FINAL REPORT

NIAGARA TUNNEL PROJECT –

QUALITATIVE RISK ASSESSMENT REPORT

Prepared for

Ontario Power Generation
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1.1 BACKGROUND

URS Corporation (URS) was retained by Ontario Power Generation Inc. (OPG) on November 16, 2004, to provide hazard identification and both qualitative and quantitative risk analysis services for the Niagara Tunnel Project (the Project).

The Niagara Tunnel Project will see the construction of a new tunnel approximately 12.5 m in diameter and approximately 10.5 km long. The tunnel will carry water from the Niagara River above the Falls, under the City of Niagara Falls, to the Sir Adam Beck 1 and 2 Generating Stations in Queenston Heights, Ontario. The tunnel will increase the amount of water available to the generating stations, thus allowing them to increase their energy production.

This Project has been under consideration by OPG and its predecessor, Ontario Hydro, for more than a decade. The Environmental Assessment (EA) for the Project was approved by the Minister of the Environment in 1998, naming a number of conditions to be met and permits required in order for construction to proceed.

The tunnel will generally follow the same horizontal alignment as the existing canal and two existing tunnels, however the new tunnel is expected to have a much deeper vertical alignment at approximately 200m below the surface at its lowest point. This deeper alignment will allow the new tunnel to avoid going through an area of glacial fill called St. David's gorge, which was considered less favourable for tunnelling than the surrounding rock at the time the conceptual design was initiated and the EA approved.

The Project is to be awarded to a design-build consortium based on a Proposal Invitation that includes a preliminary design prepared by OPG and its representative, Hatch Mott Macdonald (HMM). Proponents are to submit their proposals on the basis of the supplied concept drawings and the owner's mandatory requirements, but may offer alternatives where substantial cost savings can be realized. The EA approval was based on the design concept submitted with the EA documents, so any substantial deviation from that design will require an EA amendment. For example, a shallower alignment through St. David's gorge, technically risky at the time of the EA, may be proposed by one or more contractors as a cost- and time-saving alternative.

The RFP was issued to shortlisted design-build consortia on December 22, 2004, with a closing date in April 2005. Construction activities are expected to start in the summer of 2005, with completion of the tunnel expected in 2009.

OPG asked URS to carry out this Risk Assessment in late November 2004, at the time the RFP was in its final stages of preparation. The URS scope of work includes identification, assessment and presentation of hazards and risks associated with the Project in a way that provides a clear method of risk management for the Project going forward. The URS approach takes standard tools of expert solicitation, including one-on-one interviews and group workshops and combines these methods within an overall risk management framework provided by the *Code of Practice for Risk Management of Tunnel Works*[1] (the Code).

[1] *Code of Practice for Risk Management of Tunnel Works,* Unpublished Draft. 2005.

The URS scope of work includes both a Qualitative and a Quantitative risk assessment for this project. This report covers only the qualitative portion of the work. A report on the Quantitative Analysis will follow under separate cover.

1.2 OUTLINE AND STRUCTURE OF THIS DOCUMENT

This report forms the qualitative assessment deliverable required under our contract. It outlines our method of analysis, the purpose of the Code and how the concept of Risk Registers can be used to benefit the Project. Approved changes from standard OPG procedures are explained, followed by a detailed review of the results obtained from our work.

The risk registers are presented alongside a guideline of how to read and use these registers for future management of the Project. There follow our conclusions from this effort and some recommendations for future work associated with the risk management of the Project as it moves into detailed design and construction.

1.3 DOCUMENTS REVIEWED

Documents received by URS from OPG for our review in assessment of hazards and their causes include the following documents:

- Design Build Agreement (Draft), including concept drawings: Niagara Tunnel Facility Project. Electronic File Dated December 2, 2004.
- EA Act Section 9 Notice of Approval to Proceed with the Undertaking dated October 14, 1998.
- Community Impact Agreement between Regional Municipality of Niagara, Town of Niagara-on-the-Lake, City of Niagara Falls and Ontario Hydro dated December 22, 1993.
- Geotechnical Baseline Report 'A': Electronic file dated November 30, 2004.
- The Niagara Tunnel Project: Project Execution Plan (Second Draft): Dated September 15, 2004.
- Business Unit Risk Self-Assessment (BURSA) Framework: criteria, rating scales and classification as well as instructions on use. Electronic file dated November 26, 2004.
- OPG Risk Types and Definitions: 2004. Electronic file dated November 26, 2004.
- Excerpts from Hatch Risk Assessment carried out prior to URS involvement in the Project. Electronic file dated December 7, 2004.
- Project schedule dated November 18, 2004.
- Minutes of seven meetings held between OPG and MOE, between August 24, 2004 and November 23, 2004 and two multi-agency meetings held on October 7 and November 10, 2004.
- Fisheries Act Authorizations (to destroy fish by means other than fishing, and to harmfully alter, disrupt or destroy fish habitat) dated January 18, 1995, as amended January 25, 2000, and December 2, 2003.

- Niagara River Hydroelectric Development Environmental Assessment Summary and Environmental Assessment excluding report section Nos. 2 through 5 dated March 1991.
- Niagara River Hydroelectric Development Environmental Assessment Amendment dated June 3, 1993.

1.4 DEFINITION OF TERMS

The following definitions of terms were used by URS and OPG to conduct the assessment and develop the risk registers.

Hazard – A situation that, if it occurs, brings about a negative impact on achieving Project objectives.

Cause – The circumstances that allow a hazard to manifest itself.

Likelihood – an event's probability of occurrence expressed in this report in qualitative terms such as likely or unlikely.

Consequence – impact of hazard occurrence measured for several aspects of the Project, such as financial, schedule or environmental impacts.

Risk - expressed as the combination of likelihood of an event occurring over a specified time frame and the consequence if the event occurs.

Inherent Risk – Risk, assessed at the commencement of the Project with no specific mitigation or control measures in place.

Residual Risk – The risk assessed at a particular point during the Project and considering all mitigation and control measures in force at the particular point in time that the assessment is taking place.

Risk Register – A formalized record of risks identified from the risk assessment process including full descriptive details of mitigation and control measures, risk owners and with appropriate cross-references. The risk register is the primary means of recording and monitoring the risk management process.

High-level Risk Register – A risk register that considers only aggregate or high-level risks, of interest at the "program" or "project" level, for the purpose of overall project risk evaluation and management.

Risk Assessment – the formalized process of identifying hazards and associated risks, of evaluating their consequence and probability of occurrence, and of preparing strategies as appropriate for preventative and contingent actions.

Risk Management – the overall systematic process of Risk Assessment, risk mitigation and control.

1.5 WARRANTY, LIMITATIONS AND RELIANCE ON URS REPORTS

URS warrants that its services are performed, within the limits prescribed by its Clients, in a manner consistent with that level of care and skill ordinarily exercised by members of the same profession currently practising in the same locality under similar conditions. No other warranty or representation, either expressed or implied, is included in URS' proposals, contracts or reports.

URS' reports are based, in part, upon the application of scientific and engineering principles and professional judgment to certain facts with resultant subjective interpretations. The findings, opinions and recommendations that are made relate exclusively to URS' specific agreement for services, certain facts presently known to URS and our current understanding of the Project. URS' opinions relating to environmental and geologic conditions are based on limited data, and actual conditions may vary from those encountered and assessed at the times and locations where the data are obtained, despite the use of due professional care.

URS' reports are based, in part, upon information provided by others and no attempt is made to independently verify the accuracy of such information unless specifically noted in the reports. URS does not assume any liability for information that has been withheld or misrepresented to us.

URS' reports do not provide any legal opinion on compliance with applicable statutes or regulations by past and current Site owners unless specifically noted in the reports, which compliance is always subject to change in any event. Because regulatory evaluation criteria are subject to change, substances that are present and not ordinarily analysed under the current standard of professional care or present at concentrations currently considered to be acceptable may, in the future, become subject to different regulatory standards and require remediation.

URS' reports are intended to be used in their entirety and no excerpts may be taken to be representative of the entire reports. Where more than one report is prepared related to the same Site, all documents and reports should be referred to for a more advanced discussion of technical details, and should be reviewed prior to any reliance, decisions or actions being taken on the basis of the reports.

This report is prepared solely for the exclusive use of OPG. No third party may rely upon this report, or any part of its contents, without the express prior written consent and authorization of URS.

URS assumes no liability of any kind or nature arising out of use of or reliance on URS reports, or decisions made or actions taken based upon such reports, or any part thereof, by any third party not authorized in writing to rely upon such reports.

The analysis was carried out in several distinct stages as described below. Several of these stages were implemented simultaneously to meet OPG's required schedule. The stages include:

- Document review –familiarization with Project geometry, geology and major issues impacting progress and those issues specifically included in contract documents;
- Identification and classification of hazards and their causes/consequences –an application of our experience and professional judgment to accelerate the hazard identification process by identifying an initial list of project hazards;
- Expert solicitation from Project team to verify and complete hazard identification and assessment – individual interviews with key OPG Project staff to clarify points from the Project geometry and particular areas of hazard identification;
- Workshops to complete expert solicitation process – three day-long Expert Panel workshops with OPG Project team members to formally identify risks and provide assessment of the risks by completing risk registers of program-level risks; and
- Assessment of risks – follow-up with individuals from the Expert Panel to complete the risk assessment process both to complete the risk registers for qualitative risk analysis, and to establish the risk register format for risk management purposes

2.1 CODE OF PRACTICE FOR TUNNEL RISK MANAGEMENT

Underground construction involves inherent risks of geology and linear construction methods that have led to an unwanted reputation for late and over-priced projects around the world.

Underground construction has also proven to be exceptionally risky for the insurance companies that underwrite projects for the construction industry. In recent years this problem has worsened, with several high profile tunnel failures including a particularly egregious case in the North of England involving an $80M insurance payout on a recent project where the premiums were less than $2M.

This mounting problem was most keenly felt in the London Insurance Market, where all major international construction project insurance is held. The major London insurers considered withdrawing all insurance support for the UK underground construction market, which prompted the underground industry to take action. The Association of British Insurers (ABI) and the British Tunnelling Society (BTS) agreed to produce a Joint Code of Practice for Risk Management on tunnelling projects that is now a standard in the United Kingdom and is fast gaining acceptance elsewhere. An international Code of Practice has now been drafted for publication in spring 2005. The primary author of this code was Dr. Terry Mellors (an important member of the URS Team).

The principal elements of the *Code of Practice for Risk Management of Tunnel Works* are:

- To promote best practice for the minimization and management of risks associated with the design and construction of underground structures;

- To set out guidelines for identification of risks and their allocation to parties to a contract; and
- To provide a framework for management and control of risks through Risk Assessments and Risk Registers.

While the primary exercise to date has involved data gathering for identification and initial assessment of hazards and their causes, the real benefit of risk registers is experienced once the ongoing risk management exercise is begun and the risk registers are expanded for individual areas of work.

2.2 PURPOSE AND USE OF RISK REGISTERS

Risk identification and assessment exercises should be summarized in risk registers, which are excellent tools to present and summarize this information. In addition to presenting the inherent and residual risk along with mitigation and control measures currently in place and action items yet to be carried out, the risk register should clearly indicate the party responsible for control and management of each identified risk as well as contingency plans and measures for mitigation of risks.

Risk registers are live documents that must be continually reviewed and revised as appropriate and available for scrutiny at any time. They provide an auditable trail through the life of the Project to demonstrate compliance with the Code. They identify hazards, consequent risks, mitigation and contingency measures, proposed actions, responsibilities, critical dates for completion of actions and when required actions have been closed out.

The risk register format established for this Project follows a standard risk register format, modified to include the range of risk categories identified as important. It is divided into eight sub-registers covering the following areas:

1. Approvals and permitting
2. Stakeholder issues
3. Planning and conceptual design
4. Financial and contractual
5. Logistics and access
6. Final design and construction
7. Environmental issues
8. Safety and security

These eight hazard areas were designed to cover all aspects of the project, in terms of both chronology and technical disciplines.

2.3 EXPERT PANEL WORKSHOPS

A thorough risk assessment requires the participation of a body of experts covering all the various risk areas appropriate to the Project.

An Expert Panel, encompassing the various disciplines pertinent to the project, was assembled from OPG and HMM Project Team members. Three formal Expert Panel workshops took place during the project. During the meetings, URS presented the risk process as adapted for this assignment and facilitated the process of identifying and classifying hazards, assessing risk likelihood and consequences, and distinguishing between inherent and residual risks. Following each workshop the risk register was circulated to Panel members for feedback.

Workshop #1:

Date: December 9, 2004

Location: OPG Head Office, Mezzanine Mini-Auditorium

Objectives: During this first workshop the Expert Panel identified Project hazards in all the eight risk areas, and assigned preliminary likelihood and consequence ratings as time permitted. Following the workshop, participants were asked to review the risk register to verify that no key risks had been omitted, and to review likelihood and consequence ratings according to their understanding of the Project.

Achievements: At the completion of Workshop #1 and follow-up activities, Project risks were generally identified, with the exception of conceptual and detailed design risks. Likelihood and consequence ratings were in place for approximately half of the identified risks.

Participants:

- Dave Abbott
- Mahir Aydin
- Norm Brignall
- Neville da Silva
- Mark del Frari
- David Eden
- Emad Elsayed
- Josie Erzetic
- Rick Everdell
- John Floras
- Katherine Hammond
- Dickson Harkness
- David Heath
- Stephanie Monteith
- Ed Over
- Graham Pugh
- Greg Scallen
- Colleen Sidford
- Chris Walker
- Margaret Yu
- Andy Zielinski
- Harry Charalambu, HMM
- Judy Fedorowick, URS
- Bob Goodfellow, URS
- Ken Lyon, URS
- Terry Mellors, URS
- Susan Sherman, URS
- Colin Wasteneys, URS

Workshop #2:

Date: December 23, 2004

Location: OPG Head Office, Mezzanine Mini-Auditorium,.

Objectives: The second Expert Panel workshop focussed on technical aspects of the Project, particularly the Conceptual Design and Detailed Design/Construction subregisters, taking advantage of the presence of the senior members of the HMM team who were present at that workshop.

Achievements: At the completion of Workshop #2, the "Planning and Conceptual Design" and "Final Design and Construction" subregisters were substantially complete, with likelihood and consequence ratings in place for all identified hazards. The two remaining technical subregisters, "Access and Logistics", and "Safety and Security", were not covered in the workshop due to lack of time.

Participants:

- Norm Brignall
- Mark del Frari
- David Eden
- Emad Elsayed
- Rick Everdell
- Katherine Hammond
- Graham Pugh
- Colleen Sidford
- Andy Zielinski
- Harry Charalambu, HMM
- Russell Delmar, HMM
- Randy Essex, HMM
- Brian Garrod, HMM
- David Judge, HMM
- Chris Tattersall, HMM
- Bob Goodfellow, URS
- Susan Sherman, URS

Workshop #3:

Date: January 14, 2005.

Location: OPG Head Office, Mezzanine Conference Room #4,

Objectives: Workshop #3 focussed on the following risk areas:

- Approvals and permitting
- Stakeholder issues
- Financial and contractual
- Environmental issues
- Safety and security

Achievements: At the completion of Workshop #3 and follow-up activities, the risk registers were substantially complete to a degree consistent with this stage in the Project schedule.

Participants:

- Mahir Aydin
- Norm Brignall
- Neville da Silva
- David Eden
- Emad Elsayed
- Josie Erzetic
- Rick Everdell
- Katherine Hammond
- David Heath
- Stephanie Monteith
- Graham Pugh
- Greg Scallen
- Colleen Sidford
- Chris Walker
- Margaret Yu
- Andy Zielinski
- Michael Hughes, HMM
- Cate Mee, HMM
- Judy Fedorowick, URS
- Bob Goodfellow, URS
- Ken Lyon, URS
- Susan Sherman, URS

Mini Workshop #4:

Date: February 4, 2005.

Location: Hatch offices

Objectives: Workshop #4 focussed on the following risk areas:

- Planning and Conceptual Design
- Financial and contractual
- Final Design and Construction

Achievements: At the completion of Mini Workshop #4 the above risk areas were completed to the satisfaction of participants, with the exception of DSC claims which were to be separated into a number of individual subrisks by URS.

Participants:

- David Eden
- Andy Zielinski
- Harry Charalambu, HMM
- Brian Garrod, HMM
- Russell Delmar, HMM
- Chris Tattersall, HMM
- Mike Hughes, HMM
- Bob Goodfellow, URS
- Susan Sherman, URS

2.4 RISK ANALYSIS RATING SCALES

Figure 1 presents the criteria used in risk assessment for this Project. The criteria were based on the standard OPG criteria used for operational risk assessments with a few key differences as described below:

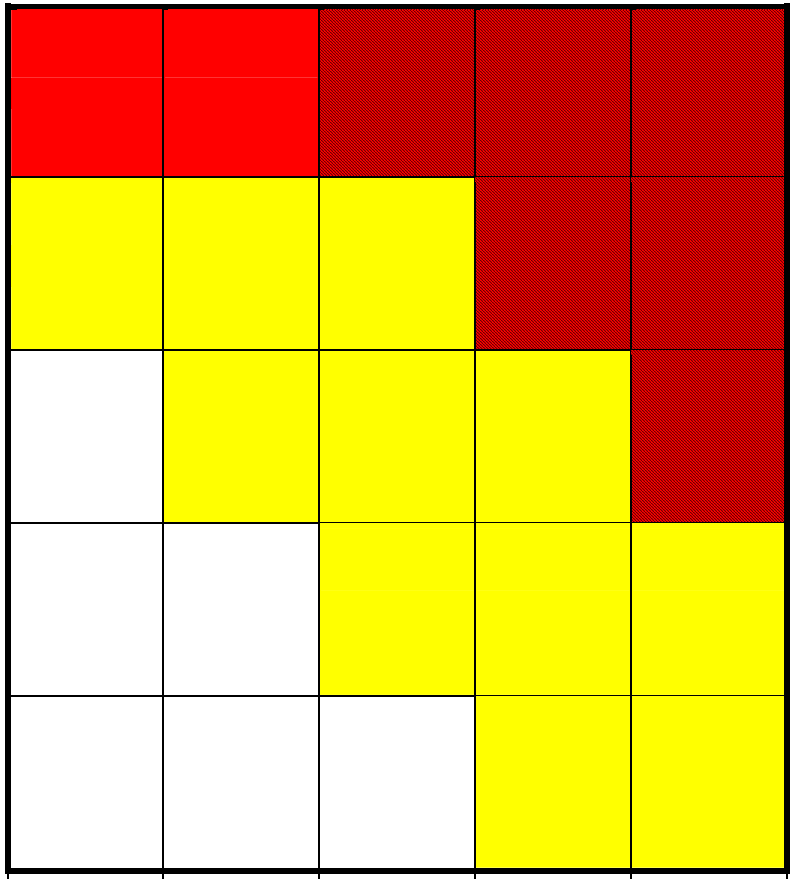
The qualitative terminology for likelihood of occurrence was altered to include terms such as "unlikely" and "possible" to provide a framework for decisions of likelihood on a scale of 1 to 5 for each hazard and cause.

The "red zone" of high-level risks was changed to encompass the entire #5 consequence rating. This is common practice for construction risk assessments and indicates the need for contingency planning for high consequence low likelihood events.

The baseline time-span over which risk occurrence is an important factor in the mathematical correctness and theory of the risk analysis. For this Project, our approach is to consider each risk over the length of exposure to the hazard in question. This approach makes the risk analysis relevant for a Project on a finite schedule, as opposed to an operating situation where risks are more appropriately expressed on a per-year basis. The duration of exposure for each risk is different (e.g. hazards associated with heavy crane lifts of TBM pieces out of the intake shaft location occur over a very short period of time) but due to the need for a standard framework for our assessment, the decision was made to normalize the period of time for exposure to the Project length (i.e. probability of occurrence over the course of the project).

Figure 1: Proposed Qualitative Risk Analysis Rating Scales for Niagara Tunnel Project

Financial		Project Schedule	Corporate Reputation	Regulatory / Legal	Health & Safety	Environ-ment	Consequence Rating
Mid-point (approx.)	*Range*						
$ 100 million	Greater than $50 million	Year	National and international adverse coverage or impacts	Non-compliance with potential for significant implications for senior personnel and potentially large damages	Multiple fatalities	Long term widespread damage to region	5
$ 25 million	$10 million – $50 million	Months	Long-term local or national impact	Legislative non-compliance with potential for fines, charges and damages	Multiple major injuries and/ or single fatality	Long term local or regional damage	4
$ 5 million	$3 million – $10 million	Month	Major local impact or minor national impact	Systematic non-compliance with potential for fines	Major injury and/ or multiple minor injuries	Medium term regional damage	3
$ 1 million	$500,000 – $3 million	Weeks	Complaints from local officials/ politicians	Systematic non-compliance with impacts to project schedule only	Minor injury	Medium term local damage or short term regional damage	2
$100,000	0 – $500,000	Week	Complaints from local public	Isolated non-compliance	Minor injury (non-reportable)	Short term local damage	1



	1	2	3	4	5
Likelihood	Improbable	Unlikely	Possible	Likely	Probable
Probability	1/1,000	1/100	1/10	1/5	0.75

Probability Rating

Changes from the OPG Consequence criteria table are described below:

- *Financial consequence range* - remains unchanged due to the size of the Project;
- *Schedule consequence range* - replaces the Production Capability classification due to the critical nature of schedule delays to a Construction project – particularly one like this where there is a revenue stream dependent on timely completion of the Project;
- *Corporate Reputation consequence range* – Five separate classes have been created for levels 1 through 5 and these cover media impact, customer and shareholder impact and to some extent construction industry impact;
- *Regulatory/ Legal consequence range* – Five separate classes have been created for levels 1 through 5 covering varying degrees of non-compliance with relevant regulations;
- *Health and safety consequence range* - Five separate classes have been created for levels 1 through 5 with additional categories of injury to reflect consequences of catastrophic events; and
- *Environmental consequence range* - Five separate classes have been created for levels 1 through 5 with consequences refined in consideration of potential construction events.

The hazards identified in the qualitative risk assessment exercise are not combined in the same sense as quantitative risks are combined to produce an overall risk assessment. They are each considered as independent contributors to the qualitative Project risk assessment.

The focus of this section is the eight risk subregisters identified for the eight major areas of Project risk exposure, as described in Subsection 2.2. Please refer to Appendix A for the risk subregisters.

3.1 HOW TO READ THE RISK REGISTERS

There are three major sections in the high-level risk registers in of this qualitative assessment.

Section 1 – Risk Identification: This section consists of four columns concerned with identification of hazards, their causes and their consequences. Each hazard is given a unique number for identification purposes.

Section 2 – Risk Assessment: This section consists of two sets of 8 columns that look identical to each other. The first of these columns contains the assessment of likelihood; the following five columns contain the risk consequences on scales of 1 to 5 as discussed earlier in this report. The eighth column in the set is the Risk Score, defined as the multiple of the likelihood and the highest consequence score. This risk score is coloured red, yellow or white in decreasing order of concern (please refer to Figure 1 for a "heat map" showing the criteria for the colour designations).

The first set of eight numerical columns represents the inherent risk picture for the particular combination of hazard, cause and consequence. The second set of eight numerical columns represents the current likelihood, consequences and Risk Score for the same hazard/cause/ consequence, including the effects of any mitigation measures currently in place.

The essential difference between the two sets of columns is that the first represents the inherent risk associated with that hazard and cause – meaning the risk without any particular control measures being applied in mitigation. This can be most easily thought of as the risk at the very beginning of a project. The second set of columns represents an assessment of the residual risk that currently exists on the Project, considering all current mitigation measures in place.

There are two important factors in reading and assessing hazards and risk registers:

1) If no mitigation or control measures are currently in place the Residual risk score is equal to the Inherent risk score; and
2) The risk register should not be aspirational: ***only*** control measures currently in place should be considered in assessment of the residual risk scores. Mitigation measures not yet in place should be included only in the "action item" column, not the "control measures" column.

Section 3 – Risk Management: The ongoing process will involve continuous re-assessment of the risk registers and the five remaining columns – entitled:

- Control Measures implemented – mitigation and control of either causes of hazards or their consequences or (rarely) control of both factors
- Indicators or metrics – measuring the impact and effectiveness of the Control Measures
- Action items for Risk Mitigation – those control measures not yet implemented

- Action item completion date – target date for making these items part of the control measures implemented column
- Risk Owner – Best to be a named individual (rather than a corporate entity) responsible for completion of each action item by the due date

The Risk Management process is a continuous improvement process of completing action items, moving these items to become control measures, measure the effectiveness and re-assess the risk scores. If further action items are required, the loop begins again until the level of risk has been mitigated to the most cost-effective level.

The use of risk registers for risk management of a project is an ongoing exercise that requires constant attention to outstanding action items and re-assessment of the risk scoring to reduce the levels of risk to acceptable levels. The process is a formalization of good engineering practice but makes this process more transparent and accountable.

In this qualitative risk analysis, there were instances of hazards that overlapped between one or more risk areas. For example, a number of items could be considered under both Approvals & Permitting (subregister 1) and Environmental (subregister 7). Where this occurred, we have placed the hazard in the subregister considered most appropriate. In some cases, overlapping risks have been included in both subregisters. The potential for "double counting" is not a concern in connection with the qualitative risk register, because the risk scores are not added together. However, care must be taken in the risk management of subsequent project phases to ensure that risk owners are clear which specific aspects of the hazard are their responsibility. As the hazards become more disaggregated it will be necessary to avoid repetition at the more detailed level.

3.2 DISCUSSION OF HIGH-LEVEL RISKS

3.2.1 General Considerations

The Risk Register displays hazards qualitatively using three colors:

- White – low likelihood and low consequence hazards that will have little bearing on the successful completion of a project;
- Yellow – moderate likelihood and consequence hazards that require mitigation and attention to reduce to white hazards wherever possible; and
- Red – where the risk is extreme and where the risk management focus should be directed because these hazards are those that can cause dire consequences for project success.

Red risks are characterized by two distinct types of hazard:

1. High likelihood / high consequence hazards – with risk scores of 15 and higher in Figure 1;
2. Low likelihood / high consequence hazards – with relatively low risk scores of 5 or 10 but coloured red. Although these hazards are very unlikely to occur, if they do the consequences are such that provision of a contingency plan is often the most prudent risk management strategy.

The risk register in Appendix A currently shows a number of red risks that are most obviously attributed to construction (i.e. where no mitigation measures are currently in place). It appears that the majority of hazards under OPG control during the planning phase have been mitigated adequately to this point. However, it is also clear from the workshops described above that additional activities are required to clarify some points related to some of the major hazards.For example, it was discovered that more information was needed to determine if a modification would be required to the EA if the upper tunnel alignment were chosen. This would help estimate the potential schedule delay and would allow a more informed assessment of the upper alignment's acceptability if it were proposed.

Care must be exercised throughout the life of the project to make sure that the risk register is not aspirational. It appears on thorough review that some of the "mitigation measures" proposed to be in place at the time of assessment may still be, in fact, tasks that have yet to be carried out. Without further review with the project team it is impossible to vet this aspect of the risk register thoroughly. However, this should be a continuing focal point for future use of the risk register.

3.2.2 Direct discussion of "Red" Risks

The following discussion focuses on each of the eight sections of the Risk Register in turn and discusses the red risks in each section.

Sub-register 1: Regulatory Approvals and Permits

The primary risks left unmitigated in this section are the risk to the project schedule if additional documentation or amendments to the EA are required if a different tunnel alignment is proposed and approved. The current thought process is that this alignment will only be approved if the financial benefit outweighs the schedule cost. For this decision to be made rationally it was discussed during Workshop #3 that more information is required on exactly what the additional requirements would be.

Contingency planning is required for several other hazards, including such global factors as loss of government support for the project and a loss of water rights at the intake site.

Sub-register 2: Stakeholder Issues

In a fine example of how risk management is presented on a risk register, this section shows how the high levels of risk associated with identified Stakeholder hazards have been mitigated. All of the identified red risks have been reduced to white risks during the planning process. This is exactly the objective with every section – but the nature of some sections makes this a very difficult objective in most cases.

Sub-register 3: Planning and Conceptual Design

The risks of innovation and failure of the design or tunnel performance can only be truly mitigated during the bid analysis and final design/construction phase, where the proposed designs are identified and clarified. The current mitigation measure of research into likely materials and approval, at least in principle, of more than one solution to a problem (while

allowing the design-builder to proceed with its own preferred alternative) seems prudent. Another mitigation measure available is that, upon review of the Contractor's bids, the consequence magnitude on both schedule and Corporate reputation can be re-assessed and perhaps down-graded to a level that will reduce the risk from red to yellow.

Contingency planning is required for the tunnel not satisfying minimum design requirements set out by the Owner's team. This is considered in more detail in later sections but is captured here in a single hazard to alert the planning team that they also have a responsibility to set realistic goals. The low likelihood shown in the risk register represents clearly that the goals are achievable and, if final design and construction hazards are managed effectively, there is no apparent inherent reason that the performance goals cannot be met.

Sub-register 4: Financial/ Commercial/ Contractual and Procurement Issues

The single riskiest aspect of the project in this section was considered to be the inability to control the final project costs within the original budget. The experts agreed during the Workshops that the somewhat chequered history of underground construction would probably out-weigh the prudent steps and measures taken to control project costs. This hazard ranks as one of the most concerning in the whole analysis and demands constant vigilance and mitigation measures to keep under control.

Contingency planning is required for other red risks that have been mitigated as much as possible, such as: the inability to collect from the bonding agency if required, occurrence of a *force majeur* event or the contractor choosing to default. Other concerns that were highlighted and need contingency planning cover various aspects of the long term operation and maintenance of the tunnel, and the inability to fix or constrain the cost of this operation over the 90 year design life in advance of design and construction.

Little can be done in these cases and they are good examples of risks that exist and that the owner must simply proceed with due care and using good practice in the hope that these extremely unlikely events do not occur.

Sub-register 5: Logistics and Access

This section reveals only one high-level red risk: the late availability of the TBM due to manufacturing problems. No mitigation measures or action items are in place for this section – primarily because these are Contractor issues that depend on means and methods including their preferred method of project site set-up.

These hazards are relatively straightforward to mitigate for Contractors. Allowance of sufficient float time in schedules, as well as prioritizing order and prompt specification of the TBM, are proven and effective means of providing both the manufacturer and the Contractor with the required information and products that they need for successful execution of the work.

While the TBM manufacture is a high-level red risk at present, with further attention and prudent mitigation steps this risk should be reduced during the early stages of final design.

Sub-register 6: Detailed Design and Construction

This section features two high-level risks that predictably focus on geologic conditions different from those expected when planning and design were underway and a host of contingency planning needs that focus on unlikely occurrences that result in consequences damaging to the health and safety of tunnel workers.

Differing site conditions (DSC), while never completely mitigated, are restricted here by the prudent contractual method of having the Contractor help draft the Geotechnical Baseline Report (GBR) for the project. In addition, there is the historic record of construction for two other tunnels mined nearby that provide good information on many of the formations that will be tunnelled here. Most of the tunnel will be mined in the Queenston Shale: TBM performance in this material will make or break the Project from a cost, schedule and DSC claim perspective.

The two highest assessed risks reflect the biggest unknowns:

- groundwater salinity and its impact on the TBM components, and
- the swelling potential of the shale that can have dramatic repercussions on lining stability and performance in the long term.

The issues of strength and abrasivity of the rock are also critical to rock TBM performance and all of the issues listed under "Hazard Number 6.5 – Encountering ground conditions more adverse than advertised in Contract" should be monitored on a continuous basis as they are all borderline red risks and should be treated as such.

Contingency planning is required for a number of safety-related construction issues including:

- flooding of the works (intake and outlet works)
- tunnel collapse due to inadequate design
- ice damage at the inlet works
- blasting damage to the PGS dike structure
- failure of the tunnel lining system to meet the performance goals of the project, and
- no Contractor submits a bid that conforms to all the requirements of the project.

Prudent design measures have been taken to mitigate the above issues as much as possible. Comprehensive monitoring on site and detailed review of the Contractor's design complete the mitigation measures that can be taken by the OPG Team. The terms set out in the Contract Documents and the competitive bidding environment are both key factors in submittal of a conforming bid.

Sub-register 7: Environmental Considerations

There are no red risks within the environmental section. This is good news as often a host of contingency planning is required in this section. It seems clear that the lack of high-level residual hazards for environmental topics is a testament to the current length of the project planning effort and the thorough and responsive approach taken by the OPG team to this aspect of the Project.

Sub-register 8: Safety and Security

The only contingency level red risk that exists in this section is the occurrence of a terrorist attack on the SAB facility that would directly impact the tunnel project. This is a good example of a hazard that would be prohibitively expensive to eliminate completely and is sufficiently unlikely that, other than the currently implemented security measures and mitigation plans, a project specific contingency plan is the most prudent course of action.

4.1 CONCLUSIONS

The discussion above shows how the high-level hazards or "red risks" can be put into two classifications:

1) Those that are high likelihood and high consequence; and
2) Those that have been mitigated as far as possible and are unlikely or improbable in likelihood but would have very high and damaging consequences if they do occur.

The principal hazards identified from the expert solicitation and construction of the risk register are listed below in no particular order of importance:

- The *inability to control project cost* is always of primary importance to the owner and this hazard has proven to be difficult to mitigate historically.
- The *degree of swelling that will be exhibited by the Queenston Shale* is a hazard that troubles the design team greatly because of potential impacts on tunnel performance.
- *Impact of the groundwater salinity on TBM performance* and availability during the project is another geologic aspect of the project that is of concern.
- *TBM manufacturing problems that impact the project schedule* are beyond the immediate control of OPG and are of concern due to experience of the OPG team on other projects.
- Whether an *amendment will be required to the EA document during the project* and what the impacts of this occurring would be to the overall schedule is of concern but the action plan currently underway hopes to reduce this risk.

The most important aspect of the risk register is that it should not be aspirational – meaning that the mitigation measures and the re-assessment of residual risks should be based on present day plans in place and monitored to be working – ***not*** items that "should be done" or "are yet to be carried out." This takes discipline during review and a consistent approach to the methodology of risk management using a risk register in concert with the planning, design and construction team.

4.2 RECOMMENDATIONS

There are several actions required to ensure that the risk management framework set out in this document can be carried forward through the project design and construction stages. We have the following recommendations of tasks and strategic planning arrangements that we feel are necessary to meet this end.

1) The first and most important single task that must be completed is to create a risk management manual for the project that will provide a detailed framework of how each aspect of the risk management program fits with the ongoing project tasks. This manual

should be similar in nature to a project management plan and provide details on the number and frequency of meetings, reviews and audits; provide contact details for the major players in the risk management task; as well as providing a methodology for creation of and risk management using a risk register.

2) Designate a Project Risk Coordinator – a full-time position that has overall responsibility for maintenance of the risk management program and coordinates the various risk registers in use.

3) Designate risk coordinators to carry out similar duties at the work activity level. These are not usually full-time positions and can be drawn from designer, contractor or owner's staff – whoever is best positioned in the Project team to compile and manage the risk register for that work activity.

4) Carry out independent audits on the overall project risk register, including all the cascading work activity risk registers. These should be carried out every 3-6 months depending on activities on site and the level of owner interest.

5) The owner must make sure that relevant risk registers are transferred as part of the design builder's Contract so that they become part of the project requirements. The risk registers transferred will be five of the eight sections included in this report (the ones excluded are: stakeholder issues, planning and conceptual design as well as the financial and contractual section).

One important factor that remains is the need to generate and maintain risk registers at the work activity level. These registers build on the existing project wide registers contained in this report but are more detailed and specific to the actual on-site activities. These registers are regularly opened and closed out as activities are completed but each risk register requires an initial (facilitated) workshop session to generate and assess the hazards.

The risk registers are then reviewed by the risk coordination team on a regular basis and the project risk coordinator reports back to the project team with significant changes and developments in the risk registers at the regular project progress meetings (usually held monthly).

This is a summary of our recommendations on how the risk management process moves forward. Thorough and transparent risk management systems have proven effective and beneficial on major projects all over the world and we look forward to being part of the successful completion of the Niagara Tunnel Project for OPG.

Appendix A

Niagara Tunnel Project High-Level Risk Register

Niagara Tunnel Project High-Level Risk Register

Hazard ID Number	Classification Area (Ref. Page 13-2 PEP)	Hazard	Cause of Hazard	Potential Consequence	Risk likelihood	Risk consequence						Risk Score	Control Measures Implemented (actually in place at time of assessment)	Indicators or Metrics (Measuring the effect of Control Measures)	Residual Likelihood - After Mitigation	Residual Consequence - Once Controls in Place						Residual Risk Score - After Mitigation Action	Action Item for Risk Mitigation	Action Item Completion Date (Target Date)	Risk Owner (Name of individual)	Comments to Revisions
						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
1	**Regulatory Approvals/ Permits**																									
1.1		Not meeting terms and conditions of EA Approval	Contractor did not submit in time	Schedule Delay	3		3					9	Contractual requirement for scheduled submittals Compliance plan submitted to MOE	Submittal Log entries	1		1					1				
			OPG did not submit/ resubmit in time	Schedule Delay	3		3					9	Internal QA Process	Submittal Log entries	2		1					2				
			MOE not in agreement with proposed work	Schedule Delay	4		4					16	Regular meetings	meeting minutes	2		4					8				
			MNR not in agreement with proposed work	Schedule Delay	4		4					16	Regular meetings	meeting minutes	2		4					8				
			Conservation authority not in agreement with the impact on the Welland River	Schedule Delay	4	4	4					16	Undertake further studies to quantify impact De-link from project if necessary		3	4						12				
			Other regulators having jurisdiction not in agreement with proposed work *	Schedule Delay	3		4					12	strong community relationships	Response from public meetings	2	2	2	2				4				
			Unexpected results from Groundwater study	Schedule Delay	3		4					12	See also Section 7 for cost impacts		3		4					12	renegotiation with regulator			
			Unexpected results from Welland River study	Schedule Delay	3	3	4					12	working with consultants and Conservation Auth. to keep abreast of findings as		3	3	2					9				
			Unexpected results from excavated materials plan	Schedule Delay	3	3	4					12	See also Section 7		3	3						9	Work needed			
			Unforeseen new requirement added by MOE	Schedule Delay	4	3	3					12	Carried out EA in accordance with MOE requirements	EA documents	2	3	3					6				
			Other regulator adds new requirements	Schedule Delay	3	5	5					15	Strong relationship with MOE established	regular recorded meetings	2	3	4					8				

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
1.2		Required Permits not obtained	Contractor did not submit in time	Schedule Delay	2	3	4	1	4			8	liquidated damages clause		2	2	4	1				8				
			OPG did not submit in time	Schedule Delay	2	3	4	1	4			8	monitoring/tracking system		2	2	4	1				8				
			Late response from third party to regulator	Schedule Delay	3		3					9	Regular meetings with regulator		2		3					6				
			Failure to issue permit by regulatory authority (I.e. a negative decision)	Schedule Delay	2		4					8	Regular meetings with regulator		1		4					4				
			Additional study required by regulatory authority	Schedule Delay	3	1	4					12	Regular meetings with regulator		2	1	4					8				
			multiple re-submissions required by regulatory authority	Schedule Delay	3		4					12	Regular meetings with regulator		2		4					8				
			required permit not identified	Schedule Delay	2		4					8	Regular meetings with regulator		1		4					4				
			permit conditions not acceptable to OPG	Schedule Delay	3		4					12	Regular meetings with regulator		1		4					4				
1.3		New Permit application required (or variance)	Selection of upper tunnel alignment through soft ground of St Davids Gorge	Schedule Delay	4	-5	4					16	Current approval goes under the gorge. If new approval is required - then nogo upper level alternative to prevent delay to schedule, unless highly favourable price		4	-5	4					16	Further work required to determine requirements			
1.4		Amendment required to EA	OPG selects method significantly different from proposed scheme, due to favourable bid price.	Schedule Delay	4	-4	4					16	established procedure with MOE for notification; establishing with MOE impact of alignment change		4	-4	4					16	Further work required to determine requirements			
			All qualified contractor propose a method significantly different from proposed scheme	Schedule Delay	3		4					12	established procedure with MOE for notification; establishing with MOE impact of alignment change		3		4					12	Further work required to determine requirements			
			Change after contract award (i.e. bid conforms to RFP requirements but not EA approval)	Schedule Delay	3		4					12	established procedure with MOE for notification; establishing with MOE impact of alignment change		3		4					12	Further work required to determine requirements			
1.5		Adverse cost impact of permit to take water from river during project (I.e. to pump out cofferdam)	Authority places punitive cost structure on water taking	Cost impact on project viability	1	2						2			1	1						1				
1.6		Adverse cost impact of permit required to take water from river during operation	Authority places punitive cost structure on water taking	Cost impact on project viability	3	4						12	active negotiation with regulator		3	4						12				

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
1.7		Treaty on water usage is dissolved and entitlement changes	International issue between Canada and US	Project terminated	1		5					5			1		5					5				
1.8		failure to meet terms and condition of Order-in-Council on water rights	failure to substantially complete by 2009 target	Project terminated	1		5					5			1		5					5				
1.9		Withdrawal of project approval by the Government in power	Change of government with 2007 Provincial election	Project halted or terminated	1		5					5			1		5					5				
1.10		project does not meet terms and conditions of the Fisheries Act authorizations		Schedule Delay	3		3					9	Regular meetings with regulator		2		3					6				
1.11		inability to obtain approval on Fish Habitat Compensation Plan	NPCA does not agree with plan	Schedule Delay	3		3					9	Regular meetings with regulator		2		3					6				
			property owners/residents do not agree with plan	Schedule Delay	3		3					9	Consultation		3		3					9				
		* **Note: Other primary stakeholders include:**																								
		a. DFO																								
		b. Regional Municipality of Niagara																								
		c. City of Niagara Falls																								
		d. Town of Niagara-on-the-Lake																								
		e. Town of Pelham																								
		f. City of Welland																								
		g. Township of Wainfleet																								
		h. Township of West Lincoln																								
		i. City of Thorold																								
		j. Niagara Escarpment Commission																								

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
2	**Stakeholder Issues**																									
2.1		Failure to address Community Issues	Financial impacts on municipalities from project	demands / possible lawsuits for financial compensation to municipalities	5	3	4	4				20	Community Impact Agreement (CIA): financial compensation package, OPG funded		1	3	1	1				3	Meet with municipalities to discuss CIA update.			
			social and economic effects from project within site communities	citizen / municipal complaints especially as known likely concern prior to construction	5	3	2	3				15	CIA: monitoring / remediation program re social and economic effects, OPG funded		1	1	1	1				1		1-Jun-05		
			Lack of community liaison to identify and address issues in advance where possible	schedule delay, loss of corporate reputation	5	1	2	4				20	CIA:Community Liaison Committee to be in place prior to construction, OPG funded		1	1	1	1				1				
			Inadequate management of construction traffic	schedule delay; loss of corporate reputation	5	3	3	3				15	CIA: Transportation management plan with municipalities, OPG funded		1	1	1	2	1			2				
			Inadequate management of tourism impacts	schedule delay; loss of corporate reputation	5	3	4	4				20	CIA: Agreement with Niagara Falls and Niagara on the Lake to provide tourism management, OPG funded		1	1	1	2				2				
			Lack of coordination between project emergency services and municipal emergency services	Impacts on municipal emergency services, schedule delay; loss of corporate reputation; failure to meet legal requirement	5	3	3	4		3		20	CIA: Agreement with municipalities to coordinate emergency services, compensation to be negotiated		1	1	1	2		2		2				
			Lack of agreement with Niagara Falls on water supply / sewage disposal	schedule delay; loss of corporate reputation	5	3	3	4				20	CIA: agreement with municipalities on water supply /sewage disposal, OPG funded		1	1	1	2		2		2				
			No encouragement of local jobs/supply opps in contract to give local economic benefit	loss of corporate reputation	5		2	3				15	CIA: OPG agrees to use best efforts to encourage local economic benefits e.g. provide information locally re job and supply opportunities		1		1	2				2				
			Citizen objections during construction e.g to relocation of local infrastructure, excessive dust or noise, other unforeseen issues	schedule delay; loss of corporate reputation	5	2	2	4	1			20	CIA, especially Community Liaison Committee, complaint handling procedures e.g. 1-800 number, stressed in Project Communications Plan.	see section 7 re environmental issues like noise & dust	1	2	2	2				2		1-Jun-05		
2.2		Adverse public reaction to Thorold - Caledonia transmission project starting May 2005	Confusion between OPG project and nearby Hydro One project	loss of corporate reputation	2		1	2				4	Project Communications Plan to include public clarification of differences between OPG project and Hydro One project		1		1	2				2		May-05		

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
3	**Planning and Concepts**																									
3.1		Unprogrammed extension to procurement Bid phase	Low bid contractor fails to comply with Contract requirements for detailed design and/or construction	project delay caused by (successful) negotiations	4		2					8	Ability to negotiate before bid acceptance 4 pre-qualified contractor teams		3		2					6				
			All contractors fail to comply with Contract requirements for detailed design and/or construction	project delay caused by (successful) negotiations	3		3					9	Ability to negotiate before bid acceptance		2		3					6				
			All contractors fail to comply with Contract requirements for detailed design and/or construction	unsuccessful negotiations leading to a requirement for overhaul of RFP documents	2		5	5				10	Contractor input to bid document criteria		1		4	4				4				
3.2		Contract documents insufficiently detailed and imprecise	Deficiencies in QC by Owner and Engineer	Inadequate communication of design requirements to Contractor	2	3	4					8	owner's rep. QA program Contractor input Ability to negotiate with Contractors after bid		1	3	4					4				
			Deficiencies in GBR (i.e. something not covered in GBR)	Increased bid prices (contingency)	3	4	4					12	owner's rep. QA program Contractor input Three stage GBR development process		2	4	4					8	Review of Contractor's baselines in GBR-B			
			Deficiencies in GBR (i.e. something not covered in GBR)	Major Type 2 DSC claims	3	4	4					12	owner's rep. QA program Contractor input Three stage GBR development process		2	4	4					8	Review of Contractor's baselines in GBR-B			
			Deficiencies in GBR (i.e. something not covered in GBR)	Minor Type 2 DSC claims	4	3	3					12	owner's rep. QA program Contractor input Three stage GBR development process		3	3	3					9	Review of Contractor's baselines in GBR-B			
			Deficiencies in concept Design	inadequate and/or inappropriate design criteria requiring issuance of multiple change orders	2	3	2					6	owner's rep. QA program Contractor input Ability to negotiate with Contractors after bid		2	3	2					6				
3.3		Performance of tunnel lining does not satisfy design requirements	No/ limited experience with tunnelling in swelling shales	Serviceability failure of tunnel structure after extended time period	2	5		5				10	Accounting for swelling is part of mandatory requirements for design; and design review		1	5		5				5				
3.4		Innovation in use of construction materials	Lack of/ limited precedent experience with construction materials (e.g. in the use of compressible grout for contact grouting of the tunnel lining)	Lining does not perform as required	2	3	5	5				10	Alternatives available to not use innovative materials		2	3	5	5				10	Review of Bids for innovation			
3.5		Selected conceptual design is suboptimal	upper alignment better than deep alignment (was selected based on available technology at the time of the EA)	cost and time	3	3	3					9			3	3	3					9	Feasibilty proposal to be submitted to MOE Detailed risk assessment of upper versus lower alignment - subject to MOE response	Jan		

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
3.6		performance of project team is suboptimal	ill-defined roles and responsibilities	cost and schedule overruns	2	4	4					8	Addressed in Project Execution Plan		2	4	4					8	OPG Senior management to agree on PEP			
			poor communication amongst team members	cost and schedule overruns	2	4	4					8	Addressed in Project Execution Plan		2	4	4					8	Update PEP			
			people with inappropriate skills for their positions	poor quality	1	3	3					3	Corporate Management controls	Measure individual performance	1	3	3					3				
			lack of team alignment	cost and schedule overruns; poor quality	2	4	4					8	team alignment initiative trining and workshops		2	4	4					8	continuation and extension of Team Alignment Initiative			
			poor communication between project team and Board	cost and schedule overruns	2		4					8	ongoing communication with major projects committee of OPG Board		2		3					6	OPG Senior management to agree PEP			
3.7		inadequate project processes and procedures	lack of clear procedures, scope and project execution document	cost, schedule and quality	2		3	3				6	Addressed in Project Execution Plan		2		3	3				6				
3.8		project processes and procedures improperly applied	lack of project management focus and direction	cost, schedule and quality	3		3	3				9	PM Controls	Monitor compliance with established processes and procedures	2		3	3				6				
			lack of buy-in from OPG organization - particularly with Senior members	cost, schedule and quality	2		3	3				6	PM Controls	Monitor compliance with established processes and	2		3	3				6				
			external political or stakeholder pressure	cost, schedule and quality	3		3	3				9			3		3	3				9	OPG Senior management aware of consequences of applied pressure			
3.9		external pressure on project configuration	political or third party pressures	cost, schedule and quality	2	4	4					8			2	4	4					8				

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4	**Financial/ Commercial/ Contractual and Procurement**																									
4.1		Insurance Premiums prohibitively high	Inadequate Risk Management process in place (i.e. not acceptable to insurer.)	Cost impact to project budget	3	4						12	insurance estimate already in place		1	4						4				
			Insurance market conditions / capacity	Cost impact to project budget	3	4						12	insurance estimate already in place		3	4						12				
4.2		inability to make insurance claim	insurance does not cover claim	Cost impact to project budget	2	4						8	gap analysis being carried out		1	4						4				
			failure to apply properly	Cost impact to project budget	2	4						8			1	4						4	assignment of responsibility to appropriate professional			
4.3		Inability to obtain sufficient size/ capacity of performance bond from Contractor	Contractor's surety does not accept terms of OPG contract	Cost impact to project budget	2	4						8	requesting proof of bond in RFP		1	4						4				
			Bond market conditions / capacity	Cost impact to project budget	2	4						8	requesting proof of bond in RFP		1	4						4				
4.4		Inability to collect from Bond if required	Dispute regarding Contractor default	Cost impact to project budget	1	4	5					5	Requested letter of credit as part of bond		1	4	5					5				
			insufficient performance bond amount	Cost impact to project budget	1	4	5					5			1	4	5					5				
4.5		Inability to obtain Board approval for project	inadequate project business case	Schedule delay + impact on corporate reputation (due to previous 2 cancellations)	3		3					9	Frequent review by Board's Major Project Committee		1		1					1				

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						Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					Financial	Project Schedule	Corporate Reputation	Regulatory/ Legal	Health and Safety	Environment					
4.6		Inability to control project cost to within approved budget	Project budget less than final cost	Project overruns	4	5						20	Budget updated to reflect latest estimates		4	5						20				
			ground conditions vary significantly from GBR	Project overruns, schedule delays	4	3	3					12	see sheet 6		2	3	3					6				
			owner triggers variations in scope of work	Project overruns, schedule delays	3	3	3					9	change control board established		1	3	3					3				
			change in law that affects cost or schedule	Project overruns, schedule delays	1	3	3					3			2	3	3					6				
			Force Majeure event occurs (other than labour dispute, which is covered in 6.7	Project overruns, schedule delays	1	5	5			5	5	5			1	5	5			5	5	5	contingency plans			
			unforeseen hazardous condition encountered at the site	Project overruns, schedule delays	2		4					8	site assessment along alignment		2		4					8				
			contractor successfully claims that OPG failed to disclose key pre-tender information	Project overruns, schedule delays	2	4						8	due diligence; will advise bidders of status of info		2	4						8				
			Inability to recover entire cost through regulated rates	Erosion of project business case during construction or operation	2		4					8	verbal commitment from government		1		4					4	Discussion with government once proposals received			
			Commodity prices change dramatically (e.g. steel price increase)	Higher than expected bid prices; claims during construction	4	3						12			2	3						6				not a risk after contractor award
			Macro-economic fluctuations, e.g. currency changes or	Price escalation during construction	4	3						12			2	3						6				not a risk after contractor award
4.7		Contractor defaults on the Contract	Reasons defined in Section 10.1 of Design-Build Agreement	Schedule Delay. Cost impact (including lost access to liquidated damages)	1		5					5	bonding		1		4					4				
			contractor chooses to default since cost of completing work exceeds payments remaining to be made plus withheld amounts. (i.e. Schedule of Values incorrect)	Schedule Delay. Cost impact (including lost access to liquidated damages)	2	4	5					10			1	4	5					5				
4.8		Inability to enforce liquidated damages clause for actual flow less than design criteria from flow test	Inappropriate gauging locations for flow test, or other reasons	Dispute over payment of liquidated damages	3	4						12	Test procedure designed to minimize potential for dispute		3	4						12	Implement appropriate flow monitoring and gauging arrangement			

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4.9		Long-term degradation of flow below design requirement at construction completion	Inadequate specification for long-term performance of tunnel to account for roughness buildup over time	loss of revenue due to flow reduction (e.g. from zebra mussel buildup on rough tunnel lining)	3	4						12	see sheet 6		3	4						12	Review and revise Contract Documents as appropriate			
4.10		Uncertainties with capital expenditure on maintenance of civil works over "design life" of tunnel	Inability to obtain warranty from Contractor for 90 year design life performance	impact to Capital Improvement Plan	1	5						5	quality control measures		1	5						5				
			Deformation of the lining in time (e.g., increased steps between concrete modules and change in	Loss of revenue due to increased losses in tunnel	3	4						12	Technical specs and quality control checks during construction to minimize the lining deformation		3	4						12				
			Durability and performance of proposed ~~of~~ construction materials in the pertaining ground conditions	impact to Capital Improvement Plan	2	5						10			2	5						10				
4.11		OPG Union dispute on outsourcing project work	Inadequate coordination and/or communication of project goals and objectives with unions	Schedule delay	3		3					9	Agreement reached with Unions for Phase 1		2		2					4	Ongoing discussions with Unions and eventual agreement for Phase 2.			
4.12		inability to enforce warranty or discharge lien	insufficient funds withheld for holdback and lien	financial impact	2	3						6	10% holdback; analysis to ensure that sufficient funds withheld		2	2						4				
			OPG not willing to shut down/dewater	financial impact	1	5						5			1	5						5				
4.13		Tax Assessment re PST exemption		financial impact																						
4.14		OPG sued for damages by unsuccessful bidder	claims for unfair process due to conflicts of interest, application, undisclosed criteria, etc.	Financial, corporate reputation	3	2						6	procedural fairness; honorarium		3	2						6				
4.15		Dispute Review Board interprets Agreement incorrectly		financial, schedule delays	3	3						9	procedure in place		2	3						6				
4.16		Delay in obtaining necessary property rights from third parties not subject to Expropriation Act	Re-evaluation of project by affected third parties	Schedule Delay	2	3		2				6	negotiations in place well before project		2	3		2				6				
4.17		uninsurable delay	insurance unavailable to cover delays in contract completion	Schedule Delay	3	4						12	liquidated damages in contract		1	4						4				

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5	**Logistics/ Access**																									
5.1		Site Access Problems	Existing seasonal traffic at intake location	delays to material deliveries and staff	4		2	2		2	1	8			4		2	2		2	1	8				
			Border traffic issues at the outlet structure and main construction site	delays to material deliveries and staff	4		2	2		2	1	8			4		2	2		2	1	8				
			work hour restrictions	Violation of permit conditions on truck traffic	3		1		3			9			3		1		3			9				
5.2		Late availability of TBM	Late Submittal/ ordering	schedule delay	2		4					8			2		4					8				
			Manufacturing problems	schedule delay	4		4					16			4		4					16				
			Shipping delays (due to weather)	schedule delay	2		3					6			2		3					6				
			Assembly and commissioning problems	schedule delay	4		3					12			4		3					12				
5.3		Interrupted power supply for site works	regional power outage	Lack of electrical power for lighting, ventilation, drainage pumps and TBM	2	2	1					4			2	2	1					4				
			site-based power outage	Lack of electrical power for lighting, ventilation, drainage pumps and TBM	2	1	1			3		6			2	1	1			3		6				
5.4		Segments not available in timely manner	Ineffective location of manufacturing plant	Schedule delay, possibly leading to stopping forward progress of TBM	2		2					4			2		2					4				no cost to OPG
			Plant breakdown (e.g. due to fire, etc.)	Schedule delay, possibly leading to stopping forward progress of TBM	2		4					8			2		4					8				
			Inadequate QC at Manufacturer	Schedule delay, possibly leading to stopping forward progress of TBM	2		3					6			2		3					6				
5.5.		Work impeded by adverse weather conditions	Storms, extreme temperature, winter weather	Schedule delay, primarily at inlet and outlet works	4		2					8			4		2					8				
		NOTE: Risks are mostly construction-related, so no mitigation yet in place																								

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6	**Detailed Design and Construction**																									
6.1		Flooding of the works during construction	breach of temporary structure at inlet works	inundation of tunnel inlet work area and shaft and reception area for TBM	2	3	3			4	1	8	pre-qualification of design professionals; design review; liquidated damages		2	1	3			4	1	8				costs borne by contractor
			breach of temporary structure at inlet works	inundation of tunnel inlet work area and shaft and entire tunnel after TBM breakthrough	2	3	3			5	2	10	pre-qualification of design professionals; design review; liquidated damages		2	1	3			5	2	10				costs borne by contractor
			breach at outlet works	inundation of tunnel outlet work, including mucking operation and active mining tunnel portal, including inundation of tunnel excavation and TBM	1	5	4			5	1	5	pre-qualification of design professionals; design review; liquidated damages		1	1	4			5	1	5				
6.2		Tunnel collapse	Engineering error or omission (inadequate or inappropriate design)	Lining overstressing and failure; legal proceedings against designer	2	2	5	3		4	2	10	pre-qualification of design professionals; designer's QA process; design review by owner; liquidated damages		1	2	5	3		4	2	5				
			Unforeseen ground conditions	Submittal of DSC claim - legal proceedings against owner; lining overstressing and failure	1	4	5	3		4	2	5	GBR-A in place with process of review of assumptions for final Baseline Report		1	4	5	3		4	2	5				
			Inadequate Contractor workmanship	Lining overstressing and failure	3	4	4					12	full time oversight by owner's representative on site; prequalification of contractors		2	3	4					8				
6.3		TBM forward progress impeded	TBM breakdown	Significant project delay to restore TBM progress	3		4	2				12	maintenance requirements specified for TBM while owned by the Owner during tunneling		3		4	2				12				

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6.4		Encountering gas in higher concentrations than anticipated.	Naturally occuring gas in rock formations - higher concentration than currently anticipated	Increased ventilation of all tunnel equipment to meet appropriate regulatory requirements	3	3	4	2		4		12	Contract requires: Monitoring of gas levels All tunneling equipment shall be flameproof Capacity for increased ventilation	Monitoring results from gas meters	3	1	1	1		1	1	3				
				Increased ventilation and flameproofing of all tunnel equipment to meet appropriate regulatory requirements	1	3	4	2		4	2	4	Contract requires: Monitoring of gas levels All tunneling equipment shall be flameproof Capacity for increased ventilation	Monitoring results from gas meters	1	3	4	2		4	2	4				
		Encountering Ground Conditions more adverse than advertised in Contract	Rock Strength higher than anticipated	Submittal of DSC claim - legal proceedings against owner;	3		4					12			3		4					12	GBR B and C makes sure that all parties agree baselines			
			Rock abrasivity higher than anticipated	Submittal of DSC claim - legal proceedings against owner;	3		3					9			3		3					9	GBR B and C makes sure that all parties agree baselines			
			High inflows at tunnel heading above Queenston Shale (e.g. intense fracturing in bedrock)	Submittal of DSC claim - legal proceedings against owner;	3	3	2			2		9	pre-qualification of design professionals; design review; liquidated damages		3	3	2			2		9	add requirement for probing ahead			
			Encountering an unexpected fault zone	Submittal of DSC claim - legal proceedings against owner;	2		4					8			2		4					8	Examine records from existing tunnel construction			
			Encountering BTEX in tunnel in higher than advertised concentrations	Submittal of DSC claim - legal proceedings against owner;	2		2			3		6			2		2			3	4	8	Examine records from existing tunnel construction			
			slabbing overbreak is higher than expected	Submittal of DSC claim - legal proceedings against owner;	3	3	4			4		12			3	3	4			4		12				
			unexpectedly high salinity content of groundwater into tunnel heading	corrosion of TBM or rolling stock - DSC Claim	4	3	4				3	16	full time inspector in tunnel		4	3	4				3	16				
			Deformation to surface structures due to time dependent deformations	Submittal of DSC claim - legal proceedings against owner;	3	3		3				9			3	3		3				9				
			Unexpectedly high degree of swelling of Queenston Shale	Lining integrity impacted - Submittal of DSC claim	4	5		4				20			4	5		4				20	Review of design			
6.5		Ice damage to temporary works at inlet structure	Reduced cross section in intake area	inundation of tunnel inlet work area and shaft and reception area for TBM	3	3	3			4	1	12	modifications to inlet structure to increase flow (move hockey stick over)		1	3	3			4	1	4			OPG	
			Reduced cross section in intake area	inundation of tunnel inlet work area and shaft and entire tunnel after TBM breakthrough	3	3	3			5	2	15	modifications to inlet structure to increase flow (move hockey stick over)		1	3	3			5	2	5			OPG	
6.6		Ice blockage of other OPG tunnel inlet structures	ice behaviour resulting from alteration to intake configuration difficult to forecast	change in hydraulic regime between hockey stick and shoreline affecting operations of existing tunnels by potentially reducing flow	2	4						8	modifications to inlet structure to increase flow (move hockey stick over)		1	4						4				
6.7		Contractor labour relations	Unacceptable pay and conditions	Schedule delay	1		2					2			1		2					2				

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6.8		loss of cross-sectional area in canal	construction debris - primarily due to blasting	loss of revenue and schedule delay for project completion carrying out remediation	3	2						6	contractual requirement to reintate to pre-construction conditions		3	2						6				
6.9		loss of cross sectional area in canal near PGS dike	sediment transport from tunnel portal activities	environmental damage and transport of fines downstream; potential damage to power station turbines and other machinery	1	3					2	3	contractual requirement to reintate to pre-construction conditions		1	3					2	3				
6.10		instability of PGS dike	blasting in general area of PGS outlet dike	inundation of downstream work zone and surrounding area	1	5	4	4		5	4	5	design criteria for blast design		1	5	4	4		5	4	5	strict design criteria for dike analysis; blast vibration monitoring at dike			
			blasting in general area of PGS outlet dike	overtopping of Beck 1 and/or Beck 2 powerplants	1	5	4	4		5	4	5	design criteria for blast design		1	5	4	4		5	4	5	strict design criteria for dike analysis; blast vibration monitoring at dike			
			original design/ construction errors in design of dike	inundation of downstream work zone and surrounding area	1	5	4	4		5	4	5	design criteria for blast design		1	5	4	4		5	4	5	strict design criteria for dike analysis; blast vibration monitoring at dike			
			original design/ construction errors in design of dike	overtopping of Beck 1 and/or Beck 2 powerplants	1	5	4	4		5	4	5	design criteria for blast design		1	5	4	4		5	4	5	strict design criteria for dike analysis; blast vibration monitoring at dike			
6.11		project design criteria not met	contractor non-compliance		3	5		4				15	pre-qualification of design professionals; design review; liquidated damages		2	2		4				8				
			failure of tunnel lining system		3	5		5				15	pre-qualification of design professionals; design review; liquidated damages		2	2		5				10				
			failure to meet guaranteed flow rate		3	5		3				15	pre-qualification of design professionals; design review; liquidated damages		2	2		3				6				
			no contractor submits conforming bid (90 year life span)		3	5	5	4				15	pre-qualification of design professionals; design review; liquidated damages		2	5	5	4				10				
6.12		instability of stockpile	inadequate engineering design of slope stability	debris in canal	2	4	4	4		2	3	8	pre-qualification of design professionals; design review; liquidated damages		2	2	4	4		2	3	8	review stability of canals			
6.13		instability of stockpile foundation	inadequate engineering design of foundation	debris in canal and instability of canal structure when cleaning	2	5	4	4		2	3	10	pre-qualification of design professionals; design review; liquidated damages		2	2	4	4		2	3	8	review stability of canals			
6.14		salt water damage	leaching from stockpile	non-compliance with environmental regs	2				3			6	documentation in RFP documents warning of potential and instructing contractor to act accordingly		2				3			6				
6.15		flyrock damaging transmission lines	blasting of plug	loss of Beck 2 revenue while lines repaired	2	2		4		3		8	requirement for blasting mat; review of contractor's blasting plan; liquidated damages		1	2		4		3		4				
6.16		design of major component not complete before its construction commences	poor scheduling by design/build team	temporary works insufficient size to accommodate permanent works	1	5	4					5	liquidated damages		1	2	4					4				
6.17		rocks inside tunnel	rock transport along bottom of river entering intake	loss of long term tunnel performance	4	2						8	rock trap at inlet works	rock trap inspection reports	1	2						2				
			rocks and sediment floating into tunnel encased in ice	loss of long term tunnel performance	5	2						10			5	2						10				

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7	**Environmental**																									
7.1		Excavated material is more contaminated than expected	Unexpected subsurface contamination (natural or anthropogenic)	Increased materials handling and disposal costs	2	4	3			2	1	8	see section 1		2	4	3			2	1	8				
7.2		High levels or additional groundwater contamination encountered during excavation dewatering	Unexpected groundwater contamination	Increased cost to handle/treat/discharge water	2	2	2			2	1	4			2	2	2			2	1	4				
7.3		Tunnel Dewatering activities significantly alter groundwater levels or flow patterns impacting area users	Effects of dewatering activities on groundwater flow regime under estimated	Mitigation costs, reputation, regulatory enforcement	2	2		2	2	1	3	6	contract terms and conditions		2	2		2	2	1	3	6				
7.4		Threat to habitat and population of dusky salamander	loss of seepage that creates habitat due to construction	non-compliance with the Ontario Endangered Species Act	1	2		1	4		4	4	discussions with MNR		1	2		1	4		4	4				
7.5		Dewatering activities significantly impact surface water levels, water quality or sedimentation	Effects of dewatering activities on surface water flow regime under estimated	Mitigation costs, reputation, regulatory enforcement	3		2	2	2	1	2	6	see section 1		3		2	2	2	1	2	6				
7.6		Dewatering shaft and/or tunnel create route for cross-contamination	Inadequate design and/or construction	Mitigation costs, third party claims	1	2	2	2	2	2	2	2	cross reference to 1.1		1	2	2	2	2	2	2	2				
7.7		Contaminant release to environment	Accident	High cleanup costs Damage to Corporate reputation, regulatory enforcement	4	1	1	2	2	2	2	8	terms and conditions of contract; site monitoring		3	1	1	2	2	2	2	6				
7.8		Project operations create significant loss of fish habitat or impact water quality in Welland River	Effects on Welland River underestimated	Mitigation cost, corporate reputation, third party claims	1	3	2	4	4	1	4	4	see section 1.1		1	3	2	4	4	1	4	4				
7.9		Dust levels exceed allowable concentrations	Inadequate control measures	schedule delays, regulatory enforcement	4			2	2	2	1	8	contract requirement to keep dust down		2			2	2	2	1	4				
7.10		Exceeding noise or vibration pollution limits	construction activities	schedule delays, regulatory enforcement	4			2	2	2	1	8	contract requirement to keep noise levels down		2			2	2	2	1	4				
7.11		Effects estimated in EA are not accurate, monitoring/compliance plans filed with regulatory authorities not complied with or not accurate	inaccurate information	mitigation costs, regulatory enforcement	2	1			2			4	adherence with Compliance/Monitoring Plan; adherence with Notification of Minor Amendment Plan		1	1			1			1				

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8	**Safety and Security**																									
8.1		Threat of terrorist attack	Disgruntled employee/ member of public	Disturbance of local environment, schedule, cost and H&S implications	4	1	1					4			4	1	1					4				
8.2		Terrorist attack	Visible location of project near international border and world-famous tourist attraction	destruction of site leading to loss of life or multiple lives	1	5	5	5		5	5	5			1	5	5	5		5	5	5				
8.3		Vandalism and/or sabotage	Disgruntled employee/ member of public	Damage to equipment, property and delay to schedule	3		2			3	1	9	Ongoing security control		2		2			3	1	6				
8.4		Significant fire during construction	hot works and/or electrical work and/or naked flames in tunnel in a potentially gassy environment	minor injury to loss of life or multiple lives	2		4			3	1	8	Contractor's H&S plan to be reviewed by H&S professional		1		4			3	1	4				
8.5		Serious construction accident	Use of explosives	Multiple major injuries	2		2	3		4	1	8	Contractor's H&S plan to be reviewed by H&S professional		1		2	3		4	1	4				
			Electrical contact	Multiple major injuries	3		2	3		4		12	Contractor's H&S plan to be reviewed by H&S professional		2		2	3		4		8				
			falls	Multiple major injuries	4		2	3		4		16	Contractor's H&S plan to be reviewed by H&S professional		3		2	3		4		12				
			crushing by equipment	Multiple major injuries	4		2	3		4		16	Contractor's H&S plan to be reviewed by H&S professional		3		2	3		4		12				
			inadequate ventilation	Multiple major injuries	2		2	3		4		8	Contractor's H&S plan to be reviewed by H&S professional		1		2	3		4		4				
			train accident	Multiple major injuries	3		2	3		4	1	12	Contractor's H&S plan to be reviewed by H&S professional		1		2	3		4	1	4				
			confined space working	Multiple major injuries	2		2	3		4		8	Contractor's H&S plan to be reviewed by H&S professional		1		2	3		4		4				
			Collapse of temporary work	Multiple major injuries	2		2	3		4		8	Contractor's H&S plan to be reviewed by H&S professional		1		2	3		4		4				
			Drowning of construction personnel	Fatality	3		2	3		4		12	Contractor's H&S plan to be reviewed by H&S professional		2		2	3		4		8				
8.6		OPG responsible for safety as "Constructor"	Directing Contractor in management of safety	increased legal and safety liability for OPG	3	1	2		3	3		9	Clarified OPG & Owner's Representative's role re: Safety		2		1		1	1		2				
8.7		OPG found negligent in duties as owner	insufficient monitoring of Contractor's safety program	Fines by MOL	3	1	2	3	3	3		9	Clarified OPG & Owner's Representative's role re: Safety		2		1		1	1		2				
8.8		Vehicle collision involving third party(ies)	Construction traffic	major injury	3			2		4		12	Transporation management plan in contract		2			2		4		8				

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8.9		Injury of third parties due to construction activities	fencing or other safety issue	major injury	2			3		4		8	Standard site control measures plus contract requirements		1			3		4		4				
8.10		Third party accident, e.g. drowning	Breach of site security and/or fencing by third parties	Fatality	3			3		4		12	Site control;bi-annual assessment of site security		2			3		4		8				
8.11		Theft of equipment and/or materials	Breach of site security and/or fencing by third parties	financial losses	3	1						3			3	1						3				
8.12		Vehicle collision in tunnel near outlet structure	Steep tunnel grade (11%)	Safety impacts	4		2	3		4		16	Contractor's H&S plan to be reviewed by H&S professional		3	1	2		3	3		9	contractor to have plan in place specifically addressing this hazard			
8.13		Vehicle collision in tunnel near inlet structure	Steep tunnel grade (11%)	Safety impacts	4		2	3		4		16	Contractor's H&S plan to be reviewed by H&S professional		3		2	3		4		12	contractor to have plan in place specifically addressing this hazard			
8.14		workplace health problems	presence of toxic substances during excavation	Safety impacts	4		2	3		4		16	Contractor's H&S plan to be reviewed by H&S professional		2		2	3		4		8	contractor to have plan in place specifically addressing this hazard			