ONTARIO POWER GENERATION	Project Number: DESJ0031	Facility: Des Joachims GS	Page: 1 of 8
	BUSINESS CASE SUMMARY Replace Main Output Transformers		

1. RECOMMENDATION

Recommend full release approval of $27.9M (which includes Definition Phase release of $80k) to purchase and install 12 new main output transformers, 1 new station spare, and associated equipment at Des Joachims GS. The existing transformers are almost 60 years old, are nearing the ends of their service lives, and the probability of failures is expected to increase dramatically over the next ten years. Since the indicated time required to manufacture a transformer is approximately 90 weeks, it is recommended that a transformer replacement program be initiated now to ensure transformers at Des Joachims GS are replaced in an orderly and timely fashion over the 2010 to 2013 period (1 bank per year).

Total Investment Cost: $28M

Recommended Alternative	LTD 2007	2008	2009	2010	2011	2012	2013	Total
Project - Capital	$54k	$1,749k	$1,771k	$6,982k	$6,412k	$6,580k	$4,337k	$27,874k
Proposed 2008-12 BP	$83k	$2,016k	$3,400k	$3,477k	$6,483k	$6,543k	$6,141k	$28,143k

Expenditure Type: Capital
Investment Type: Sustaining
Release Type: Full release under OAR element 1.1
Funding: The total project cash flows have been programmed in the 2008 Budget Version of the Work Program Catalogue.
Investment Financial Measures: NPV: $6,542 k (Relative to the Base Case)

2. SIGNATURES

Submitted by:

28 Jan 2008.
EVP - Hydro date

Recommended by:

Feb 5/08
EVP & COO date

Finance Approval:

Feb 1/08
SVP & Chief Financial Officer date

Line Approval per OAR 1.1:

Feb. 11/08
President & CEO date

3. BACKGROUND & ISSUES

- Des Joachims GS is an eight unit, hydroelectric station located on the Ottawa River, 20km north of Deep River. The facility was placed in service in 1950 and 1951. The station is controlled from the Chenaux Control Centre. The station capacity (MCR) and average annual energy production are 428.8 MW and 2,247 GWh respectively, with 2006 revenue of $121.4M. The ten year average of the station Capacity Factor is 58%.
- The asset classification of this station is "Flagship" and is ranked 4th in both capacity and energy production in Hydroelectric. The Life Cycle Plan expenditure strategy for this station includes planned investments, over the next 30 years, totalling about $100 million. Major projects include the turbine replacement and overhaul program ($40M), transformer replacement program ($28M), rehabilitation of sluice gates ($17M) and generator rewind program ($6M).
- Reliability has been excellent over the past 10 years with an Incapability Factor (ICbF) in the 7% range. The Equivalent Forced Outage Rate (EFOR) is less than 1%.
- Due to its asset classification, Des Joachims receives high priority for sustaining investments to maximize return on investment. The recommended preferred alterative will ensure that similar reliability will be sustained.
- Originally all eight units produced 45 MW each. In the late 70's and early 80's new runners were purchased as replacements for the original runners to increase the output of the units. The unit output was increased by 9.0 MW. The transformers were never upgraded or replaced. All cables have recently been replaced; have no visible signs of leaks in the floor penetrations and will not need to be changed.
- The transformers are water cooled original installations (1950 vintage) and have previously experienced a failure in 1981. The T2 Blue Phase transformer ruptured and oil entered the tailrace area.
- The Des Joachims Generating Station consists of four transformer banks, each supplied by two generators. Each bank is made up of three single phase transformers plus one single phase spare transformer for the station. (Total of thirteen transformers). The nameplate sizes of the in-service transformers are rated at 33 MVA each but are operating at 110 MVA per bank or 10% above rated capacity.
- Due to 20+ years of operation at 10% above rated capacity, the life expectancy of the transformers has been reduced to where they are now approaching the ends of their service lives. Oil test results show elevated concentrations of carbon monoxide and moisture. High carbon monoxide levels are a symptom of elevated thermal stress within the transformer that results in accelerated ageing of the critical insulation system. Moisture in a transformer is also a major accelerant of insulation deterioration, particularly when combined with elevated operating temperatures, and moisture levels are now approaching recommended ASTM limits for reliable operation. No field process can remove the moisture from deep within the insulation system; therefore, rehabilitation is not practicable.
- Transformer reliability can be characterized by the "bathtub curve", which correlates the risk of failure with equipment life. The curve suggests that a long period of low failure risk operation is followed by a relatively shorter period of escalating probability of failure as the equipment approaches its end of life. The recent test results indicate that the transformers are now approaching the ends of their service lives and the risk of failure can be expected to dramatically increase.
- There are additional operational concerns due to:

- The 30º C transformer operating temperature. Cooling pump use must be restricted during winter operation to avoid over-cooling the oil, which has resulted in gasification problems.
- Lower level flooding of the powerhouse due to PVC cooling water piping failures
- The risk of oil spills due to leaking oil-filled Low Voltage Box connections
- Signs of deterioration in the concrete beams that support the Ring Gaps

- The first transformer replacements will not occur until 2010 due to the 90 week lead time for delivery, with the planned in-service date of the final bank of transformers occurring in 2013. Due diligence dictates that a prudent, orderly transformer replacement program be initiated to avoid transformer failures.
- The failure of one of the main output transformers in any transformer bank could result in the loss of energy output from two units. Although the spare transformer could be used to replace the first failed transformer, replacement would still require a dual unit outage of at least one month. If a second transformer failure occurred before the spare was replaced, it would result in a dual unit outage of up to 2 years. The probability of this occurrence is expected to escalate over the next few years as the transformers approach end of life.
- The manner in which a transformer could fail is not predictable. A catastrophic failure could result in an uncontrolled loss of oil, presenting a risk to station personnel, the environment, and to the station itself. (Each transformer contains approximately 5,100 imperial gallons (23,000 litres) of oil).

4. ALTERNATIVES & ECONOMIC ANALYSIS

Approval was attained during the project Definition Phase in 2006 for $80k to retain a transformer consultant in order to prepare a Technical Specification and request proposals for the supply of 13 transformers over the period of four years. (One bank per year) The transformer consultant performed a performance evaluation for each of the four proposals received and recommended the preferred supplier.

Base Case:
Do nothing – Replace upon failure

- The existing transformers are operating at 10% above rated capacity with oil test results indicating unacceptable oil moisture and gasification levels. This indicates these transformers are approaching end of life and an escalating risk of failure, jeopardizing production.
- The results of a previous transformer refurbishment program have been unsatisfactory and the service lives of these transformers will not be extended through refurbishment. The Plant Group strategy is a transformer replacement program.

For asset equipment protection and personnel safety concerns in the event of a transformer failure, this alternative is unacceptable.

Alternative 1: (13 Transformers)
Replace with Single Phase – Water Cooled

- Water cooled transformer will require ongoing maintenance costs, which are not required by the **Alternative 3** air cooled design.
- There is a risk of cooling water failures which could result in flooding of the powerhouse, and a risk of cooling water freeze up conditions.

The financial cost of this alternative is very similar to the preferred alternative, but due to the cooling risks identified and ongoing maintenance costs this alternative was rejected.

Alternative 2: (5 Transformers)

Replace each bank (3 single phase transformers) with (1) three phase transformer

- The loading capacity of the existing concrete structure will require major civil upgrades. The 3 phase transformer weight is 130 tons, while the existing single phase transformer weighs 60 tons. The runway, transformer base and moving trolley will not withstand the increased load.
- A transformer rotation mechanism will be required to rotate the transformer 90 degrees at the corner of the runway due to the increase in outside dimensional size.
- The transformer deck door opening is not sufficient in size to move the transformer in and out of the powerhouse erection bay to the transformer deck area.
- The installation of radiators must be conducted outside the powerhouse; therefore, a mobile crane is required for these installations.
- The existing oil containment system will require major civil modifications due to the extensive difference in size vs. a single phase transformer.
- There is a marginal efficiency gain for three phase over single phase transformers.

Although the procurement of three phase transformers (5) is less expensive than single phase transformers (13), the lower cost is more than offset by the need for major civil modifications.

Alternative 3: (13 Transformers)

Replace with Single Phase – Air Cooled

- Single phase air cooled transformers will require minimal civil modifications due to the similar structural dimensions as the existing.
- The transformer increased output capacity will provide sufficient capability intended for the existing turbine replacement program, plus an additional 10% capacity for future unit upgrades.
- Major civil oil containment and structural modifications will not be not required.
- The spare transformer cost is 1/13 of the total supply cost vs. 1/5 for three phase design.
- No additional major adaptation will be required for low voltage cable modifications.

This is the recommended alternative.

Other alternatives considered but discounted

- Refurbish – Past refurbishment efforts did not produce the expected end result.
- Like-for-like capacity replacement - The existing transformers are under-capacity; therefore, an increase in transformer output is required.
- Partial bank replacement – All transformers are approaching end of life. Partial replacement would also require two sets of spare transformers; one for the new and one for the existing.

Financial Analysis

	Base Case	Alt. 1	Alt. 2	Alt. 3
Initial or Remaining Costs (k$)	$30,824	$29,227	$34,555	$27,874
NPV (2007 PV (k$) 40 years	($30,319)	($24,446)	($27,870)	($23,777)
Impact on Economic Value (2007 PV k$)		$5,873	$2,449	$6,542

5. THE PROPOSAL

Results to be delivered

- Prepare installation engineering specification.
- Purchase and install twelve 30/40/50 MVA ONAN/ONAF1/ONAF2 transformers plus one station spare.
- Dispose of existing transformers
- Modify existing deluge system
- Modify oil containment system and perform minor civil modifications
- Provide spare parts
- Provide operation and maintenance training
- This investment is linked to the Turbine replacement project to avoid duplicating outages. Installation of the transformers will be coordinated with the outages for the Turbine replacement and major overhauls.

Project Management

- A Project Execution Plan (PEP) will be used to monitor the project progress.
- Lessons Learned meetings will be conducted following the first bank outage and a list of actions developed an implemented on the subsequent outages. The PEP will be revised and issued by Q2 of each outage year.

Project Execution Outage Schedule

Station	Transformer Bank Outage	Turbine Replacement	Execution Date
Des Joachims GS	T1	G4	2010
Des Joachims GS	T3	G8	2011
Des Joachims GS	T2	G1	2012
Des Joachims GS	T4	G5	2013
Des Joachims GS		G3	2014

6. QUALITATIVE FACTORS

- Transformer replacement will reduce the risk of injuries to personnel in the vicinity of the transformer deck in the event of a failure, environmental impact (oil spillage, vapour/particulates in the event of transformer fire, etc.), and collateral damage to adjacent structures and the facility.

7. RISK ANALYSIS

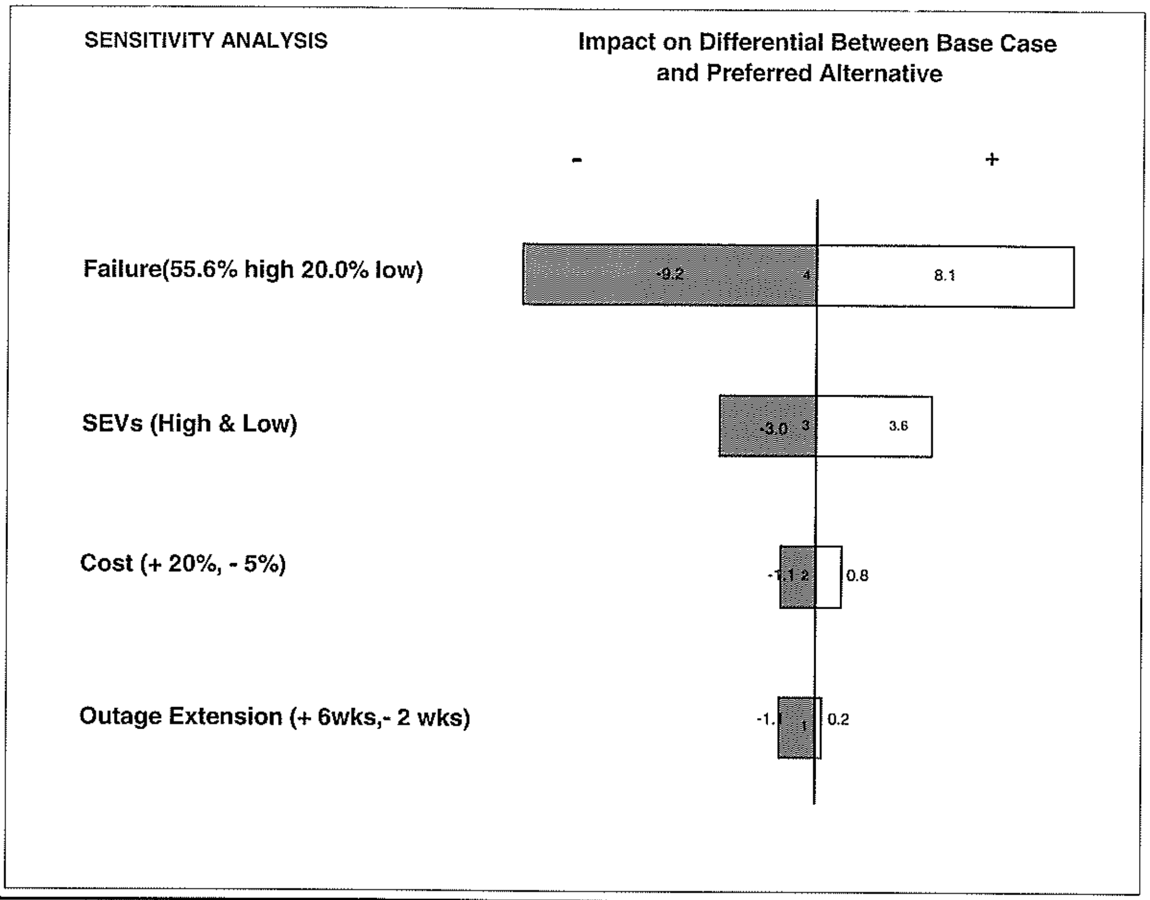
Risk Description	Impact	Initial Risk (before Mitigation) (H,M,L)	Mitigating Activity	Residual Risk (after Mitigation) (H,M,L)
Cost				
1. Project costs escalation.	1. Exceeding release amount.	1. M	1. Estimated costs associated with the procurement of the transformers were obtained from four proposals to supply thirteen transformers over the period from 2010 to 2013.	1. L
2. Unknown installation costs.	2. Exceeding release amount.	2. M	2. Cost estimates provided by [redacted] and [redacted] were used to fully develop the costs for procurement and installation.	2. L
3. Material escalation costs.	3. Exceeding release amount.	3. M	3. Project Contingency included covering the anticipated copper steel price increases. If the price of copper escalates beyond the anticipated amount, a superseding BCS release may be required.	3. L
Scope				
1. Unknown civil modifications required prior to transformer installation.	1. Increased project cost due to design changes.	1. M	1. Air cooled transformers are similar in size as the existing transformers The suppliers were given station drawings of the existing structure and station components (E.g. high voltage connections) that the transformers must be designed to.	1. L
Schedule				
1. Unable to remove transformer from service.	1. Delays the start of each outage and shifts costs to future years.	1. M	1. The transformer outages will be coordinated with the Turbine replacement program outages.	1. L
2. Exceeds outage request.	2. Outage would extend into the following year.	2. M	2. Transformers will be delivered to site three months prior to the scheduled outage commencement date. This is sufficient time to prepare the transformers for installation.	2. L
3. Defer one year due to expected 90 week delivery window.	3. Outage would extend into the following year.	3. M	3. The transformer outage will still continue to be coordinated with the Turbine replacement program the following year. No additional transformer outages would be required.	3. L
Resources				
1. Lack of PWU resources on site.	1. Lengthens the transformer outage. There is a risk that the PWU portion could be higher depending on the CPA assignment.	1. L	1. Transformer installation will adhere to the Chestnut Park Accord process.	1. L
Technical				
1. Replacement transformers and associated equipment	1. Additional future outages required to repair equipment.	1. M	1. Pre-approved qualified transformer manufacturers were asked to bid on a Request for Proposal as per	1. L

will not meet expected performance or reliability standards. 2. Insufficient scope of work.	2. Future outages required to complete additional scope items.	2. M	the Transformer specification. Technical data and standards will be measured during factory acceptance and in-service testing. 2. Numerous Stakeholder meetings, component assessments, engineering reviews, life cycle planning and equipment needs exercise in developing the project scope of work.	2. L

The results of the sensitivity analysis are shown in the diagram below. This shows the variance from the Base Case to the preferred option (Alt. 3) resulting from changes to Failure Probability, Cost, Outage Time and SEV's. Difference from the Base Case to the preferred option is ($8.1M) based on a 55.6% failure rate assumption. The diagram illustrates that Probability of Failure represents the greatest risk of influencing the NPV value with Cost and Outage Time expected to present the least risk.

VARIABLE/RISK	HIGH/LOW RANGES	NPV (2007 $M) Base Case	NPV (2007 $M) Preferred Alternative	+/- From Initial Difference Between Base Case & Pref. Alt. (2007 $M)
Probability of failure	HIGH 55.6% Failure	-67.5	-52.9	8.1
	LOW 20% Failure	-17.5	-20.1	-9.2
Cost	HIGH 20% increase	-32.4	-26.9	-1.1
	LOW 5% decrease	-29.8	-22.4	0.8
Outage Extension	HIGH 10 weeks (add'n 6weeks)	-30.7	-25.3	-1.1
	LOW 2 weeks (reduce 2 weeks)	-30.2	-23.5	0.2
SEVs	High SEVs	-36.3	-26.1	3.6
	Low SEVs	-25.8	-22.3	-3.0

Initial Difference Between Base Case & Preferred Alt. (2007 $M) 6.5



8. POST IMPLEMENTATION REVIEWS

- Project management will conduct a Lessons Learned exercise following the first bank outage and review:
    - Transformer purchase and installation cost variances
    - Outage duration variances
    - Coordination complexity associated with the turbine/overhaul and transformer outages

  The lessons learned will be incorporated into the subsequent transformer bank installations.
- Project Management will provide results of the Factory Acceptance and In-service Test reports to verify that the transformers have met specified performance criteria:
    - The manufacturer shall perform all tests, before transformer shipment, in accordance with CAN/CSA-C88-M requirements.
    - OPG will repeat some low voltage tests at site, such as core insulation, sweep frequency response analysis, and insulation dissipation factor tests. The basis for acceptance at site will be the same as the Factory Acceptance tests performed before shipment.
- The final PIR report will be completed by the Ottawa/St. Lawrence Plant Group Asset Management Department by the end of December 2013

ONTARIO POWER GENERATION

HYDROELECTRIC
Summary of Estimate CAPITAL

Date	Dec. 2007
Project #	DESJ0031

Facility name: Des Joachims GS

Project Title: Replace Main Output Transformers

	LTD	2008	2009	2010	2011	2012	2013	TOTAL	%
Project Management/Engineering **(012)**	$8k	$20k	$20k	$20k	$20k	$20k	$20k	$128k	.4
Consultant/Engineering **(310)**	$33.5k	$220k	$20k	$20k	$20k	$20k	$20k	$353.5k	1
Construction/Installation									
Hydroelectric (PWU labour) **(010)**		$10k	$10k	$20k	$20k	$20k	$20k	$100k	3
Contractor/ (BTU labour)/EPSCA **(310)**	[redacted]								
Materials **(200)**	[redacted]								
Interest **(700)**	$0.5k	$99k	$100k	$395k	$359k	$364k	$238k	$1,555.5k	5
Contingency **(998)**	[redacted]								
TOTAL (GROSS)	$42k	$1,749k	$1,771k	$6,982k	$6,412k	$6,580k	$4,338k	$27,874k	100

Notes: 1 Full Release: **Y2008**
In-service Date: T1-2010, T3-2011, T2-2012, T4-2013
2 Interest and escalation rates are based on current allocation rates provided by Corporate Finance
3 Includes removal costs of: $500k
4 Includes Definition Phase Cost of: $80k

Prepared by:	Approved by:
Project Engineer	Production/Project Manager
Date: Dec 11/07	Date: Jan 2/08