shall be adequately heated to ensure reliable winter operation, and prevent icing of the gate to allow for remote position indication.

4. If the gate is in the open position it shall remain in the open position if power to the gate is interrupted.

5. Gate control shall be interconnected to the Owner's existing plant control system.

6. Hoist motors to be TEFC, CEMA-MG-1, Section 2.

7. Electrical enclosures and junction boxes to be CEMA 4X, stainless steel.

8. Cabling to be steel armoured TECK FT1 with black outer neoprene.

7.2.7. Painting

1. Gate section shall be prepared and painted in accordance with OPG's specification WIP — HO0386.

7.2.8. Maintainability

1. Components subject to wear or deterioration (e.g., bearings, seals, wire ropes) will require servicing and maintenance at regular intervals as recommended by the manufacturers or as dictated by observed conditions. Design and detailing of these components shall be such as to maximize ease of maintenance and minimize maintenance interventions.

2. The design and construction of all equipment and structures shall consider the following maintenance requirements:

   (a) personnel safeguards during all phases of the maintenance work

   (b) partial and full lowering of the outlet gate, once yearly to ensure proper operation

(c) adequate access to all serviceable components

(d) provision for suitable lifting and handling equipment

(e) suitable spare parts to minimize downtime of all systems.

8. TUNNEL

8.1 General

1. The tunnel shall be capable of being dewatered within a specified time of 3 weeks and the tunnel lining shall be capable of resisting all internal and external loads that are anticipated during the service life of the diversion tunnel.

2. The tunnel lining system shall be designed, detailed, fabricated and constructed to deal with the highly corrosive environment that will exist along its alignment.

8.2 Hydraulic Design

1. The hydraulic conveyance system shall extend from intake structure at the GIP to the outlet water level gauge in the outlet canal and include the intake channel, intake structure, tunnel, outlet structure, and outlet canal to the point immediately upstream from the transition at the junction with the PGS channel.

2. The tunnel conveyance system shall be designed, detailed and constructed to provide the optimum hydraulic efficiency.

3. The tunnel shall be capable of delivering a GFA with the hydraulic head and energy grade design level defined in Appendix 1.1(aa) considering the hydraulic conveyance system defined in Section 8.2(1).

4. Transient load analysis shall be performed based on powered and unpowered closure rates for outlet gate and appropriate intake and outlet water levels.

5. Loads determined from the transient load analysis shall be used for input into the design of the outlet gate and structure and tunnel liner. The outlet surge shaft shall be sized to limit the transient load while retaining the upsurge water level within the confines of the shaft.

8.3 Tunnel Lining Design

8.3.1. General Considerations

1. Only the following design approaches are acceptable, individually or a combination thereof,

   (a) a tunnel lining system (either pre-cast or cast-in-place) capable of adequately supporting all loads including those imparted on the lining from long-term rock swelling effects

(b) a tunnel lining system which incorporates an impermeable liner so that long-term rock swelling is prevented from developing.

The Contractor is to provide confirmatory analysis to support that its selected approach meets the requirements of this Agreement.

2. The Contractor's tunnel excavation and lining design may investigate all the above approaches, with the following restriction:

   (a) an impermeable lining system will not be acceptable as the sole design approach, unless a testing method acceptable to the Owner is included to prove that the constructed lining system is impermeable and will not allow the passage of water or chloride ions.

3. Rock support systems shall be provided with suitable corrosion protection.

4. The tunnel lining shall be made of concrete and reinforced as necessary to control cracking during construction and after installation, and to prevent overstressing at the joints in the case of precast lining.

5. The tunnel lining shall be designed to be as watertight as practical under normal operating conditions commensurate with the tunnel design approach.

8.3.2. Tunnel Lining Load Conditions

1. Internal hydrostatic pressure will correspond to the water surface level at the GIP and the transient upsurge due to closure of the outlet gate.

2. Loads to be considered in the design of the concrete lining shall include, but not limited to, the following:

   (a) self-weight of the lining

   (b) rock loading of a loosened slab of thickness not less than 3 m up to the full width of the tunnel and shear deformations along bedding planes

   (c) immediate elastic deformation of the rock mass

   (d) elastoplastic deformations prior to filling of the tunnel

   (e) grouting pressure

   (f) external groundwater pressures prior to filling the tunnel

   (g) loading resulting from stress changes caused by tunnel excavation

   (h) time-dependent rock deformation loading on the lining

(i) internal hydrostatic pressure. Unbalanced hydrostatic pressure at the time the tunnel is filled. Additionally, pressure differential due to closure of the gate.

(j) thermal effects due to differential temperatures between lining and rock at time of installation and between lining and water

(k) full external groundwater pressures following dewatering of the tunnel unless a pressure relief system that is consistent with the selected tunnel lining system design, and acceptable to OPG at its sole discretion, is provided. In any case, the external pressure shall not be taken as less than 50% of the external groundwater pressure.

8.3.3. Load Combinations

1. Loads and load effects in Section 8.3.2 shall be considered in appropriate combinations and take into account the stages and sequences of construction and operation, and ground/structure interaction.

2. Appropriate analyses shall be performed to ensure that adequate vertical and sidewall cover exists at the St. Davids Gorge under all loading conditions and combinations.

8.3.4. Numerical Modelling

1. The tunnel lining system shall be modeled by appropriate numerical methods. Closed-form solutions are not acceptable. The design shall account for the loads and loading conditions identified in Sections 8.3.2 and 8.3.3.

2. For portions of the tunnel in the Queenston Shale subject to swelling if applicable by the design approach in Section 8.3.1(1), modeling using FLAC or an equivalent numerical method acceptable to the Owner, is required.

   (a) Considerations during analysis and design shall include, but not be limited to,

      (i) the accessibility of the rock to freshwater (or high relative humidity) during construction and throughout the lifetime of the structure and the influence of bedding planes on freshwater access

      (ii) the variability of the amount and rate of time-dependent deformation along the length of the tunnel and other structures

      (iii) the effect of stress on rock swelling rate

      (iv) the state of stress in the rock mass after excavation which affects the rate the swelling

      (v) swell anisotropy

      (vi) non-uniform loading.

(b) The modeling shall include

(i) analyses for both the deepest and shallowest tunnel sections in the Queenston formation

(ii) both unwatered and operational tunnel conditions.

(c) The following parameters shall be included in the analyses:

(i) appropriate rockmass and bedding plane strength and deformability values as given in the GR

(ii) The horizontal effective stress values given in Section 6.6 of the GR shall be used as input into an analysis that considers the relative stiffnesses of the various rock formations. The input in situ stresses shall then be reduced appropriately until no overall plastification of the rock mass occurs. These modified values for horizontal stress will be used in subsequent analyses.

For the Queenston Formation the following horizontal effective stresses are to be considered as input into the design.

Approxi-mate Station	Queenston Subunits	Horizontal Effective Stress (respect to tunnel) (MPa)		Remarks
		Radial	Axial	
0+000 to 1+700	Q2 to Q10	15	23	tunnel is nearly parallel to maximum stress, transformed stresses quoted
1+700 to 3+800	Q2 to Q3	22	16	orientation of stress field uncertain and tunnel curves in this section; maximum values quoted
3+800 to 7+800	Q4 to Q5	19	17	stress orientation is known and consistent with regional stress field; transformed values quoted
7+600 to 10+000	Q6 to Q10	17	11	stress orientation uncertain and tunnel curves, maximum values quoted

(iii) Hoek-Brown residual rock mass strength parameters: $m_r = 1.0$, $s_r = 0.001$ (or equivalent)

(iv) plastic shear strain in rock for peak to post-peak: ranging from 0.5% to 2.0%

(v) design line for rock swelling rates as shown in Figure 8.1 (maximum free swell potential of 0.3% per log cycle is based on overall average of all free swell test results)

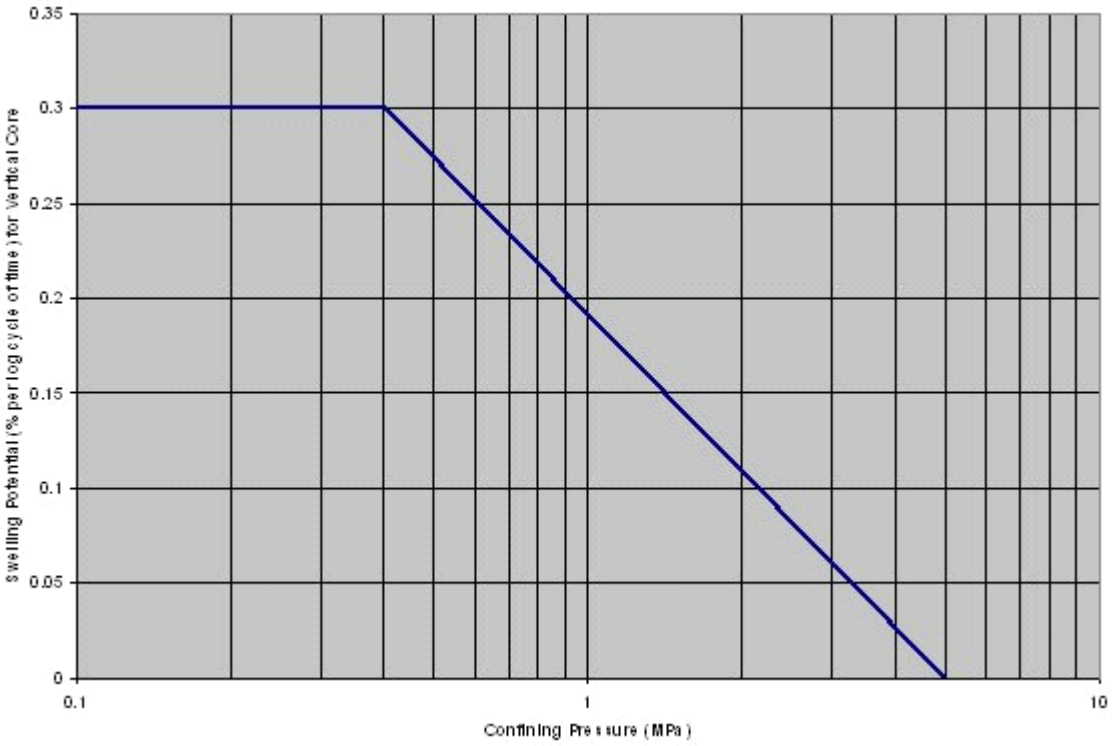


Figure 8.1 - Design Line for Rock Swelling

(vi) time steps up to 4.5 log cycles of time in increments of days

(vii) rock mass permeability of 1 x 10^{-6} cm^2/s in the plastic zone (after grouting)

(viii) chloride diffusion coefficient of 1.5 x 10^{-6} cm^2/s for the lower Queenston Formation

(ix) chloride diffusion coefficient of 1.5 x 10^{-5} cm^2/s for the plastic zone and the upper Queenston Formation

(x) rock swelling commences at a reduction in chlorides of 2%

(xi) horizontal rock swelling is equal to 0.6 the vertical rock swelling.

(d) effective stresses, accounting for 100% of the porewater pressure, shall be used in the calculation of confining pressures for use in analyses of rock mass strengths and swelling loads on the liner.

8.4 Tunnel Excavation and Construction

1. The tunnel shall be excavated by means of a TBM starting from the outlet end of the tunnel. The use of drill and blast method of excavation shall be limited to the following areas only:

   (a) intake structure

   (b) intake channel

   (c) outlet structure

   (d) outlet canal

   (e) other limited areas subject to the acceptance by the Owner.

2. No drop shafts shall be constructed along the tunnel with the exception of the dewatering shafts and tunnel piezometers.

3. The design and construction of the tunnel must consider the effects of high horizontal in situ stresses and variations in rock mass strength that will cause stress induced failure of the rock resulting in slabbing and spalling in the crown and invert of the tunnel. The effects of stress-induced failure of the rock will be further influenced by the presence of sub-horizontal bedding planes, sheared or otherwise and vertical joints.

4. In the Queenston Formation stress induced spalling at the sidewalls which will be exacerbated by the presence of vertical/sub-vertical joints and sheared bedding planes must be considered. Sidewall spalling of 0.1- to 0.2-m depth due to overstressing can occur within ½ hour of excavation.

5. In the Queenston Formation a maximum of up to 3-m thick crown slabbing and 1 m thick sidewall spalling shall be considered. Crown slabbing in the Queenston Formation will initiate in front of the cutterhead and progress to the maximum depth above the cutterhead/roof shield.

6. Invert slabbing will occur immediately and be of similar depth as the crown slabbing. The extent of overbreak will be less than at the crown due to the effects of gravity.

7. In the formations above the Queenston Formation a maximum of up to 2.5-m thick crown slabbing shall be considered.

8. The presence of major sheared bedding planes at specific elevations in the Queenston formation must be accounted for. The weathered zone below the contact with the

Whirlpool Formation and below the St. Davids Gorge represents a weaker zone with the potential for gravity induced block failure near the Whirlpool Sandstone. Sheared bedding planes have been observed throughout the test adit along Type IV (reddish-brown silty mudstone) and Type V (mudstone) rocks. These sheared planes are of low strength, are planar on a large scale and observed to be continuous. There is potential for these sheared bedding planes to be continuous throughout the tunnel alignment.

9. All shale formations through which the diversion tunnel passes will degrade when subject to changes in humidity and must be protected to prevent degradation.

10. Rock support will be required over the entire tunnel length.

11. In the Queenston Formation, the initial support must be installed within or immediately behind the shield of the TBM. In the rocks above the Queenston Formation, the initial support must be installed within or immediately behind the shield of the TBM where there is potential for slabbing.

12. A grouting gallery will be constructed at the intake portion of the tunnel to control water ingress in the permeable upper units prior to TBM tunnelling through this section.

13. Grouting design and procedures will follow the best modern practices, using stable cement/bentonite grout mixes with additives, together with electronic monitoring equipment for real-time control of pressures and volumes, in order to optimize grout takes and migration.

8.5 Tunnel Survey

1. Perform an as-built survey in plan and profile of the completed tunnel and related to the final adjusted tunnel traverse. Profiles shall be taken generally at 50-m intervals and at start and end of horizontal and vertical curves, low points of the tunnel and dewatering shafts and tunnel piezometer locations. Profile measurements shall be taken at 45° intervals over the internal perimeter of the tunnel.

2. The final position of the tunnel with respect to the legal limits of the easement must be confirmed by an Ontario Land Surveyor.

3. Reasonable access shall be provided to the Owner to independently audit tunnel TBM guidance systems and tunnel survey.

9. TUNNEL BORING MACHINE

9.1 General

1. Design, manufacture, assemble and test at works, disassemble, deliver to Site, reassemble and test at Site, install and commission a new high-powered, robust, Tunnel Boring Machine (TBM) suitable for safely excavating in the ground conditions as described in the GR. If the TBM does not have a complete shield, it

shall have sufficient shielding and other features necessary to assure safe excavation at all times.

2. Ensure that the electrical components and systems of the TBM, back-up plant and equipment are fully compatible with the site power supply and are suitable for use in a highly corrosive and potentially gassy environment.

3. Use only non-contaminating lubricants.

9.2 Monitoring Equipment

1. Provide remote computer data display and logging systems including real time and historic data capture above ground in the site offices of the Owner.

   (a) Supply a data logging system to comprise a Pentium 4 computer with software, 14-inch color monitor, color printer, modem and CD burner for data.

   (b) Supply communication wiring to provide complete transfer of data of TBM functions.

2. Data transfer and display to include but not be limited to all TBM key functions

   (a) cuttinghead direction, torque, speed and thrust

   (b) gauge cutter pattern

   (c) main bearing lubrication pressure, flow and temperature

   (d) electrical power

   (e) ram pressures

   (f) time, date

   (g) stroke

   (h) penetration rate

   (i) radial pressure on the TBM shield.

9.3 Probing and Proof Drilling Equipment

1. Provide probe drilling equipment suitable for drilling holes for sampling and grouting the rock ahead of the TBM.

2. Provide proof drilling and contact grouting equipment and staging on the TBM backup gantries to enable drilling and grouting through any position around the ring.

9.4 Ventilation Equipment

1. For the purpose of tunnel ventilation equipment design and operation, the tunnel shall be classified as 'potentially gassy' in accordance with US Department of Labor OSHA Part 1926. Provide ventilation systems with reversible fans to meet the requirements specified therein.

2. Provide built-in equipment to monitor continuously, and having the capability of giving audible and visual warning of, any hazardous gas concentration above threshold limit values as required by Applicable Laws.

3. Provide build-in equipment to monitor continuously and having the capability of giving audible and visual warning in respect of oxygen levels except that warning devices shall be activated when level falls to threshold limit value as required by Applicable Laws.

4. Routinely maintain monitoring devices in accordance with manufacturers' recommendations to ensure they are in good working order at all times.

5. Fabricate ventilation ducting from nonflammable material.

9.5 INTENTIONALLY DELETED

10. TUNNEL WATER-UP PROCEDURES

1. The Contractor shall submit a procedure for tunnel water-up for approval by the Owner, and implement thereafter. Procedure to include testing of sectional service gates, intake and outlet closure gates. Typical tests for gates to include, but are not limited to, checking seal contact and leakage, setting limit switches, setting emergency closing speed, checking hoisting and testing all protection, as appropriate. These tests shall be conducted in dry, wet static and wet flowing conditions, as appropriate.

2. Monitor instrumentation at the instrumented tunnel section during tunnel water-up.

Appendix 1.1(hhh)
Project Change Directive Form

Appendix 1.1(hhh) – Project Change Directive Form

PROJECT CHANGE DIRECTIVE

To: **Strabag Inc.** 2520 Stanley Avenue, Niagara Falls, ON L2E 6S4 (the "**Contractor"**)	Contract: Amended Design/Build Agreement (the **"Agreement"**) dated [date], 2009 between the Contractor and Ontario Power Generation Inc. (**"OPG"**) Project Change Directive No.: _____ [brief description] Date: _____

Defined terms used in this Notice have the same meanings given to those terms in the Agreement as amended.

Description of Change

In accordance with Section 5.1A([•]) of the Agreement OPG hereby ***[CHOOSE AS APPLICABLE:* [directs the Contractor to effect]][consents to] [confirms]*]*** the changes as described in Appendix No.1 attached hereto.

As a general description only, the change(s) provided for in Appendix No.1 relate to [brief description].

Expected Change to Target Cost.

OPG expects that the changes set out in this Notice will have the following effect on the Target Cost:

Target Cost, as set out in the Agreement as of the date of the Agreement	$_985,000,000.00
Total Target Cost, as set out in the Agreement as of the date of the Agreement, as adjusted by all changes in the Target Cost made under all Amendments	$_____
Total expected change to the Target Cost under this PCD	$_____

Expected Change to Contract Schedule

OPG expects that the changes set out in this Notice will have the following effect on the Contract Schedule:

_____

ONTARIO POWER GENERATION INC.

_____

Name:
Title:

NOTE: The optional language that follows is to be included only if the PCD does not effect changes:

1. to the Work, Target Cost or Contract Schedule as a result of a change in Applicable Laws; or
2. to the Contract Schedule; or
3. to the Target Cost greater than $100,000
and only in accordance with Section 5.1(d):

DEEMED AMENDMENT TO AGREEMENT in accordance with Section 5.1(d)

The Parties agree to adopt the changes evidenced by this Project Change Directive as an Amendment for purposes of Section 5.1 and Section 5.8 of the Agreement and in accordance with Section 14.2 of the Agreement, without further written agreement. The Agreement is hereby deemed to be amended in accordance with the changes described above and as may be further reflected by the wording changes to the following Sections of the Agreement:

Change to Appendix 1.1(sss) – Summary of Work

[insert any specific language changes to Appendix 1.1(sss) required as a result of the agreed changes to Work prefaced by one of the following]

> Section 1.2(1) [•] in Appendix 1.1(sss) of the Agreement is deleted in its entirety and replaced with the following: **OR** Section 1.2(1) [•] in Appendix 1.1(sss) of the Agreement is deleted in its entirety: **OR** The following Section is added as a new Section 1.2(1) [•] in Appendix 1.1(sss) of the Agreement:

Change to Appendix 1.1(TTT) – Target Cost

Item 1.19 – Scope Changes **OR** Item [insert alternative applicable item # and title] in Appendix 1.1(TTT) is increased [or decreased] by exactly $_____ in accordance with the agreed Target Cost adjustment for this Project Change Directive excluding GST.

Item [1.19 **OR** alternative item #] of Appendix 1.1(TTT) is therefore deleted in its entirety and replaced by the following:

[1.19 **OR** alternative item #]	[Scope Changes **OR** alternative title]	**[#]**	**[#]**	**[#]**

Change to Appendix 1.1(TTT) – Table

The table in Appendix 1.1(TTT) of the Agreement is deleted in its entirety and replaced with the table attached as Annex 1 hereto.

Accepted and Agreed:

ONTARIO POWER GENERATION INC.

_____

Name:
Title:

STRABAG INC.

_____

Name:
Title:

Appendix No.1 to PCD [#]

[•]

ANNEX 1 to PCD _____

ITEM	DESCRIPTION	Pre Effective Date	Post Effective Date	TOTAL
1.1	Mobilization/Demobilization	25,037,603.51		
1.2	Maintenance Bond in the form of Appendix 4.1(f)	0.00		
1.3	Performance LC	2,135,833.33		
1.4	Insurance Premium	2,293,333.33		
1.5	Design	5,425,340.78		
1.6	Accelerating Wall, Intake Channel and Approach Wall	58,386,649.32		
1.7	Diversion Outlet Canal	11,395,047.88		
1.8	Dewatering System Shafts	3,159,097.60		
1.9	Intake Structure	304,440.00		
1.10	Intake Gates	0.00		
1.11	Outlet Structure	2,292,196.28		
1.12	Outlet Structure Gate and Hoist	0.00		
1.13	Diversion Tunnel	112,171,914.06		
1.14	Tunnel Boring Machine	78,242,470.00		
1.15	Flow Verification Test	0.00		
1.16	Demolition and Disposal of Dewatering Structure	0.00		
1.17	OPG's 50% portion of DRB Estimated Cost	291,671.11		
1.18	Item not used			
1.19	Scope Changes	739,235.99	**[#.##]**	**[#.##]**
1.20	Provisional Sum	206,152.03		
1.21	Changes in Applicable Laws	117,500.00		
1.22	Warranty Administration Fee	0.00		
1.23	Office and General Cost	0.00		
	Target Price	302,198,485.22	**[#.##]**	**[#.##]**

Appendix 1.1(iii)
Project Change Notice

Appendix 1.1(iii) – Project Change Notice

STRABAG INC.
NIAGARA TUNNEL FACILITY PROJECT

2520 Stanley Avenue
Niagara Falls, ON L2E 6S4

Tel: (905) 353 – 5500
Fax: (905) 353 – 0636
niagara@strabag.ca

To: Ontario Power Generation Inc. Attention: Harry Charalambu, Project Manager	Contract: Amended Design/Build Agreement between Ontario Power Generation Inc. and Strabag Inc. (the "**Contractor**") dated as of December 1, 2008, (the "**Agreement**") Project Change Notice: XXX Date: dd.MM.YYYY

Defined terms used in this Notice have the same meanings given to those terms in the Agreement.

CHANGE TO WORK

In accordance with Section 5.2 of the Agreement, the Contractor hereby requests OPG's consent to make the changes in the Work described as follows:

IMPACT OF THE CHANGE

The Contractor expects that the changes will have the following impact on the Tunnel Facility Project with regards to Section 5.1(b) of the Agreement:

EXPECTED CHANGE TO TARGET COST

The Contractor expects changes to the approved Target Cost as follows:

Target Cost, as set out in the Agreement as of the date of the Agreement	$ 985,000,000.00
Total Target Cost, as set out in the Agreement as of the date of the Agreement, as adjusted by all changes in the Target Cost made under Amendments	$ _____
Total expected change to the Target Cost under this Notice	$ _____

STRABAG INC.
NIAGARA TUNNEL FACILITY PROJECT

2520 Stanley Avenue
Niagara Falls, ON L2E 6S4

Tel: (905) 353 – 5500
Fax: (905) 353 – 0636
niagara@strabag.ca

Expected Change to Contract Schedule

The Contractor expects that the changes will have the effect on the Contract Schedule as described as follows:

STRABAG Inc.

_____
Name:
Title:

_____
Name:
Title:

Appendix 1.1(sss)
Summary of Work

Appendix 1.1(sss) - Summary of Work

1. WORK BY CONTRACTOR

1.1 General

The Contractor shall

1. Perform the Work as required and implied by the Agreement, as shown on the Concept Drawings and in conformance with the Owner's Mandatory Requirements.

2. Perform the Work in a manner that will assure a service life of 90 years for all the fixed facilities of the Tunnel Facility Project. The Work to be performed by the Contractor includes preparation and submission of analysis and design documentation that clearly demonstrates how the required service life will be achieved and how the Tunnel Facility Project will be constructed in a manner that assures the required service life.

3. Perform the Work in a manner that also ensures compliance with:

   (a) all Applicable Laws, the requirements of the Environmental Assessment (EA) and EA Approval and such other Approvals as the Contractor determines are required for the Project; and

   (b) the requirements of the Community Impact Agreement between OPG and local stakeholders.

1.2 Specific Elements of Work

1. The Work to be performed or provided by the Contractor includes but is not limited to the provision of the following:

   (a) review and consideration of all documentation identified in the Agreement

   (b) identification of all Approvals necessary for the Work, unless specifically excluded in the Agreement, including this Appendix. The Contractor must obtain all such Approvals in a timely manner in order to meet the Contract Schedule.

   (c) final design basis for all elements of the Work including submission of same for review and acceptance by the Owner prior to proceeding with detail design

   (d) geotechnical and other investigations necessary to support the design and construction of the Work

   (e) Specifications for all elements of the Work including submission of same for review and acceptance by the Owner prior to procurement and construction.

Specifications must bear the seal and signature of a Professional Engineer licensed to practice in the Province of Ontario.

(f) engineering analyses and designs for all elements of the Work including submission of same for review and acceptance by the Owner prior to procurement and construction. Analyses and designs must bear the seal and signature of a Professional Engineer licensed to practice in the Province of Ontario.

(g) drawings for all elements of the Work including submission for review and acceptance by the Owner prior to procurement and construction. Drawings must bear the seal and signature of a Professional Engineer licensed to practice in the Province of Ontario

(h) other Submittals required in the Agreement for review and acceptance by the Owner

(i) revision and resubmission of documents for review and acceptance by the Owner, where such documents had previously been submitted to the Owner and found to be incomplete or unacceptable

(j) submission of the Notice of Project and registration for the Applicable Governmental Authority and execution of responsibilities as the "Constructor", except with respect to the INCW Part Project

(k) mobilization of all necessary forces, equipment, supplies and other requirements to Site

(l) on-Site trailer accommodation and parking facilities for Owner at the intake and outlet areas of the Site

(m) water and sewage services including necessary connections to municipal services and water meter and metering house

(n) Site access connection to Stanley Avenue at the outlet area and to Portage Road at the intake area

(o) traffic control at entrances and exits to the Site areas including traffic control devices and traffic control personnel and paid-duty police as necessary

(p) site security, public safety and emergency response in accordance with the minimum requirements set out in Appendix 2.4(g)(3)

(q) provision of all temporary construction facilities and services to enable and facilitate the performance of the Work

(r) environmental protection measures required by the Agreement and required by Applicable Laws

(s) disposal of Hazardous Materials to an off-Site location provided by the Contractor

(t) construction power including connections to appropriate power supplies

(u) emergency power supply at the intake and outlet areas to provide back-up power to all safety systems and other critical Site functions

(v) unhindered access for Owner to the Site, fabrication, manufacturing and test locations associated with or related to the Work

(w) temporary facilities (including temporary structures) necessary and required to facilitate performance of the Work. Submit details, designs and drawings of all temporary works to Owner for review and acceptance, prior to procurement or installation. Submitted designs and Drawings of temporary works must bear the seal and signature of a Professional Engineer licensed to practice in the Province of Ontario. Remove and dispose off-site all temporary works when no longer required for the performance of the Work

(x) in-river approach channel at the intake area including removal of overburden and glacial till from the riverbed, disposal of such overburden and glacial till, and all other ancillary work required to complete the in-river approach channel

(y) in-river approach wall along the river bank at the intake area including removal of overburden and glacial till from the riverbed, disposal of such overburden and glacial till, supply and placement of tremie concrete below precast concrete units and all other ancillary work required to complete the approach wall

(z) a temporary groyne upstream of the INCW structure to enhance ice flow in the intake channel during construction. Remove and dispose of groyne prior to removal of intake area cofferdam

(aa) modification and extension of the INCW structure

(bb) demolition of the existing in-river accelerating wall at the tunnel intake area and off-site disposal of same at location(s) provided by the Contractor and acceptable to the Owner

(cc) disposal of excavated and other surplus materials from the tunnel intake area at an off-Site location(s) provided by the Contractor and acceptable to the Owner

(dd) in-river accelerating wall at the intake area, including removal of overburden and glacial till, boulders and other obstructions from the riverbed on the alignment of the accelerating wall, disposal of such overburden and glacial till, boulders and other obstructions, supply and placement of tremie concrete below precast concrete units, and all other ancillary work required to complete the accelerating wall. Also to include installation of navigation strobe light on new wall with associated cabling and connection to power supply at INCW

(ee) supply, installation and calibration of intake gauge, acceptable to the Owner

(ff) supply, installation and calibration of intake gauge, acceptable to the Owner

(gg) tunnel intake structure and associated work to interface with and connect to existing structures and facilities

(hh) tunnel intake sectional gate, including removable guide extension to river surface and associated platforms to provide safe installation and removal, and associated requirements including removal of sectional gate after tunnel commissioning and transportation and unloading of same at a facility to be designated by the Owner within 25 km of the Site

(ii) tunnel outlet structures and related facilities

(jj) outlet canal between the tunnel and the existing canal system at the outlet area

(kk) demolition and disposal to off-Site location(s) of the existing dewatering structure in the PGS canal. This element of Work shall be undertaken only at the sole option and direction of the Owner.

(ll) new tunnel boring machine (TBM) and required backup and support equipment to construct the diversion tunnel. Contractor to dismantle the TBM at completion of tunnelling and remove from the Site

(mm) diversion tunnel facility including tunnel driving, water inflow management, probe drilling, ground consolidation and support, installation of tunnel lining, installation of tunnel grouting, tunnel cleanup and tunnel finishing

(nn) material handling and management systems to transport, place, compact and manage excavated material from the outlet area and the tunnel drive to the on-Site Owner-designated disposal site

(oo) leachate collection and handling systems, leachate treatment and disposal systems at excavated material storage areas on Site as required by the Agreement, Applicable Laws and Approvals

(pp) instrumentation necessary for the performance of the Work, including instrument reading, data reduction and provision of data to Owner in a timely manner, at least monthly, and at significant construction events

(qq) instrumented tunnel section

(rr) installation of four tunnel piezometers into the tunnel crown to an average depth of 180 m below grade

(ss) establishment and maintenance of necessary QC/QA for performance of the Work and submission of copies of all QC/QA and related reports to the Owner in a timely manner

(tt) tunnel dewatering shafts and associated civil infrastructure

(uu) tunnel outlet gate and associated hoisting, electrical and control requirements including interconnectors to permanent power supply

(vv) rework necessary to achieve compliance with the Agreement

(ww) maintenance of temporary facilities, services and environmental protection until the later of the Final Completion Date and any date established in any Approvals or Applicable Laws

(xx) water-up and commissioning of the diversion tunnel and associated facilities. Allow for detailed inspection of tunnel by the Owner prior to water-up

(yy) sounding survey in the PGS canal both before and after connection of the outlet canal to the PGS canal, to determine changes in the side and bottom profile of the canal as a result of the Work

(zz) removal of rock and other debris from the PGS canal, deposited as a result of performance of the Work

(aaa) Flow Verification Test

(bbb) restoration of all areas of the Site

(ccc) as-built drawings

(ddd) affidavit(s) of compliance signed by Engineer(s) of Record

(eee) operations and maintenance manuals and training of OPG personnel

(fff) demobilization and removal of all temporary facilities and services from the site

(ggg) any requirements for communications with INCW personnel and other persons affected by Contractor activities

(hhh) support and assistance to Owner with respect to reporting requirements required for compliance with Project Approvals

(iii) support and assistance to Owner with respect to implementation of the Community Impact Agreement

(jjj) obtain necessary exemptions for navigation in the Niagara River

(kkk) administration of the Jagger Hims Limited groundwater monitoring program

(lll) temporary recreational trail in the vicinity of the intake area

(mmm) finalise the separate quarterly groundwater monitoring reports and provide a stand-alone groundwater mapping report as required by the Ontario Ministry of Environment ("MOE"). Include attendance at all meetings required to execute this work. Develop and submit an action plan acceptable to MOE to address groundwater monitoring wells not reaching static conditions, and implement this plan, including well development, drilling, installation and retrofitting at five (5) monitoring locations

(nnn) drill two new groundwater monitoring boreholes, MW16-IR and MW 16-IIR, a minimum of 10 metres from existing holes. Boreholes to be HQ cored to the appropriate depth. Jagger Hims Limited staff to be on-site only during the start of drilling, during coring through the Grimsby and Whirlpool formations, and during well installation. Following installation, develop the wells and incorporate them into the groundwater monitoring program. Document the well installation program, including borehole logs and well construction details. Borehole construction will include

(i) core boreholes in HQ size to retirement;

(ii) retain core as requested;

(iii) remove rods and core barrel, install casing shoe on rods, lower rods to bottom of hole;

(iv) install one-inch diameter pipe and screen inside rods to bottom of hole;

(v) install sand pack and coated bentonite tablets;

(vi) use drill rod and tremie grout thirty percent (30%) bentonite solid grout to surface;

(vii) include pressure packing testing in the deep hole;

(viii) modify monitoring well size based on discussions with MOE; and

(ix) install Levellogger units in each well.

(ooo) supply and install one (1) Latchways Unistrut Mansafe Travel Restraint System, approximately 512 metres long on the new accelerating wall, for the purpose of travel restraint only. Include stainless steel anchors anchored to the concrete deck using a chemical adhesive. Upon completion, hold a Training Session to train the primary operators on the use and care of the system. The system will be rated for two (2) workers simultaneously, and will allow Hand-Free movement along the entire length of the lifeline without

having to disconnect and reconnect at intermediate supports .The horizontal travel restraint system will allow workers to cover the entire extent of the accelerating wall while continuously connected (no double lanyards) to the lifeline. Two (2) only Transfasteners and two (2) only 2.74 metre lanyards will be included with the system supplied, and the system will be made of stainless steel or other corrosion resistant materials to ensure a long service life.

(ppp) provide a power feed from Strabag's 12M1 (13.8-kV) feeder to the Niagara Plants Group's (NPG) crossover gauge house to provide power to this facility as requested by NPG to accommodate disconnection by Hydro One of the existing power feed to this facility.

(qqq) provide for the supply and installation of an additional embedded conduit and an additional 3C#12 cable to the new accelerating wall strobe light.

(rrr) locate the existing Sir Adam Beck Generating Station watermain, in the vicinity of the tunnel dewatering shaft work area.

(sss) grout investigative boreholes NF-39 and SD-8.

(ttt) perform remedial and maintenance work for the cleaning of the Butterfly Conservatory after the 2007 dust events.

(uuu) supply, install, and maintain a tunnel radio communications system for use by the Owner's Representative while travelling and working within the tunnel.

(vvv) demolish a portion of an existing buried concrete structure that conflicted with the dewatering system pipeline alignment, and excavate, contain stockpiling and dispose off- site hydrocarbon contaminated soil from beneath the concrete structure.

(www) decommission and seal Wells SD-3 and SD-5 at the on-site disposal area.

(xxx) reimburse Jagger Hims for work carried out to complete well monitoring up to the Effective Date that was in escess of the original estimate provided by OPG when the Contractor assumed the Jagger Hims contract.

1.3 Environmental Approvals

1. The Environmental Assessment Approval for the Project includes a number of Conditions that must be met during the planning, design and construction of the Tunnel Facility Project. Table 1.1A, in this Appendix, indicates responsibility for developing documentation and obtaining respective Approvals. Table 1.1A is not intended to detract from the Contractor's obligation to comply with the Environmental Assessment and the EA Approval, and all procedures, programs, plans and clearances thereunder. For purposes of interpreting the "Summary of Condition" column in Table 1.1A, the EA Approval should be reviewed in its entirety.

2. The abbreviations in Table 1.1A have the following meanings:

   (a) P = Primary responsibility for preparing and submitting required documentation, obtaining and implementing Approvals, if applicable

   (b) P1 = Primary responsibility for preparing and submitting initial documentation, and reviewing and submitting final documentation and obtaining Approvals

   (c) P2 = Primary responsibility for finalizing documentation and submitting to OPG for review, and supporting obtainment of Approvals

   (d) S = Support to the Party with primary responsibility for developing documentation and obtaining Approvals including collecting and providing data and information, and attending meetings.

3. Approvals, recommendations and exemptions under the following treaties and acts have been obtained.

   (a) International Niagara Diversion Treaty

   (b) Navigable Waters Protection Act

   (c) Department of Fisheries and Oceans Authorization 5250-43

      (i) Authorization for Destruction of Fish by Means other than Fishing (including Amendment, Amendment #2 and Amendment #3); and

      (ii) Authorization for Works or Undertakings Affecting Fish Habitat (including Amendment, Amendment #2 and Amendment #3).

4. Other environmental Approvals and responsibility for obtaining such Approvals include those shown in Table 1.1B, where P and S have the meaning given in Section 1.3(2) in this Appendix.

5. The Contractor shall abide by the conditions and requirements included in all of the above Approvals, recommendations and exemptions.

2. WORK BY OTHERS

1. The following work is to be undertaken by others and is not included in the Work to be performed by the Contractor:

   (a) subject to Sections 2.15(b) and 2.15(k) of the Agreement, obtaining rights of way

   (b) installation of groundwater monitoring wells necessary to achieve compliance with the EA Approval

(c) intentionally deleted

(d) access barriers and parking for operators at INCW

(e) installation of survey control monuments at the intake and outlet areas

(f) OPG manages ice flushing at the INCW. OPG will make its best efforts to ensure that ice is continually flushed past the construction area.

(g) OPG manages Grass Island Pool (GIP) water levels and outflow to meet 1950 Niagara Treaty requirements

(h) pre-construction and post-construction condition surveys of existing infrastructure for review and acceptance by the Contractor and other interested parties

(i) control and operation of the Sir Adam Beck Generating Complex during performance of the Work

(j) construction at the outlet area access road to the right-of-way at Stanley Avenue and Portage Road at the intake area

(k) provision of sewer and water interconnection point at the east side of Stanley Avenue right-of-way at the outlet area

(l) installation of first order horizontal and vertical control monuments at the outlet and intake areas for tunnel set out and survey control.

3. CONSTRAINTS

1. Performance of the Work will be constrained by a number of requirements that include, but are not limited to, the following:

   (a) the drill and blast method of tunnel construction will not be permitted

   (b) access shafts, drop shafts and ventilation shafts will not be permitted along the tunnel alignment

   (c) flow disruption in the power canals will not be permitted except as follows:

      (i) flow may be interrupted in the PGS canal for no more than 6 hours in duration, in any 48-hour period, for Work associated with

         - connection of the outlet canal to the PGS canal

         - for Work associated with demolition and disposal to off-site location(s) of the existing dewatering structure in the PGS canal should such Work be directed by the Owner

(ii) Contractor to provide a tentative schedule of any required interruption of flow in the PGS at least 3 months prior to the required interruption

(iii) Contractor's schedule will show, and Contractor's operations will support, a maximum overlap of Work associated with connection of the outlet canal to the PGS canal and Work associated with demolition and disposal to off-site location(s) of the existing dewatering structure in the PGS canal such that the total number of 6-h closures required is at a minimum

(iv) Contractor to provide at least 5 calendar days Notice if it requires interruption of flow in the PGS

(v) in all cases, Owner determines at its sole discretion the specific date and time for allowable interruption of flow in the PGS canal

(d) The more stringent of the following requirements will apply:

(i) On-Site and off-Site activities governed by the Niagara Falls Noise Control By-Law 2004-105 and relating to the performance of the Work shall comply with such By-Law except for TBM tunneling Work and any other exemptions that may be obtained by the Contractor.

(ii) On-Site and off-Site activities governed by MOE Publication NPC 205 and relating to the performance of the Work shall comply with such publication at sensitive noise receptors unless specific exceptions have been approved by MOE.

(iii) Truck traffic to and from the Site at the intake area shall not take place on Sundays unless noise at sensitive receptors are mitigated to OPG's and MOE's satisfaction.

(e) load limits on INCW deck structure - GVW of 90 tonnes for triple axle vehicle, GVW of 36 tonnes for double axle truck

(f) tourist movement, both pedestrians and vehicular

(g) Marine Operation at the INCW

- Tourist Season Flow (TSF) is defined as

(i) April 1 through September 14, inclusive, and during the hours of 08:00 to 22:00, inclusive

(ii) September 15 through October 31, inclusive, and during the hours of 08:00 to 20:00, inclusive

(iii) all other hours during these periods are defined as the nighttime hours.

- Reference Drawing 6-B-214 defines restrictions on ice breaking operation near the INCW structure. These restrictions shall be followed for all marine operations in the river.

- During the TSF, fourteen of the existing eighteen gates must be available to pass the required scenic flows to the Niagara Falls. In the nighttime hours, all bays are normally closed and unrestricted marine operations can take place subject to obtaining approval for nighttime construction activity in this area. However, abnormal streamflow or power entity diversion restrictions may require operation of INCW gates during the TSF nighttime hours.

- The Contractor shall be aware that conditions on the river and the gates in the INCW can change at any time. The Contractor shall interface with OPG regarding operation at the INCW.

- During the period from December 15 through April 30, inclusive, or as otherwise indicated by OPG, no marine based operations or other in-water activities shall take place that affect ice management as determined by OPG.

- Installation of the new Ice Accelerating Wall and removal of the existing Ice Accelerating Wall shall be completed before construction of the cofferdam upstream from INCW Bay 1. A minimum of three bays must be available within the ice channel for ice management at all times.

(h) INCW Part Project Area

The gates at the INCW are required to be under the control of OPG at all times during execution of the Tunnel Facility Project. In addition, OPG requires regular access along the INCW structure to service and maintain the gates. A comparatively small portion of the Tunnel Facility Project requires the Contractor to perform certain in-water elements of Work in an area near and on the INCW structure as shown on Drawing NAW130-D0E-80000-0015 in Appendix 1.1(h) and defined as the "INCW Part Project Area". During the time period when this portion of the Work is performed, OPG will assume the role of "constructor" (as that term is used under the Occupational Health and Safety Act (Ontario)) for the INCW Part Project Area only.

OPG shall only be the constructor in this limited area, and only during the specific times to be agreed upon in advance in writing by OPG and the Contractor, for the performance of the relevant portion of the Work by the Contractor, including

- construction of the new ice accelerating wall and removal of the existing ice accelerating wall

- underwater excavation (if any) for the intake approach channel
- construction of the cofferdam
- placement and or removal of the sectional service gates
- dismantling and removal of the cofferdam.

The Contractor shall only have access to the INCW Part Project Area at the agreed times. The Contractor shall take specific precautions to ensure that it does not access the INCW Part Project Area at any other time.

(i) Regional Roadworks

On behalf of OPG, the Regional Municipality of Niagara will be reconstructing Stanley Avenue (Regional Road 102) from Whirlpool Road to Niagara Townline Road with intersection improvements at Portage Road, the outlet construction site access road entrance, and Thorold Stone Road commencing approximately August 2005. Intersection improvements will also be undertaken at the intake construction site access road entrance on Portage Road south of Upper Rapids Boulevard.

4. SPECIFIC SITE CONDITIONS

4.1 Survey Datum

1. UTM Universal Transverse Mercator
2. NAD North American Datum
3. IGLD International Great Lakes Datum
4. USLS United States Lake Survey
5. Horizontal control for the survey in the project area is a UTM projection based on the NAD83 datum. A second order horizontal control network is represented by several monuments throughout the Site. The Owner grid previously used at the Site shall only be used for reference so that existing drawings can be oriented to the current Work.
6. The coordinates of the tunnel right-of-way defined on Drawing NAW130-D0E-29230-0015 are based on second and third order horizontal control.
7. Vertical control is based on Geodetic Surveys of Canada (GSC), Fifth Edition (1983), vertical datum. Where NAD83 is referred to as a vertical datum, it is meant to be GSC 1983 and are, therefore, considered equivalent within this agreement. However, the stated elevations on vertical control monuments in the project area vary according to the agency which has previously surveyed the area. To establish a single datum,

existing elevation data from the IGLD have been converted to NAD83 by means of the elevation relationships shown in the following table. IGLD55 is an imperial datum while IGLD85 is a metric datum. The conversion between IGLD55 and IGLD85 is geographically dependent with specific conversion defined below for the Material Dock gauge and the cross-over gauge locations.

Table of Values Used for Standardization of Elevation Datum

To Get	From	Additive Constant
NAD83	IGLD55	+0.144 m Material Dock Gauge
NAD83	IGLD55	+0.120 m Cross Over Gauge
IGLD85	IGLD55	+0.164 m Material Dock Gauge
IGLD85	IGLD55	+0.152 m Cross Over Gauge

4.2 Water Surface Elevations

1. Water surface elevations in the GIP and at the Cross-Over are as follows based on NAD 83 (following the 1973 International Niagara Board of Control Directive).

	Design Water Levels (m)	
	GIP	**Cross-Over**
Normal minimum	170.74	164.20
Normal mean	171.19	167.78
Normal maximum	171.65	169.80
Energy emergency minimum	170.58	164.20
Flood allowance maximum	171.80	171.80
200-year flood	172.11	172.11
Probable maximum flood	173.17	173.17

4.3 OPG's Site Office Facilities

1. OPG's offices shall be provided in trailers, GE Capital or equal, and located as agreed by OPG.

2. Provide and maintain an office complex for OPG at the main site area at the outlet with a minimum area of 300 m^2, with floors able to withstand 4.8 kPa live loads, and covered with resilient flooring. The office shall contain a meeting room, storage

room, gallery area, reception and secretarial area, lockable air conditioned computer room, washrooms and offices for OPG's staff. The layout of the office shall be determined by OPG.

3. Provide and maintain an office trailer for OPG at the intake Site with a minimum of 60 m^2. The office shall contain a meeting room, gallery area, washroom and offices for OPG's staff.

4. Provide lighting to uniformly deliver not less than 100 footcandles at desk height in all areas except the restrooms. Adequately light and ventilate the change room, complying with code requirements.

5. Locate exterior lighting over the entrance doors. Provide grounded duplex electrical receptacles at approximately 3-m spacings for interior walls, with at least one in each wall except in the restrooms.

6. Provide automatic heating and air conditioning equipment capable of maintaining an ambient office temperature between 20°C and 25°C.

7. Provide drinking water chilled by an electrically operated drinking fountain.

8. Provide separate staff change rooms, with mine safety personnel clothing and equipment storage, for male and female staff. The male washroom to include two urinals, two flush toilets, two wash basins and two showers. The female washroom to include one flush toilet, one wash basin and one shower. Both washrooms to be provided with a mirror, grounded duplex electrical receptacle, soap holder, toilet paper holder, paper towel dispenser, waste basket and related supplies.

9. Provide a hot water heater of not less than 400 L storage capacity.

10. Provide doors and locks for exterior doors to each office and interconnecting doors between offices where applicable depending on the floor plan agreed to by the Engineer. Doors between the central office and the washrooms shall have a privacy lock. Exterior doors shall have cylinder keyed alike, and sixteen keys shall be furnished for each lock.

11. Provide a burglar alarm motion detection systems with a central control box and audible alarm to secure the entire facility. Provide burglar proof bars in all windows. Provide a smoke detector system and alarms.

12. Provide a telephone system consisting of six external lines plus intercom and twelve extensions in addition to a dedicated line for a fax machine. The telephone system shall include a speaker phone with dedicated line, touch tone dialing with hold button feature, plus one phone for the fax machine. OPG will determine the distribution of equipment and telephone service in the office. The Contractor shall pay monthly charges for the telephone system but long distance calls are for OPG's account. Provide high speed internet connection.

13. Provide office furnishings of the type and quantity listed below.

Quantity	**Description**
6	Double pedestal lockable drawer desk
12	Single pedestal lockable drawer desk
2	Secretarial posture chair
6	Reference tables
16	Swivel arm chairs
14	Credenza cabinets
1	Conference table (20 person capacity) or equivalent
30	Stack chairs
20	Bookcases metal
8	Five-drawer lateral files
2	Fireproof file, four-drawer legal
6	Metal utility cabinet with lock
1	Coat rack (20 coats)
6	Desk lamps
4	Bulletin board (1800 mm x 1200 mm) with metal edge
4	12-stick plan racks
8	Whiteboards wall fixed (1200 mm x 900 mm)
20	Waste baskets
6	Tri-class dry chemical fire extinguisher, 3.9 kg, including service
1	First aid kit and equipment in accordance with the Workers' Compensation Board and the Ontario Ministry of Labour, requirements with maintenance and supplies

Table 1.1A (See Section 1.3, Paragraph 2)

EA Condition Number	Summary of Condition	Responsibility for Developing Documentation and Obtaining Approvals	
		Owner	**Contractor**
1.3	Expiration of Approval	P	S
1.4	Implementation Plan for Phased Construction	P	
1.6	Compliance Monitoring Program	P	S
1.8	Implementation Plan for Undertaking	P	
1.10	Notification Procedure for Minor Amendments	P	
1.11	Facilitate information flow requirements under the Community Impact Agreement	P	S
1.12	Provision of public record documents	P	S
2.1	Establish Re-Use of Excavated Materials Committee	P	S
2.2	Preparation of Re-Use of Excavated Materials Report	P	S
2.3.1	Submit plan for disposal of excavated materials on OPG lands	P1	P2
3.1	Disposal Monitoring and Contingency Plan for BTX	P1	P2
4.1	Hydrogeology - groundwater mapping	P1	P2
4.2	Hydrogeology - groundwater monitoring plan	P1	P2
5.1	Construction effects of tunnel and shafts	P1	P2
7.1	Documentation of the effects of flow changes on a number of components	P	
7.2 a	Documentation on effectiveness of mitigation measures to address TSS loadings	P1	P2
7.2 c	Erosion and Sedimentation Control Plans	P1	P2
7.4	Assessment of the effects of reduced flows in the lower Welland River to fish habitat and to adjacent properties/users	P	

7.5	Demonstration that hydraulic grade line in Welland River will remain within present range and not reduce sediment carrying capacity	P	
8.2	Reassessment of Noise assessment	P	S
9.2	Citizen Complaints Procedure	P	S
9.4	Erosion and storm water runoff plan	P1	P2
9.5	Carry out Community Impact Agreement Plans and Programs	P	S
10.1	Aquatic habitat survey and habitat compensation if applicable	P	
10.2	Verification of design to limit fish entrainment at intake	P	

Table 1.1B

Approval	**Key Agency**	**Responsibility**	
		OPG	**Contractor**
International Niagara Diversion Treaty, 1950	International Joint Commission, External Affairs Canada	P	
Navigable Waters Protection Act	Fisheries and Oceans Canada (Canadian Coast Guard) now Transport Canada (Marine)	P	S
Transportation of Dangerous Goods Act	Transport Canada		P
Temporary magazine licence	Natural Resources Canada, Minerals & Metal		P
Authorization of destruction of fish by means other than fishing	Fisheries and Oceans Canada	P	S
Authorization for harmful alteration, disruption or destruction of fish habitat	Fisheries and Oceans Canada	P	S

Work Permits (under Lakes and Rivers Improvement Act, and Public Lands Act)	Ministry of Natural Resources		P
Permit to take water (construction)	Ministry of the Environment		P
Certificate of Approval (AIR)	Ministry of the Environment		P
Certificate of Approval for an Industrial Sewage Works	Ministry of the Environment		P
Generator Registration	Ministry of the Environment		P
Dust Suppressant License	Ministry of the Environment		P
Tree Cutting By-Law	Regional Municipality of Niagara		P
Liaison Committee	Regional Municipality of Niagara, City of Niagara Falls, Town of Niagara on the Lake, OPG	P	S
Transportation Impact Management	Regional Municipality of Niagara/City of Niagara Falls	P	S
Tourism Impact Management	City of Niagara Falls, Town of Niagara on the Lake	P	S
Emergency Services	City of Niagara Falls, Town of Niagara on the Lake, Regional Municipality of Niagara	P	S
Municipal Services	City of Niagara Falls, Regional Municipality of Niagara	P	S
Municipal Approvals	City of Niagara Falls, Regional Municipality of Niagara	S	P

Appendix 1.1(TTT)
Target Cost

Appendix 1.1(TTT) – Target Cost

The Target Cost is **$985,000,000.00**

For the purposes of cost control, cost projection and cost performance indices only, the Target Cost will be allocated in the following manner:

Item	Description	Pre Effective Date	Post Effective Date	Total
1	Mobilize/Demobilize	$25,037,603.51	$5,940,000.00	$30,977,603.51
2	Maintenance Bond	$ 0.00	$700,000.00	$700,000.00
3	Performance LC	$2,135,833.33	$3,291,458.00	$5,427,291.33
4	Insurance Premium	$2,293,333.33	$2,000,047.00	$4,293,380.33
5	Design	$5,425,340.78	$4,277,000.00	$9,702,340.78
6	Intake Channel and Walls	$58,386,649.32	$6,372,932.00	$64,759,581.32
7	Diversion Outlet Canal	$11,395,047.88	$1,511,734.00	$12,906,781.88
8	Dewatering Shafts	$3,159,097.60	$490,035.00	$3,649,132.60
9	Intake Structure	$304,440.00	$8,331,354.00	$8,635,794.00
10	Intake Gates	$ 0.00	$2,478,138.00	$2,478,138.00
11	Outlet Structure	$2,292,196.28	$10,527,698.00	$12,819,894.28
12	Outlet Gate and Hoist	$ 0.00	$3,603,112.00	$3,603,112.00
13	Diversion Tunnel	$112,171,914.06	$576,844,664.93	$689,016,578.99
14	Tunnel Boring Machine	$78,242,470.00	$ 0.00	$78,242,470.00
15	Flow Verification Test	$ 0.00	$569,097.00	$569,097.00
16	Dewatering Structure	$ 0.00	$1,452,034.00	$1,452,034.00
17	DRB Estimated Cost	$291,671.11	$75,000.00	$366,671.11
18	Item not used	$ 0.00	$ 0.00	$ 0.00
19	Scope Changes	$739,235.99	$ 0.00	$739,235.99
20	Provisional Sum	$206,152.03	$ 0.00	$206,152.03
21	Changes in Applicable Law	$117,500.00	$117,500.00	$235,000.00
22	Warranty Administration Fee	$ 0.00	$100,000.00	$100,000.00
23	Office and General Cost	$ 0.00	$54,119,710.85	$54,119,710.85
	Target Price	**$302,198,485.22**	**$682,801,514.78**	**$985,000,000.00**

Appendix 1.1(UUU)
Target Cost Baseline Items

Appendix 1.1 (UUU) – Target Cost Baseline Items

The parties have agreed to baseline certain items within the Target Cost. The tables in this appendix provide the baselined items and the means by which adjustments are made to the Target Cost to allow for variations from the baseline.

Table 1 - Adjustment to Target Cost for Inflation

Year	Eligible Amounts to be Escalated (2008 $ CAD)	Baseline Inflation Rate (1%/annum Compounded Annually)	Eligible Amounts Escalated at Baseline Inflation Rate ($)	Actual Blended Annual Statistics Canada Inflation Index[1]	Eligible Amounts Escalated by Actual Blended Statistics Canada Inflation Index ($)	Adjustment to Target Cost[2] ($)
2008	790,000	100.0%	790,000	100.0%	790,000	0
2009	14,940,000	101.0%	15,089,400			
2010	15,830,000	102.0%	16,148,183			
2011	10,330,000	103.0%	10,643,009			
2012	5,520,000	104.1%	5,744,134			
2013	1,220,000	105.1%	1,282,232			
Total Cost	**48,630,000**		**49,696,959**			

Notes:

1 Average actual monthly Statistics Canada Construction Price Index (July to June) applied to the year at the end of the period.

where

Blended annual inflation index (BAII) = 30% x (v1575797) + 9% x (v1574827) + 7% x (v1575502) + 43% x (v1575348) + 11% x (v1575745)

and (vxxxxxxx) is the commodity from Table 2, Industrial Product Indices, by commodity – Statistic Canada for the following commodities

(v1575797) – Cement, Portland

(v1574827) – Foamed and expanded plastics

(v1575502) – Rock drilling and earth boring machinery and parts

(v1575348) – Structural shapes, steel including fabricated

(v1575745) – Wire and cables, insulated, not exceeding 1000 volts

and BAII(2008) = 127.8 = 30% x 133.20 + 9% x 112.13 + 7% x 109.6 + 43% x 132.8 + 11% x 117.9

Actual Blended Annual Statistics Canada Inflation Index = BAII (Current Year) / BAII (2008)

2) Adjustment to target cost (up or down).

Eligible Amounts Escalated by Actual Blended Statistics Canada Inflation Index less **Eligible Amounts Escalated at Baseline Inflation Rate**

3) Calculations to be performed to two decimal places and rounded to one decimal place. Final costs rounded to zero decimal places.

Table 2 - Adjustment to Target Cost for Diesel Price

Year	Predefined Quantity[1] (L)	Baseline Cost[2] ($/L)	Baseline Cost ($)	Weighted Average Price[3] ($/L)	Revised Cost[4] ($)	Target Cost Adjustment[5] ($)
2008	168,000	0.80	134,400			
2009	2,928,000	0.80	2,342,400			
2010	6,270,000	0.80	5,016,000			
2011	6,687,000	0.80	5,349,600			
2012	4,001,000	0.80	3,200,800			
2013	155,000	0.80	124,000			
Total	**20,209,000**		**16,167,200**			

Notes:

1 Predefined quantity despite actual usage.
2 Average unit price of diesel used in calculating the Baseline Cost.
3 Weighted average price of diesel in the period incurred.
4 **Weighted Average Price** times **Predefined Quantity**.
5 **Revised Cost** less **Baseline Cost** (up or down).

Table 3 - Adjustment to Target Cost for Baselined DBA Items

Cost Baselined in Items of Appendix 1.1(TTT)	Baseline Cost ($)	Allowed Cost ($)	Target Cost Adjustment[1] ($)
Item 2, Maintenance Bond			
• Provision of maintenance bond	700,000		
Item 5, Design			
• Additional design by ILF including provision of site representative	4,000,000		
Item 6, Intake Channel Walls			
• Claim by DCC[2] for delayed performance and sequencing of Intake Channel excavation			
• Claim by DCC for delayed performance of work of approach wall.	207,000		
Item 7, Outlet Canal			
• Claim by DCC for delayed performance of work	73,000		
Item 9, Intake Structure			
• Claim by DCC for delayed performance of work	253,000		
Item 11, Outlet Structure			
• Claim by DCC for delayed performance of work	358,000		
• Claim by DCC for outlet slab sequencing and increased reinforcing in structure	1,536,000		
Total	**7,127,000**		

Notes:
1 Adjustment to target cost: **Allowed Cost less Baseline Cost** (up or down).
2 DCC: Dufferin Construction Company.

Table 4 – Adjustment to Target Cost for Final Designed Overbreak Formwork System for Overbreak Greater Than or Equal to 2 m

Description of Baselined Formwork System	Formwork Length Basis for Target Cost Calculation (m)	Baseline Formwork Cost ($/m)	Baseline Formwork Total Cost ($)	Revised Formwork Cost(1) ($/m)	Revised Formwork Total Cost ($)	Target Cost Adjustment(2) ($)
The baseline cost for the supply of material for the formwork system required to support concrete and/or shotcrete to infill overbreak in areas where overbreak is ≥2 m. The formwork system includes the lost form (expanded metal, steel lining plate or similar construction), structural form reinforcement, support system from rock, rock dowels and all associated hardware. The revised formwork cost will be determined from the estimated cost of the formwork system determined during final design.	2,515	3,210	8,073,150			

Notes:

1 **Revised Formwork Cost** to be inserted into (Adjustment to calculated crown overbreak in excess of target volume requiring forming) of Table 1 in Appendix 5.3(C), Major Risk Table.

2 Adjustment to target cost: **Revised Formwork Total Cost** less **Baseline Formwork Total Cost** (up or down).

Appendix 1.1(hhhh)
INTENTIONALLY DELETED

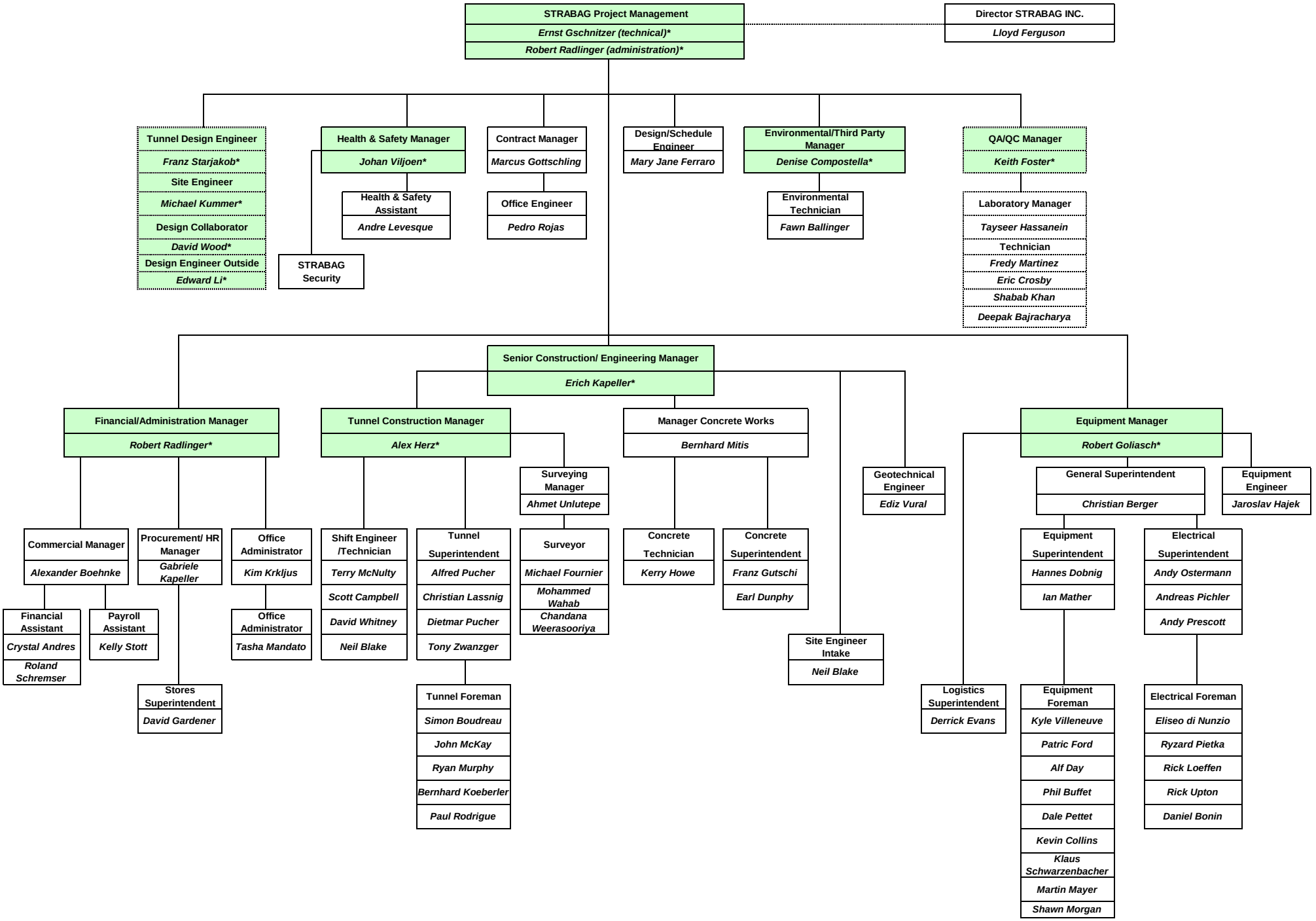
Appendix 1.1(hhhh) - INTENTIONALLY DELETED

Appendix 2.2(a)
Organizational Chart

Appendix 2.2(a) - Organizational Chart

[See attached]

Appendix 2.2(a) - Organizational Chart



* Staff requiring approval as per Amended Design/Build Agreement

Appendix 2.2(b)
Scopes of Authority for Contractor's Delegates

Appendix 2.2(b) - Scope of Authority for Contractor's Delegates

DELEGATION OF AUTHORITY
(or change in delegation of authority)

To: Ontario Power Generation Inc. ("OPG")	Contract: Amended Design/Build Agreement (the "**Agreement**") dated as of December 1, 2008 between Strabag Inc. (the "**Contractor**") and OPG Delegation No.: • Date: •

Defined terms used in this Notice have the same meanings given to those terms in the Agreement. In accordance with Section 2.2(b) of the Agreement, the Contractor hereby delegates authority to the individuals named below for the subject matters and subject to the limitations set out in this Notice. These delegations will continue in full force until revoked by the Contractor in another delegation of authority Notice.

Title	Delegate	Effective Date	Scope of Authority
			•

STRABAG Inc.

By: _____

Name:
Title

Appendix 2.4(c)
Contractor’s Safety Program

Appendix 2.4(c) - Contractor's Safety Program

[to be attached on submittal]

Appendix 2.4(d)
Preliminary Project Specific Site Safety, Security, Public Safety and Emergency Response Plan