

AMEC Earth & Environmental
a division of AMEC Americas Limited
2227 Douglas Road, Burnaby, BC
Canada V5C 5A9
Tel +1 (604) 294-3811
Fax +1 (604) 294-4664
www.amec.com



DRAFT

DAM SAFETY REVIEW

**Mount Polley Mine
Likely, British Columbia**



Submitted to:

**Imperial Metals Corporation
200 – 580 Hornby Street
Vancouver, BC**

Submitted by:

**AMEC Earth & Environmental Limited
Burnaby, BC**

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SUMMARY

A Dam Safety Review (DSR) has been carried out for the tailings storage facility (TSF) at the Mount Polley Mine in British Columbia. Though the mine has had a consistent dam safety inspection program and two independent reviews of the facility, this was an initial formal DSR for the mine which recently restarted operations after a hiatus of several years of less favourable economic conditions.

The DSR was carried out in compliance with tailings dam specific dam safety classification guidelines (Ontario Dam Safety Draft Guidelines) though consistency with the Canadian Dam Safety Guidelines (CDA, 1999) and British Columbia Dam Safety guidelines was an evaluation requirement. The evaluation is also considered compliant with the provisions for dam inspections from the Mining Association of Canada (MAC) Guide to the Management of Tailings Facilities (MAC, 1998).

In general, the three embankments that impound the Mount Polley tailings are well-designed and well-constructed entities from a dam safety perspective. Each of the three dams has demonstrated similar good performance behaviour with little indication of potential concerns in the future provided the design, continuance of past construction practices, and inspection procedures remain in place. There are some operational issues that could be addressed in a more proactive fashion to optimize both the operating condition of the TSF as well as facilitate a more successful facility closure consistent with stated closure objectives.

The DSR addressed the key elements required for such a review of a tailings embankment dam(s). From the results of the DSR, summary comments include:

- The overall impoundment is formed by the South, Main and Perimeter embankment dams that form a contiguous crest and toe footprint. The embankments are robust in terms of mass, material and, to date, monitored performance. No safety issues of concern have been noted in the comprehensive documentation available for the facility.
- The embankment cross-section is relatively complex but a review of documented records and observations of the construction controls made on-site during this DSR indicate that this has not caused any concern to date in the construction of sound dam sections that meet design objectives.
- The reliance on constructed drainage measures post closure is unclear in the documentation reviewed and should be clearly stated in all future dam safety documentation (inspections and reviews).
- Dam surveillance and operations protocols appear to have been followed appropriately in comparison to original design recommendations.

- Monitored results are evaluated on a “plane by plane” basis (i.e. a series of two-dimensional dam sections) and overall trends in terms of seepage and/or drainage efficacy are not being tracked (or at least reported in that fashion). A three-dimensional pore pressure profile for the facility should be the basis of reporting piezometric measurements.
- The dam designer is being appropriately engaged in the ongoing construction and operational planning for the TSF.
- Operating criteria for pond and beach management are presently at odds with optimal dam seepage performance and stated closure objectives, with the latter item being the issue of greatest concern.
- The amount of wave induced freeboard being allowed for is likely excessive by at least a factor of two.
- As the facility has no operating spillway, the selection of a 24-hour probable maximum precipitation event may not be appropriately conservative (even with the suggested hazard classification noted below).
- The lack of determination of the nature of potential preshearing in the glaciolacustrine foundation leads to uncertainty in terms of present and post closure stability condition and, commensurately, uncertainty for the need, or lack thereof, of the closure toe berm presently in the mine’s plans. This issue also impacts certainty on consequence classification.
- The recommended consequence classification ratings from this DSR were based upon their highest incremental consequence, which was deemed to be environmental impact in all cases (with the tacit assumption issues related to potential brittle or pre-sheared foundation units can be shown to be non-existent in the near future). Potential threats to public safety or non-TSF infrastructure were both considered nominal. Owner’s costs were not included in assignment of the ratings. This recommended approach is subject to owner approval.
- The dams require continued annual dam safety inspections and, given the excellent manner with which these have been completed to date, and in interests of continuity, it is recommended that the original designer continue in this function. Assuming a continuance of operations, the next DSR should be carried out not later than 2011 or during detailed closure design, whichever is earlier.

In general, between the programs in place, the expertise of the site personnel tasked with dam safety and the inclusion of the original designer of the facility throughout the operating life of the TSF, the Mount Polley TSF is adhering to an excellent dam safety program.

The mine has a recent and thorough Operation, Maintenance and Surveillance (OMS) Manual for the TSF. This OMS Manual, which was found to adhere well to the Mining Association

Guidelines (MAC, 2004), should be followed explicitly in terms of operational practices (including development and maintenance of tailings beaches) and reviewed during each annual DSI and updated as required. The Mount Polley OMS clearly states the following is explicitly required from a DSR (and the required information deduced from this review is also presented):

- *The consequences classification of the dam* – The Mount Polley Embankment Dams all have a **LOW** consequence classification with the assumption that owner's costs are not to be included. This classification is at odds with that previously adopted for the dams; the previous classification being considered conservative. One uncertainty with the classification assignment is whether the foundation conditions can be "signed off" as not having a potential pre-sheared and/or brittle condition.
- *The adequacy of past annual inspection practice, the annual inspection recommendations, and their implementation* – The annual inspections to date have been thorough. There are minor upgrade suggestions present in terms of data presentation (e.g. piezometer information) but these reports fully meet the expectation of such documentation for similar facilities.
- *The Operation and Maintenance Manual* – The 2006 Mount Polley OMS for the TSF is, as noted above, thorough and deemed appropriate for the site provided regular updates are completed and closure objectives are reflected by firm requirements of operating procedures.
- *Timing for the next regular DSR* – approximately 2011 as described above.

1.0 INTRODUCTION

This report presents the findings of a dam safety review (DSR) carried out for the tailings storage facility (TSF) at Imperial Metals Corporation's Mount Polley Mine near Likely, British Columbia.

AMEC Earth & Environmental Limited (AMEC) carried out the DSR at the request of Imperial Metals Corporation. The on-site review portion of the DSR was completed during 5 - 6 October, 2006, inclusive. Mine site personnel, in particular Messrs. Ron Martel and Matt Silbernagel, greatly assisted the DSR process. Complete access to relevant documentation and to physically inspect the Tailings Storage Facility (TSF) was provided. As the Environmental Superintendent, Mr. Martel also coordinated the overall DSR on behalf of Imperial Metals. The AMEC DSR engineer was Dr. Michael Davies from AMEC's Burnaby, British Columbia office. Dr. Davies is an experienced tailings dam design engineer who has no previous involvement in the Mount Polly project, and is registered as both a Professional Engineer and Professional Geoscientist in the Province of British Columbia (No. 16408), meeting the requirements to complete such a review.

The overall objective of the DSR was to evaluate the safety of the Mount Polley TSF from the perspective of the current and the future (expected) dam conditions and, if required, make recommendations as to the necessary means to maintain the dams in adequately safe conditions consistent with Imperial Metals Corporation's objectives, regulatory requirements and current engineering practice standards.

The Mount Polley TSF Operation, Maintenance and Surveillance (OMS) Manual, updated in 2006, includes the mine's own perspective on the DSR process as follows:

The principle objective of a Dam Safety review (DSR) is to ascertain that a dam has an adequate margin of safety, based on the current engineering practice and updated design input data. A DSR may also be carried out to address a specific problem.

A qualified engineer will be responsible for conducting each DSR at the Tailings Storage Facility. The engineer conducting the DSR must be qualified to conduct safety evaluations and be familiar with the designs and other site-specific conditions and requirements pertaining to operations of the impoundment and associated facilities; but ideally should not have been involved in the design, construction or operation of the TSF.

Routine DSR's at the TSF will be carried out every 5 years but this scheduling requirement should be confirmed or revised at the time of each annual inspection. The next DSR for the TSF is scheduled for 2006.

A detailed scope of work for each DSR will be defined by the engineer prior to conducting the review, and be consistent with current engineering practice at the time it is conducted. Each DSR will evaluate the safety of the TSF and incorporate a detailed review of the following:

- *The consequences classification of the dam;*
- *The adequacy of past annual inspection practice, the annual inspection recommendations, and their implementation;*
- *The Operation and Maintenance Manual;*
- *Timing for the next regular DSR.*

Each DSR report should include conclusions and, if necessary, recommendations pertaining to the safety of the TSF. Copies of the DSR will be sent to the Environmental Superintendent and the Ministry of Energy and Mines for review. Similar to the annual inspection report, an action plan should be prepared by the Mill Superintendent to address the DSR recommendations. A copy of each report will be sent to the Ministry of Energy and Mines and will also be available at the site and at the office of the Design Engineer.

This description embodies the key aspect for any DSR and includes Mount Polley's site specific considerations. The description is also consistent with regulatory guidance literature. Summarizing the combined language from the Canadian Dam Association (CDA) Guidelines (CDA, 1999), the British Columbia Dam Safety Regulations (BCDS) (2000), and the draft Ontario Dam Safety (ODS) Guidelines (1999), the objectives and scope of a DSR can be defined as follows:

The DSR includes a review of the design, operation, maintenance, surveillance and emergency plan, to determine if they are safe in all respects, and, if they are not, to determine required safety improvements. A DSR is a systematic evaluation of the safety of a dam, by means of comprehensive inspection of the structures, assessment of performance, and review of the original design and construction records to ensure that they meet the current criteria. Special attention should be given to those areas of design and performance having known or suspected weakness or which are crucial to dam safety. The level of detail required for a DSR should be commensurate with the importance, design conservatism and complexity of the structure, as well as with the consequences of failure.

The ODS Guidelines are noted only inasmuch as they remain the only Canadian regulatory published set of dam safety criteria that implicitly addresses the nature of actual concerns for tailings dams versus other types of dams. Specifically, the ODS Guidelines include environmental issues in a manner consistent with the issues that tailings impoundments bring to both owners of these facilities and their regulators. The CDA and BCDS approaches include environmental considerations, but not from a specific tailings dam perspective.

The Dam Safety Review process can vary in terms of approach and reporting style as long as three fundamental components have been adequately addressed:

1. The dam(s) are appropriately evaluated in terms of a thorough visual inspection, a review of salient documentation and a review of any relevant monitoring information (e.g. piezometers) as they relate to the safety of the dam(s).

2. Potential failure modes for the dam(s) are recognized and tested against the available information to determine what, if any, of the candidate failure modes may be possible given the as-evaluated state of the dam(s).
3. The dam(s) is provided a classification in terms of its potential for:
 - Environmental Impact(s)
 - Economic Losses
 - Loss of Life

This document is provided to summarize the work completed to meet the above fundamental requirements.

2.0 BACKGROUND

2.1 General

The Mount Polley mine commenced production on 13 June 1997. The mine operated until October 2001 when a decision was made to cease operating during a low point in the metal market price cycle. The mine was on care and maintenance status from October 2001 to February 2005 when it was restarted in a more favourable economic climate.

Ore is crushed and processed by selective flotation to produce a copper-gold concentrate. The mill throughput rate is approximately 18,500 tonnes per day (about 6.8 million tonnes per year). Tailings are slurried and delivered into the TSF located on the south area of the Mine property. The tailings are impounded within three contiguous dams:

1. South Embankment
2. Main Embankment
3. Perimeter Embankment

These embankment dams are part of the overall TSF. The embankments have been raised by the “modified centerline” method of construction and have a consistent cross-section with several zones (using current site nomenclature) as follows:

- Zone S: Core – fine-grained glacial till.
- Zone CS: Upstream shell – tailings (depending upon location of spigots, may be coarser or finer than average tailings grind).
- Zone B: Embankment shell – fine-grained glacial till.
- Zone F: Filter, drainage and chimney drain – processed sand and gravel.
- Zone T: Transition filter – well-graded fine-grained rockfill.
- Zone C: Downstream shell – rockfill.
- Zone U: Upstream shell – parameters vary depending on material availability.

The embankments also have the following overall features:

- A low permeability basin liner (natural and constructed) underlies the TSF. The basin liner has minimized seepage from the TSF and we understand that there have been no indications of adverse water quality reporting to groundwater monitoring wells.
- A foundation drain and pressure relief well system, located downstream of the Stage 1B Main Embankment. This system was constructed to reduce potential excess pore pressure in the foundation and to transfer groundwater and/or seepage to collection ponds.
- Seepage collection ponds downstream of the Main and Perimeter Embankments which were excavated in low permeability soils to store water collected from the embankment drains and from local runoff.
- Instrumentation in the tailings embankments and embankment foundations. Instrumentation includes vibrating wire piezometers, survey monuments, and inclinometers.
- Groundwater quality monitoring wells installed around the TSF.

As described in the project's design documentation, the embankments have been raised in stages. The most recent raise, Stage 5, was being constructed during the DSR site review period.

2.2 Relevant Documentation to DSR

A comprehensive set of design, as-built and annual inspection documents relevant to the tailings storage facility were made available for review. A list of these reports is provided in Appendix A. Included in this appended listing are commentary notes made during the review of these documents.

2.3 Existing Dam Safety Program

2.3.1 Dam Safety Inspections

There have been annual inspections each year of operation for the Mount Polley TSF. These inspections have all been documented (listed in Appendix A) and provide a summary record of the reporting period's construction activity, instrumentation readings and any other salient observations. Other than one year, all of the on-site component of the inspections have been completed by a registered professional engineer.

2.3.2 Dam Safety Review

This current DSR is the initial one for this facility. As described in Section 1, the mine is fully committed to the concept of DSRs as part of their overall dam safety program.

2.4 Water Balance

The water balance for the Mount Polley was updated by mine personnel prior to the DSR and we understand it has been reviewed by Knight Piésold. The water balance appeared to reflect site conditions. Based upon the balance, the TSF operates with a water budget surplus. Inflows from precipitation and surface runoff exceed losses from evaporation, tailings void retention and seepage losses. The TSF is required to have sufficient storage capacity for runoff from the 24-hour probable maximum precipitation (PMP). Given the lack of a spillway, perhaps this event is of too short a duration and a longer duration PMP should be used during operation (though there may be little change to the computed inflow volumes). We understand the 24-hour PMP volume is approximately 680,000 m³, which apparently is equivalent to an incremental rise in the tailings pond level of about 0.4 m. The freeboard design also incorporates an additional allowance of 1 meter for wave run-up. As noted elsewhere in this report, that value appears excessive given the combined wind loads and fetch geometry. A value of 50% or less would likely remain conservative. It is recommended that this run-up value be revisited by the designer of the TSF (along with the evaluation of a longer duration PMP which may counterbalance any gain from a reduced run-up requirement).

3.0 DAM SAFETY EVALUATION

3.1 General

The available records/information related to the original design and construction of the Mount Polley tailings embankment dams is thorough and meets current practice expectations. This record of original design and construction has been augmented, as shown in Appendix A, with documented ongoing inspections and construction monitoring by the original dam design team. This has created a current, and comprehensive, database for a DSR. Coupled with the site inspection of the facility, which included viewing Stage 5 (to elevation 951 metres) raise construction, sufficient information was provided for an effective DSR to proceed. Appendix B includes some sample photographs taken during the site review portion of the DSR.

The format of the DSR was chosen to, per Section 1, allow identification of any deficiencies in overall dam safety from a design, construction or operating perspective that could impart undue risk to the mine and/or overall corporation. To meet this objective, the 2006 DSR included a step-by-step evaluation of various dam safety issues as follows:

- Static Load, Hydrologic, Seismic and Other External Loads – The project setting does not offer extreme “loads” of any kind beyond that anticipated for like facilities. The site seismicity is relatively low with the 10% chance of exceedance in 50 year peak ground acceleration being less than 0.05g coming from an M=6.5 event. The annual annual precipitation is approximately 0.75 metres with just under 0.5 metres of average evaporative removal from open water surfaces. The 24 hour probable maximum precipitation is just over 0.2 metres. None of these, or any other, external loads could be considered unusual or “extreme”.
- Environmental Conditions – The tailings facility is located in a relatively remote part of British Columbia. There are not any apparent unique aspects of the environment where the facility is situated included no indication of a fishery of critical importance in the receiving waters to the site drainage area. Consultation with environmental regulators and regional stakeholders is not part of a DSR scope though, based upon judgment and knowledge of the region, the project setting is likely in as “logical” a location as is possible for a tailings impoundment at a mine in British Columbia.
- Engineering Analyses and Design – The designers of the embankments, Knight Piésold, have remained the engineers of record and continue to complete the annual DSIs. As such, there has been consistency in the analyses and design from project inception through to the time of the DSR. There are some notable exceptions with the manner with which some of the analyses were completed but none of these raise dam safety concerns.
- Dam Structures – The three embankment dams all appeared in a good state of repair at the time of the DSR. There was no visual evidence of significant past issues (nor any documented). The lack of a tailings beach and inconsistency with beach profile and the closure concept for the TSF are notable but do not present immediate dam safety

concerns. The lack of a beach profile consistent with closure objectives would address the lack of beach against the embankments and, for a number of reasons, should be addressed as soon as possible by the mine to avoid increased costs in this regard in the future. Again, however, dam safety is not a driving reason to address this lack of beach/positive beach profile.

- Discharge Facilities – Currently the TSF has discharge via (in decreasing importance):
 - pump back from the fixed barge pumphouse on the west side (native ground) of the impoundment
 - seepage, largely through the drainage collection system
 - evaporation

There is currently no surface discharge facility (spillway) and one will be required for closure (and is the prime reason why the current beaching practices should be modified to allow effective placement of a spillway). At other similar facilities in British Columbia, where there is no operating spillway, a longer duration PMF event than the 24 hour event has been used with the 24 hour duration being adopted for closure when there will be an appropriate spillway. This approach is recommended for the Mount Polley TSF.

- Dam Instrumentation – there are a number of instrumentation “planes” (8 in total, planes A to H) for the TSF embankments. These planes are largely populated with vibrating wire piezometers. There is very little redundancy in the system and some of the piezometers lost should be replaced. A review of the piezometers data shows no overall concern (the core and drains appear to be functioning but, as described later in this report (Section 4), an alternative DSI presentation style is recommended (as are clear concern trigger levels). The inclinometers and survey monuments have not demonstrated any deformation(s) of concern.
- Upstream of Dams – no indicated potential factors to influence dam safety such as failure of another facility impacting the tailings area.
- Runoff Management System – no major issues though, per discharge facilities, will need to be addressed for TSF closure. The runoff largely ultimately reports to the seepage collection ponds.
- Downstream of Dams – nothing of concern noted. The two seepage collection ponds appeared in good condition.
- Past Performance and Failures of Dam – no noted failures had ever occurred with the Mount Polley TSF embankments.
- Review of Tailings Dam Operations Manual – the 2006 update appears thorough and appropriate for the nature of the facility. The plan needs to be appropriately updated for any changes in instrumentation or monitoring protocols that may arise as the construction raises proceed.

- Trigger for Additional Dam Inspections – in addition to the current annual inspection, there should be a visual inspection of the facility by a qualified (e.g. dam’s designer or their designate) engineer if the maximum design, or close to it, earthquake was to occur, or after any 24-hour rainfall storm event deemed to have been a 1 in 100 year, or lower statistical probability (i.e. greater return period). Any change in instrument reading into a “red” zone (see Section 4) that occurs without ready explanation should also trigger an additional inspection.

3.2 Potential Failure Modes

3.2.1 Potentially Applicable Modes

The general nature of the embankment dams described in Section 3.1 in terms of dam key safety issues shows that, at a summary level, there appears to be no obvious and/or significant dam safety issue. Nonetheless, to be complete, the DSR necessarily needs to review potential modes of failure specific to the embankment dams at the Mount Polley TSF.

Table 3.1 summarizes the potential physical failure modes deemed applicable to the Mount Polley Embankment Dams. Table 3.1 is a list of potential modes for facilities akin to the three contiguous embankment dams. Inclusion of a failure mode in Table 3.1 in no way implies that such a failure mode is a concern for these structures. The judged potential for issues listed in Table 3.1 is provided in Section 3.2.2.

Table 3.1 - Potential Failure Modes Applicable to Mount Polley Embankment Dams

Mode	Description
Slope Instability of Containment Structure	
Shear failure of the slope, including failure through the foundation due to self-weight of structure and elevated water levels in the containment structure	<p>Excessive loading at or near the crest or a weakness in the foundation or within the embankment can lead to a failure of the slope or failure through the foundation. Excessive loading can develop during construction or when raising the structure. The rising reservoir water level may lead to an excessive load and/or increased pore pressures, and consequently a dam failure.</p> <p>Weakness of the foundation soil or embankment dam material can develop through softening of the soil over time or an increase in water pressures.</p> <p>Rapid drawdown of a pond on the upstream side of the containment structure can result in slumping of the upstream slope, which, if large enough, might lead to an embankment failure (see drawdown below).</p>

Mode	Description
Sliding due to tailings and/or water load	Tailings and/or water on the upstream face of the embankment can exert a lateral force causing it to slide in the downstream direction. This is particularly true if there is a near-horizontal plane of weakness within the structure or foundation. In addition, water against the upstream slope can lead to elevated pore pressures and excessive seepage forces.
Slumping due to earthquake	When an earthquake occurs, it applies cyclical horizontal and vertical forces on a containment structure. The increased horizontal forces can reduce the stability of the embankment structures and result in deformations that could lead to overtopping and/or damage to the internal seepage control elements.
Bearing capacity failure of an embankment into tailings due to liquefaction of tailings (although only slight section for Modified Centreline Dykes)	Liquefaction of the tailings on the beach can occur if the tailings are loaded too quickly during construction. As fill is placed over the tailings, excess pore water pressures are generated that dissipate over time. If the rate of loading is faster than the dissipation of pore pressures, then liquefaction can occur and the tailings would lose a significant portion of their strength. This loss of tailings strength can have a direct impact on the stability of structures built on or directly adjacent to tailings, resulting in reduced factor of safety against a bearing capacity failure into the upstream beach foundation.
Slumping due to rapid drawdown	If the level of the pond is drawn down rapidly, then the upstream slope of the embankment dam could slump. A rapid drawdown event could occur if there is a sudden loss of pond contents.
Flooding	
Overtopping	Overtopping of the containment structures can occur, typically during an extreme flood event and diversions are lost and/or when a spillway becomes blocked (no spillway currently present at Mount Polley TSF). Waves that are generated at high reservoir levels may also lead to erosion of embankment crest; this can lead to progressive erosion and, ultimately, a dam breach.
Surface Erosion Leading to Uncontrolled Release of Tailings or Water	
Gullies in downstream shell due to overland runoff	Runoff resulting from rainfall and/or snowmelt can flow down the slopes of the embankments or abutment contacts and incise gullies in the shell of the structure. If the gullies are left unattended (i.e., not repaired), then the gullies can become large enough to trigger a slump by over-steepening portions of the slope locally. The local failures could trigger an overall failure of an embankment dam (dam breach).
Erosion of upstream slope and crest	If there is no tailings beach, wave action can cause erosion (e.g., benching and/or slope undercutting) on the upstream slope and crest of an embankment even under normal operating pond levels. If left unattended, the erosion could progress in the downstream direction or lead to an over-steepened upstream slope that could fail locally.

Mode	Description
Internal Erosion Leading to Uncontrolled Release of Tailings or Water	
Internal erosion (piping) through the containment structure	Seepage through an embankment under sufficient hydraulic gradient can mobilize material from within the structure and transport it downstream if there is no suitable filter zone to inhibit movement of solids. The removal of material will begin at the downstream face and continue in the upstream direction until a “pipe” or channel has formed through the embankment, which may lead to dam failure.
Internal erosion (piping) through the foundation	Seepage through the foundation of a containment structure can be complex with the seepage velocity varying in different soil and rock units and the contact between units that are variable and not filter graded. Piping in the foundation could lead to a loss of contents through the base of the facility, resulting in strength loss and pore pressure increase. If the piping occurs at the toe of an embankment, then this could undermine the toe, lead to local slumping of the toe area that could, in turn, result in a failure of the structure through slumping/sliding of the downstream face.
Internal erosion around pipes through the structures	Seepage can occur along the outside of pipes installed through containment structures (e.g., seepage collection pipes, culverts or decant pipes, active or abandoned). This can be a preferential seepage path because of poor bond or control of material placement along the pipe during construction and improper seepage control measures along the pipe (or the lack of such measures). Such seepage could result in internal erosion (piping) through the embankment similar to that described above.
Collapse of Pipes Through Structures	
Collapse of pipe	Pipes within and/or through embankments can deteriorate over time and collapse. Old and damaged pipes that have not been properly plugged and backfilled can result in the following: loss of dam fill into the pipe; loss of pond contents through the pipe; and/or development of a preferred seepage path along and through the pipe that could result in uncontrolled seepage through the embankment, and eventual failure of dam.

3.2.2 Mode Evaluation

Each of the potential failure modes listed in Table 3.1 were judged in terms are their potential to manifest themselves, individually or in combination, and create a dam safety issue for the Mount Polley TSF embankments. Following is an issue-by-issue discussion on the items from Table 3.1 in that same order.

Slope Stability

Foundation Conditions

As the embankments are massive zoned rockfill/till structures, the largest stability concern in terms of a downstream failure is for a foundation weakness mechanism to develop. The

foundation conditions at the Main Embankment consist of glacial till underlain by fluvial and glaciolacustrine silts (and clays?) up to 20 m thick. Information indicates that the glaciolacustrine materials can be overconsolidated. The foundation conditions at the Perimeter Embankment generally consist of glacial till that is generally in excess of 5 m thick. For the South Embankment, the foundations consist of a relatively thin, glacial till overlying bedrock. Knight Piésold present a number of reports that detail the foundation conditions (Appendix A).

While design documentation contains laboratory testwork on the foundation that indicates adequate shear strength to provide for foundation stability of the embankments, all of this testwork has apparently been by triaxial stress path. Direct/simple shear along potential pre-shears within the glaciolacustrine would be more relevant. We understand that recent samples of foundation material have been taken. These should be thoroughly evaluated for pre-shearing evidence. Such an examination would include picking the samples apart via a pocketknife in an attempt to find any pre-shearing indications. Where geologic conditions are such that there is a potential for pre-shearing, it is often considered prudent to assume pre-sheared features are present and then to proceed, via field and laboratory investigations, to prove that they are not. Any future testwork also needs to include direct shear along potential planes of weakness even if no evidence of pre-shearing exists, as concern would remain for highly brittle response (shear strength loss) in response even to minor straining. If this material is found to exhibit brittle response, then stability analyses considering reduced (or residual) shear strength conditions would be prudent.

In terms of foundation piezometric conditions prior to embankment construction, artesian pressures existed at the base of the Main Embankment. Pressure relief wells were installed to depressurize underlying glaciofluvial deposits. Monitoring has shown design objectives have been met to date.

Available Stability Assessments

The most recent design work for the Mount Polley TSF, the Stage 5 design documentation by Knight Piésold, includes a summary of stability work undertaken to evaluate the static and transient loading conditions for the Main and Perimeter embankments. Both upstream and downstream candidate failure planes were evaluated. Table 3.2 presents the summary from that design document.

From the analytical results summarized in Table 3.2, a few items are notable:

- The post-liquefied stability of the facility is shown to be “greater” than any other evaluated case. This is an analytical artifact only and is not representative of actual conditions under such loading. It is, however, agreed that there is not a liquefaction failure mode of concern that has a viable trigger at this TSF (e.g., even the tailings liquefy, it really would not matter to the overall embankment stability).
- The minimal increase in computed factor of safety for a 2H:1V geometry over a 1.4H:1V embankment for all cases analyzed is consistent with no plane of weakness in the foundation soils being assumed.

- Though not implying a plane of weakness, evaluating the potential ramifications for a subhorizontal presheared plane in the glaciolacustrine (or similar) soil would be prudent dam safety engineering.
- At the computed seismic factors of safety, essentially zero deformation of the embankments is indicated and at this minimal movement, disruption of drainage “plumbing” would be expected to occur. This is a key conclusion that impacts other potential failure modes (assuming the potential foundation weakness is, per the summarized analyses, not present).

Table 3.2 – Stage 5 Design Documentation Stability Summary¹

Stage 5 Embankment Section		Minimum Factor of Safety	
		Shell Zone Downstream Slope	
		1.4:1 (interim slope)	2:1 (final slope)
Static Stability			
Downstream	Main	1.5	1.7
	Perimeter	1.9	2.0
Upstream	Main	>2.0	>2.0
	Perimeter	>2.0	>2.0
Seismic Stability			
Downstream	Main	1.4	1.6
	Perimeter	1.7	1.8
Upstream	Main	>2.0	>2.0
	Perimeter	>2.0	>2.0
Post-Liquefaction Stability			
Downstream	Main	1.5	1.7
	Perimeter	1.9	2.0
Upstream	Main	>2.0	>2.0
	Perimeter	>2.0	>2.0

¹Adapted from Knight Piésold (2006)

Summary of Slope Stability Dam Safety Concerns

In terms of potential slope stability concerns relative to the modes of failure deemed possible for the embankment dams at the site, there are no real dam safety issues. The question about potential foundation pre-shears has not been, however, sufficiently dealt with in available documentation and having the designer sign off on this issue (e.g. that it is not an issue) is recommended. This sign off should include lack of evidence from a thorough evaluation of the core obtained from the 2006 foundation drilling.

Though not a strict dam safety issue, based upon the geologic model presented and stability analyses summarized, no substantive case for the closure toe berm could be located.

Assuming the rationale is gradual deterioration of the core/drainage measures and not an uncertainty in the foundation condition (e.g. that pre-shear item noted above), it is recommended future raise design reports include both an operating (e.g. current raise) and closure sections analyzed with the compromised core/drainage measures pore pressure regime in the embankments. These analyses will allow the case for the closure berm to be clearly demonstrated and judgment on placement timing, based upon monitored response, can be optimized for economic prudence.

Flooding

Assuming continued function and booster pump capacity of the pump barge during tailings deposition, given the location of the facility (limited upgradient catchment) and the relatively low peak and annual precipitation in comparison to minimum (without wave run up component) design criteria freeboard, flooding is judged a remote concern for dam overtopping at the Mount Polley TSF though it is possible that a more conservative duration for the PMP should be adopted for the operating period (while there is no spillway present). For mine closure, the spillway will need to be located and the impoundment configured such that runoff flow is directed from the impoundment surface to the spillway. This is a function of the site having a natural net positive water balance.

Surface Erosion

Although surface erosion is a concern for many closed facilities, it is a rare operating mine that has surface erosion as a viable embankment dam failure mode. This lack of recognition as a viable failure mode for operating mines is due simply to the slow process that surface erosion typically is (almost never a single event but many repetitions of erosive events) and the number of visual observations the embankment(s) will undergo from all the personnel present on an operating site. Moreover, the downstream embankment shells are ROM waste rock and would be highly resistant to any potential erosion. Downstream surface erosion failure modes are not considered a concern at the Mount Polley TSF for either the operating or closure period (the latter assuming a correctly located spillway is in place and the impoundment runoff drains to that spillway).

Internal Erosion

Internal erosion of earthfill embankments is likely the most catastrophic potential failure mode as it can develop undetected for years and, yet, when it occurs it is often rapid and can lead to complete embankment breach. Some of the most dramatic earthfill embankment dam failure case histories, many of them tailings dams, have had internal erosion as their primary failure mode.

The key component to the Mount Polley TSF embankments is the till core. This material is protected by filters that were designed and placed to prevent piping of fines from the till core due to seepage through the dam. The visually inspected filter material (Phase 5 raise) appeared consistent with design specifications.

The embankments do have a system of drainage measures that would be the most likely location for an internal erosion concern. For that reason, the nature of the system was reviewed and an understanding summarized herein. The embankment drainage measures in place assist in draining the tailings mass keeping lower heads in foundation soils, and generally keeping embankment pore pressures below threshold levels. The drainage systems include foundation drains, chimney drains, longitudinal drains, outlet drains, and upstream toe drains. All of the drains route to seepage collection sumps at the Main and Perimeter Embankments where the flow quantities and water quality are monitored. We understand that a sump was being developed at the South Embankment as part of the Stage 5 raise.

Of key relevance to internal erosion potential are the chimney drains. Chimney drains have been placed in the Main and Perimeter Embankment and such a drain is also being developed for the South Embankment. The chimney drains provide a redundant pore pressure control mechanism for the embankments and could potentially also act as a crack retardant downstream of the core zone. Monitored results demonstrate that the chimney drains, coupled with other drainage features, have resulted in a significant head drop across the embankment core in the Main and Perimeter Embankments.

Collapse of Pipes through the Structures

While there are drainage pipes within the footprint of the embankment, they are not considered a dam safety risk in terms of collapse. There is no major internal decant and so, in terms of pipe collapse, though there is a significant number of pipes in the embankment sections, collapse of any/all of these would not create a structural concern. The ramifications in terms of changes in pore pressures due to inoperative drains was described under slope stability (and appears to be part of the assumed closure condition to justify placement of a rockfill toe berm).

Overall

The review of potential failure modes for the Mount Polley TSF embankment dams suggests that there is no clear or present dam safety concern.

The minor items noted can be readily addressed by continued adherence to the dam safety program the mine has in place.

3.3 Consequence Classifications

3.3.1 Preliminary Rating

Consequence classifications are a valuable way to compare embankment dams and allow appropriate design criteria to be selected. All dam safety guidance literature, regulatory and otherwise, will note that design criteria (e.g. design earthquake) is a function of dam classification. Quite simply, in most cases the higher the consequence classification the more stringent the criteria that should be adopted for the facility.

A key requirement of the DSR is to assign a consequence classification to the embankment dam(s). The assignment of consequence classification allows a comparison between dams,

setting of surveillance requirements and determining design/operating criteria. What is often lost in the process is that the ranking is not an indication of the state of the dam but an indication of the hazard the dam represents should a concern arise. There may be negligible failure likelihood but an embankment dam can still have an elevated consequence rating.

Knight Piésold (2006), citing the Canadian Dam Association (CDA) guidelines and the British Columbia Dam Safety Regulation, proposed the following:

“The assessment indicates that the TSF has a “HIGH” hazard classification (or consequence category) based on the economic and social loss category. The classification for the life safety and environmental and cultural loss is “LOW”, as there is a low potential for multiple loss of life, the inundation area is typically undeveloped, and there is unlikely to be loss or significant deterioration of provincially or nationally important fish habitat. However, the ultimate TSF embankments will be up to 55 m high, and the estimated costs associated with repairing the damage, loss of service to the mine, and the potential economic impact on Imperial Metals, could exceed \$1,000,000, which places the TSF into the “HIGH” economic and social losses category under the British Columbia Dam Safety Regulation guidelines.”

As described in the following section of this DSR, the approach of including owner's costs in the assessment is not considered standard practice for mine tailings embankment dams.

3.3.2 2006 DSR Considerations

The first consideration in the selection of a consequence classification is what classification scheme to adopt? The Provinces of British Columbia and Ontario provide Dam Safety Guidelines (BC and ODS Guidelines). There are also the CDA guidelines, which may not be as appropriate for dams associated with mining activities, particularly tailings dams, as the current version explicitly exclude any environmental impacts that are key to the mining process in the consequence of classification. The ODS Guidelines make specific reference to tailings dams and have been used on many other similar DSR assignments as the basis for classifying the consequence of embankment dam failure. The selection of the ODS Guidelines was based upon both their completeness and better relevance to mine tailings facilities than, for example, the current CDA Guidelines. The BC Guidelines, which used the ODS publication as a guide, are also deemed acceptable for tailings embankment dams though the BC Guidelines do not specifically address the unique character of tailings dams. The Consequence Classification Categories according to the ODS and BC guidelines are summarized in Tables 3.3 and 3.4.

Table 3.3 – Ontario Dam Safety Consequence Classification Categories

Hazard Potential	Loss of Life	Economic and Social Losses	Environmental Losses
Very Low	Potential for loss of life: None	Damage to dam only. Little damage to other property. Estimated losses do not exceed \$100,000	Environmental Consequences: Short-term: Minimal Long-term: None
Low	Potential for loss of life: None. The inundation area (the area that could be flooded if the dam fails) is typically undeveloped.	Minimal damage to agriculture, other dams or structures not for human habitation. No damage to residential, commercial, industrial or land to be developed within 20 years. Estimated losses do not exceed \$1 million.	No significant loss or deterioration of fish and/or wildlife habitat. Loss of marginal habitat only. Feasibility and/or practicality of restoration or compensating in kind is high, and/or good capability of channel to maintain or restore itself.
Significant	Potential for loss of life: None expected Development within inundation area is predominantly rural or agricultural, or is managed so that the land usage is for transient activities such as with day use facilities. There must be a reliable element of warning if larger development exists.	Appreciable damage to agricultural operations, other dams or residential, commercial, industrial development, or land to be developed within 20 years. Estimated losses do not exceed \$10 million.	Loss or significant deterioration of important fish and/or wildlife habitat. Feasibility and/or practicality of restoration and/or compensating in kind is high, and/or good capability of channel to maintain or restore itself.
High	Potential for loss of life: One or more. Development within inundation area typically includes communities, extensive commercial and industrial areas, main highways, public utilities and other infrastructure.	Extensive damage to communities, agricultural operations, other dams and infrastructure. Typically includes destruction of or extensive damage to large residential areas, concentrated commercial and industrial land uses, highways, railways, power lines, pipelines and other utilities. Estimated losses exceed \$10 million.	Loss or significant deterioration of critical fish and/or wildlife habitat. Feasibility and/or practicality of restoration and/or compensating in kind is low, and/or poor capability of channel to maintain or restore itself.

Notes for Table 3.3:

1. Consideration should be given to the cascade effect of dam failures in situations where several dams are situated along the same watercourse. If failure of an upstream dam could contribute to failure of a downstream dam(s), the minimum hazard potential classification of the upstream dam should be the same as or greater than the highest downstream hazard potential classification of the downstream dam(s).
2. Economic losses refer to all direct and indirect losses to third parties; they do not include losses to owner, such as loss of the dam, associated facilities and appurtenances, loss of revenue, etc.
3. Estimated losses refer to incremental losses resulting from failure of the dam or mis-operation of the dam and appurtenant facilities.
4. For Hazard Potential Classification and Safety Criteria for tailings dams, refer to "Guidelines for Proponents, Rehabilitation of Mines", issued by Ontario Ministry of Northern Development and Mines, 1995.

It is important to note that in the ODS Guidelines, there is explicitly no consideration given to the owner's losses, including public/market reaction (see Note 2, Table 3.3). This is the prime reason the ODS Guidelines are preferable for mining projects as it clearly separates owner concerns from those of downstream stakeholders.

The British Columbia Water Act, Reg. 44/2000, has its own classification as shown in Table 3.4

Table 3.4 – BC Dam Safety – Downstream Consequence Classification Guide

Rating	Loss of Life	Economic and Social Loss	Environmental and Cultural Losses
Very High	<p>Large potential for multiple loss of life involving residents and working, travelling and/or recreating public. Development within inundation area (the area that could be flooded if the dam fails) typically includes communities, extensive commercial and work areas, main highways, railways, and locations of concentrated recreational activity. Estimated fatalities could exceed 100.</p>	<p>Very high economic losses affecting infrastructure, public and commercial facilities in and beyond inundation area. Typically includes destruction of or extensive damage to large residential areas, concentrated commercial land uses, highways, railways, power lines, pipelines and other utilities. Estimated direct and indirect (interruption of service) costs could exceed \$100 million.</p>	<p>Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and/or practicality of restoration and/or compensation is low.</p>
High	<p>Some potential for multiple loss of life involving residents, and working, travelling and/or recreating public. Development within inundation area typically includes highways and railways, commercial and work areas, locations of concentrated recreational activity and scattered residences. Estimated fatalities less than 100.</p>	<p>Substantial economic losses affecting infrastructure, public and commercial facilities in and beyond inundation area. Typically includes destruction of or extensive damage to concentrated commercial land uses, highways, railways, power lines, pipelines and other utilities. Scattered residences may be destroyed or severely damaged. Estimated direct and indirect (interruption of service) costs could exceed \$1 million.</p>	<p>Loss or significant deterioration of nationally or provincially important fisheries habitat (including water quality), wildlife habitat, rare and/or endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high.</p>
Low	<p>Low potential for multiple loss of life. Inundation area is typically undeveloped except for minor roads, temporarily inhabited or non-residential farms and rural activities. There must be a reliable element of natural warning if larger development exists.</p>	<p>Low economic losses to limited infrastructure, public and commercial activities. Estimated direct and indirect (interruption of service) costs could exceed \$100 000.</p>	<p>Loss or significant deterioration of regionally important fisheries habitat (including water quality), wildlife habitat, rare and endangered species, unique landscapes or sites of cultural significance. Feasibility and practicality of restoration and/or compensation is high. Includes situations where recovery would occur with time without restoration.</p>
Very Low	<p>Minimal potential for any loss of life. The inundation area is typically undeveloped.</p>	<p>Minimal economic losses typically limited to owner's property not to exceed \$100 000. Virtually no potential exists for future development of other land uses within the foreseeable future.</p>	<p>No significant loss or deterioration of fisheries habitat, wildlife habitat, rare or endangered species, unique landscapes or sites of cultural significance.</p>

3.3.3 Classification Summary

Using the logic that owner costs are not part of the DSR evaluation of consequence classification, the same logic described by ODS, the following classifications would result for all three Mount Polley embankments:

- Ontario Dam Safety Guidelines – **LOW**
- BC Dam Safety Guidelines – **LOW**

In both cases, the environmental losses were “about” right for the **Low** ranking. The BC guideline notes for **LOW** that:

“Low economic losses to limited infrastructure, public and commercial activities. Estimated direct and indirect (interruption of services) costs could exceed \$100,000.”

In terms of owner’s costs, noted by judgment by the embankments’ designer in Section 3.3.1 as “approximately \$1 million”, it is important to note that the actual owners cost of an embankment dam failure would likely be much higher. There is a large database on tailings dam failures that suggests costs from other indirects can easily exceed by many times the direct costs of clean-up and/or dam repair. These indirect cost items include:

- Loss of production
- Legal costs
- Loss of market capitalization
- Imposed evaluative studies

The decision to classify tailing embankments based upon consequences to the receiving environment and general public property concerns has been the approach recommended by this DSR. If there is a wish to include potential owner’s costs, these would likely need to assume a mine shut down for at least the repair period, all associated legal and technical evaluative costs and to have Imperial Metals make some estimate as to the market impact of the event. It would be, based upon past experience of facility failures without life safety concerns, difficult to imagine the total would result in the consequence rankings remaining within **LOW** classifications.

An additional step of a DSR is to evaluate the combination of the classification of the dam(s) in terms of potential hazard and the corresponding potential for a dam safety issue to arise which would allow any given hazard to become a realized outcome. In very simplistic terms, the dual assessment is a form of risk assessment where:

$$\text{Risk} = (\text{Likelihood of Event}) \times (\text{Consequence of Event})$$

In the case of a DSR, the likelihood is not explicitly defined in terms of a probability or even a qualitative likelihood of failure. However, the level of dam safety issue relative to the “concern” it raises can be thought of as a reasonable approximation of a qualitative likelihood. In other

words, using a qualitative scale to rank dam safety issues for any given dam allows a form of assignment of dam failure likelihood.

For this DSR, a four point scale of dam safety issue concerns used on many other similar DSR assignments was judged appropriate and is as follows:

- None: No dam safety issue(s) noted that will require attention as of 2006 DSR and it would be unlikely to develop an issue prior to next DSR.
- Minor: Issue(s) that will require observation and perhaps modest non-urgent works on an as-need basis.
- Moderate: Issue(s) that may require attention within a year or so and heightened observation is essential through to next DSR if issue not completely addressed.
- Major: Issue(s) that could seriously impact dam safety. Reasonable likelihood of providing a trigger(s) mechanism for dam failure if not addressed.

For the three contiguous embankment dams at the Mount Polley mine, in terms of dam safety issues detailed in Section 3.1, all three dams would be considered in the “None” to “Minor” ranking assuming the issue of whether there is any pre-shearing or brittle foundation materials can be put to rest with the recent (or previous) work carried out. Coupling this ranking with the **LOW** consequence evaluation in terms of public safety and actual environmental impact associated with a dam failure, there is little overall tailings dam safety concern at this mine. With the tacit assumption design, inspection and construction approaches and practices will not change; the three embankment dams indicate very low likelihood of having a dam safety issue of significance.

Finally, it is worth noting that the design criteria for the embankment dams at the Mount Polley TSF are consistent with a high consequence classification. As such, the argument can be made is that this facility has some robustness which is not a reason to reduce design criteria, but rather an observation that should provide added comfort to owner and the regulator.

3.4 Operational and Closure Challenges

As described earlier, the current lack of a tailings placement strategy that is compatible with closure objectives (e.g. perimeter spigotting and beach developing sloping away from all embankments) remains a project liability. An upstream tailings beach separating the dam from the water pond is good practice and such a beach is generally considered an integral requirement of the design. Lack of such a beach represents a deficiency that should be rectified as soon as practical particularly given the closure expectations of the facility. While the dam safety implications of having essentially no subaerial beach against the dam are not necessarily large given the robust dam section, it still is not designed as a water dam nor can it be closed like one. Post operation settlement of the tailings will also occur (although variable due to hydraulic sorting, thickest sections will tend to commensurately settle the most, e.g. nearest the embankments) and for reasons that include settlement considerations, aggressively creating a beach that keeps the pond in the area of the proposed closure spillway is recommended.

4.0 GENERAL OBSERVATIONS

In the course of completing a DSR, there are items that are noticed that while not necessarily significant or immediate dam safety concerns, if addressed would be in the best interest of overall dam stewardship. For the Mount Polley TSF, the issue with tailings beaching has been noted in other locations and will not be repeated here. The need to provide confirmation that the glaciolacustrine foundation unit poses no concerns in terms of over-estimated shear strength or potential brittle response is another matter that has been noted earlier in the report and one that should be signed off on by the facility designer, preferably prior to the next annual DSI of the facility. Finally, one additional issue briefly noted earlier in the report has to do with the recording and reporting of piezometric information. It is that issue that is discussed herein.

There are "about the right" number of piezometers in the embankment dams but certainly there is nothing in the way of much redundancy and any lost instrument locations need to be re-established with a new installation. As importantly, the information that is being gathered appears to be evaluated on a plane-by-plane basis versus an overall potentiometric surface within the foundation and the embankments. By presenting the information in the form of three-dimensional surfaces of equal pore pressure, potential anomalies in a given plan relative to the other planes can be readily identified and the early signs potential dam safety issues such as loss of drain efficacy, internal erosion or other similar concerns readily identified. As the embankments all share the same essential constructed cross-section, any difference in the gradient of head loss to a drain, across the core or within the foundation may be significant. By evaluating the information on a plane-by-plane basis alone, such differences may not be noted as they can be both subtle and relative. An evaluation of the most recently available piezometric information (from the 2005 annual inspection), for example, does show some subtle differences between planes in terms of drainage efficacy. These differences are likely benign but tracking the differences or, as importantly, the trends in any differences is recommended.

Another item with the piezometer information is the lack of a clearly defined trigger system. What that means is dam safety programs that include something like a three-stage piezometer specific value (typically noted as a pore pressure ratio) can readily have any anomalous or poor trending reading flagged for the level of concern. A typical approach is to have each piezometer provided with three levels of reading response:

- Green - no concerns when values below the stated threshold value (either pressure head or, as noted, an appropriate pore pressure ratio). Pore pressures are within values that provide the dam with demonstrated stability and/or lack of internal erosion and/or seepage concerns.
- Yellow - elevated concern when values exceed the stated threshold value but are below a value deemed to indicate a significant dam safety concern - engineer of record notified and more attention provided to instrument's readings until it returns to a "Green" level. This level could be thought of as where the, for example, limit-equilibrium factor-of-safety related to instability is reduced to just under the stated design criteria.
- Red - significant concern and one that invokes notification of appropriate regulatory personnel with a full description of mitigation strategies in place. This typically

corresponds to, for example, instability concerns where the computed factor-of-safety is marginally above mass equilibrium values (e.g. slightly above unity).

For the reporting of the Mount Polley embankment dam piezometer readings, it is suggested that threshold values that fit some form of a format as outlined above be adopted, incorporated into the OMS Manual, and updated regularly by the mine. This format should also be included in annual inspection reporting that is shared with regulators.

5.0 REPORT CLOSURE

This report has been prepared in draft for comment. The report will be issued in final following receipt and discussion of review comments from Imperial Metals Corporation

Recommendations presented herein are based on an evaluation of the findings of the dam safety review. If conditions other than those reported are noted during subsequent stages of mine operation, AMEC should be notified and be given the opportunity to review and revise the current recommendations, if necessary. Recommendations presented herein may not be valid if an adequate level of review or inspection is not provided during ongoing mine operations and into the mine closure period by the mine and/or its design engineer(s).

This report has been prepared for the exclusive use of Imperial Metals Corporation for specific application to the dam safety aspects of the Mount Polley Mine Tailings Storage Facility. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted tailings dam safety engineering practices. No other warranty, expressed or implied, is made.

Sincerely,

**AMEC Earth & Environmental,
a division of AMEC Americas Limited**

Reviewed by:

Michael Davies, Ph.D, P.Eng., P.Geo.
Principal Geotechnical Engineer

Todd Martin, P.Eng., P.Geo.
Principal Geotechnical Engineer

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APPENDIX A

Reference Documents and Review Commentary



APPENDIX B
Selected Photographs