THURBER ENGINEERING LTD.

CULLATON LAKE MINE
DAM SAFETY REVIEW

Report
to
Barrick Gold Corporation

PROFESSIONAL ENGINEER
JEREMY BOSWELL
20 July 20
ALBERTA

Samuel A. Proskin, Ph.D., P.Eng.
Permafrost Engineering Specialist

Jeremy Boswell, M.Eng., P.Eng.
Senior Tailings Engineer, DSR Lead

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John Sobkowicz, Ph.D., P.Eng.
Review Principal

THURBER

EXECUTIVE SUMMARY

Thurber Engineering Ltd. (Thurber) was retained on August 31, 2015 by Barrick Gold Corporation (Barrick) to undertake a Dam Safety Review (DSR) of the Cullaton Lake Gold Mine Tailings Pond No. 1 (TP1) in Nunavut.

The Cullaton Lake Gold Mine Tailings Facility TP1 is located in the southern part of the Kivalliq Region, Nunavut, immediately southwest of Cullaton Lake and northwest of the Kognak River, and 237 km west of Arviat, NU, (population 2318, census 2011), the nearest identifiable human settlement.

Cullaton Lake Gold Mine was operated for four years, from 1981 until temporary closure in September 1985. As a high cost producer, the mine was never re-opened. Barrick acquired the Cullaton Lake site in 2001 from Homestake Canada Inc. (Homestake), the owners at that time by succession in title. Aboriginal Affairs and Northern Development (AANDC) (now Indigenous and Northern Affairs Canada – INAC) officials in Iqualit instructed that a DSR be conducted for TP1, using the guidelines of the Canadian Dam Association (CDA).

The DSR was carried out by Thurber in September and October 2015 and included:

- Site inspection of the Cullaton Lake Mine area on September 3, 2015.
- Review of all relevant background documents and reports provided by Barrick (Appendix A provides a list of reviewed documents).
- Dam classification using CDA Dam Safety Guidelines (2007 and 2013 Revision).
- Review of design & construction issues, stability, seepage, permafrost aspects and acid rock drainage (ARD) potential.
- Review of surveillance and monitoring, emergency preparedness and other procedures.
- Recommendations.

In view of the long passage of time since temporary closure, there is substantial documentation regarding the site, including the detailing of a large number of site inspections and site assessments by a breadth of specialists.

In terms of the CDA Dam Safety Guidelines (2007 and 2013 Revision), TP1 has been recommended for classification (in terms of this DSR) as a low category dam, with low consequence of failure for any credible failure mode.

The following recommendations are made in this DSR:

1) The approach to management of TP1 is sound and with the exception of recommendation no. 3 below, no improvements to ongoing dam safety management in the short term are considered necessary.
2) The analysis conducted by NHC (Appendix D) as part of this DSR, confirmed that the IDF flow can be safely routed through Spillway 1 within the current design. However, the wind setup and wave runup analyses indicated that the current TP1 does not meet CDA guidelines with respect to freeboard requirements to account for wind setup and wave runup.
3) It is recommended that consideration be given in the short term to reducing the spillway level, to enable TP1 to meet CDA guidelines for wind setup and wave runup.
4) In the longer term, consideration should be given to decommissioning of TP1 as a dam and an investigation of the potential of not storing water at all.
    a) It is not in anyone's interest to continue to operate a dam whose purpose appears to have been served, and where the consequences of failure are low.
    b) The potential for ARD has been demonstrated from specialist opinion and long term monitoring to be very low, and may be dismissed.
    c) The site is very remote. Access to the site and monitoring are challenging.
    d) No dam is completely weatherproof. The longer the dam needs to be maintained, the greater the exposure to the effects of weathering. Freeze-thaw cycles will continue to act on the dyke, and have potential to cause long term deterioration both externally (weathering) and internally (piping). The life of the spillway may also not be indefinite without some maintenance in the long term.
5) While TP1 continues to be operated as a dam, monitoring of TP1 should be more closely aligned with the credible modes of failure as described in this report.

The following additional observations are made in the report:

Closure efforts by Barrick (and others) and ecologically restorative natural processes have largely been successful in restoring the land to near natural condition for this very small tailings deposit (entire extent not more than 1.5 metres in depth and area of around 4 ha). Only a well-trained or informed eye would now be able to identify the location of any gold tailings, as they are now well covered by natural soil and vegetation. In inspecting some 300 gold tailings facilities over the last 30 years, this is the smallest deposit with the smallest environmental footprint that one of the authors of this report (Jeremy Boswell) has ever visited.

Issues such as permafrost effects, embankment seepage and stability and ARD have been reviewed based on the information provided and have been found to be of low consequence, and low probability. The risks facing the site have been identified, assessed and addressed by a number of experts over the years. A risk based approach rather than a prescriptive checklist approach would now be more effective in addressing long term requirements to achieve true decommissioning of such areas as TP1, and allowing the closure of the mine site and the return of the land.

If this approach is acceptable, then confirming the absence of long term risks and monitoring the site accordingly appears logical. A somewhat more strategic monitoring approach with less frequent site visits may be useful.

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LIST OF ACRONYMS

A&R	Abandonment and Restoration
AANDC	Aboriginal Affairs and Northern Development (previously and subsequently named INAC)
AECOM	AECOM Canada Ltd.
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage (preferred term to AMD)
Barrick	Barrick Gold Corporation
BGC	BGC Engineering Inc.
CCME	Canadian Council of Ministers of the Environment
CDA	Canadian Dam Association
Corona	International Corona Corporation
DSR	Dam Safety Review
EPP	Emergency Preparedness Plan
ERP	Emergency Response Plan
EXP	EXP Services Inc. (previously Trow Associates Inc.)
Final A&R	Final Abandonment & Restoration Plan
Homestake	Homestake Canada Inc.
INAC	Indigenous and Northern Affairs (previously AANDC)
ML	Metal Leaching
mgd	metres above geodetic datum
MMER	Metal Mining Effluent Regulations
NWB	Nunavut Water Board
OMS	Operations, Maintenance and Surveillance
PMF	Probable Maximum Flood
TOR	Terms of Reference
TP1	Tailings Pond Number 1
TP2	Tailings Pond Number 2

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1. INTRODUCTION

1.1 General

On August 31, 2015, Barrick contracted Thurber to conduct a DSR for Cullaton Lake Gold Mine TP1 in Nunavut. The facility is administered through a post-closure water monitoring program which requires Barrick to report annually to NWB.

The Cullaton Lake property consists of a gravel airstrip, gravel access road, waste rock dump, covered subaerial tailings (dry), a tailings pond and a water pond. TP1 contains deposited tailings from the mining operations. Tailings Pond 2 (TP2) functioned only as a polishing pond and provided supplementary retention for natural cyanide degradation at the time.

The mine produced about 100,000 ounces of gold from some 373,000 tonnes of processed ore during its operations between 1981 and 1985 from two separate underground mining operations; the B-Zone and the Shear Lake Zone. After acquiring Cullaton Lake Gold Mine Ltd. in June 1985, International Corona Corporation (Corona) placed the property on a care and maintenance program in August 1985 due to economic reasons. In 1990, it was decided not to re-open the mine and to commence decommissioning of the mine. By 1992, the Cullaton Lake site was in the final stages of decommissioning, and was acquired from Corona by Homestake Canada Ltd. (Homestake). In 2001 Barrick acquired Cullaton Lake Mine from Homestake.

Barrick followed up with post-closure monitoring according to the terms of the NWB water license and, following several years of stable monitoring, approached the NWB in 2005, with the view that the objectives of the approved 1996 Final Abandonment and Restoration (Final A&R) Plan had been achieved. In response the NWB requested inputs from AANDC, and AANDC retained BGC Engineering Inc. (BGC) to advise them in 2006 and to conduct a site inspection and mine closure review. BGC concluded that the site reclamation work had not yet achieved the objectives of the Final A&R Plan, especially the criteria for demonstrating physical, chemical and thermal stability.

One of the recommendations from the BGC report of 2006 was that a DSR be conducted for the facility.

After two briefing telephone discussions and an email from Barrick with the key documents, the scope of work for the DSR was outlined in a Thurber proposal letter dated August 21, 2015.

Authorization to proceed with the work was received from Barrick on August 31, 2015, and the work has been undertaken under the Agreement of Service signed by Barrick and Thurber on September 1 and September 2, 2015 respectively.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1.2 Objectives, Standards and Tasks

The objective of this review was to provide an independent, third party assessment of dam safety aspects of the Cullaton Lake Tailings Facility. The review was undertaken in accordance with the CDA Dam Safety Guidelines (2007 and 2013 revision), CDA Guidelines for Public Safety around Dams (2011) and technical bulletins, including the most recent one on mining dams (CDA, 2014). The main tasks performed during this DSR for TP1 are as follows:

- Review all background information, relevant documentation, maps, reports and drawings.
- Conduct a site visit with the closure manager and the EXP geotechnical inspector.
- Review the overall dimensions, typical cross-sections, dam design and construction in light of current dam safety standards.
- Review seepage control measures, evaluate dam structure interfaces for seepage/ weakness.
- Review stability of slopes.
- Conduct a dam classification and consequence rating.
- Review surveillance and monitoring methods, emergency preparedness and the dam safety management system.
- Review relevant dam safety failure modes.
- Provide recommendations.

With the exception of the field inspection, and the general reference documents listed in Section 13.2, the review was based entirely on information provided by Barrick. A listing of the documents provided by Barrick is included in Section 13.1 References. The most recent information provided was the Cullaton Lake Geotechnical Inspection Report, completed by EXP in 2015.

1.3 Review Team

The DSR was conducted by a team of engineers with experience in the design, construction, and safety evaluation of tailings and water retention dams, and also including permafrost conditions and gold tailings reclamation. The key members of the review team were as follows:

- Dr. John Sobkowicz, Ph.D., P.Eng., Review Principal.
- Mr. Jeremy Boswell, M.Eng., P.Eng., Senior Tailings Engineer, DSR Lead.
- Dr. Sam Proskin, Ph.D., P.Eng., Permafrost Engineering.
- Dr. Mauricio Pinheiro, Ph.D., P.Eng., Geotechnical Engineering.
- Ms. Nancy Sims, M.Sc. (Eng), P.Eng., Hydrotechnical Engineering.

1.4 Organization of Report

The report is organized so that the text includes all key discussions and areas of interest, while the appendices contain all supporting information, such as background information, figures, tables, photos and data. Recommendations in all areas are prioritized and summarized in Section 10.

2. BACKGROUND

The Cullaton Lake Gold Mine Tailings Facility TP1 is located in the southern part of the Kivalliq Region, Nunavut, immediately southwest of Cullaton Lake and northwest of the Kognak River, and 237 km west of Arviat, NU, (population 2318, census 2011), the nearest identifiable human settlement. The site is located 416 km northwest of Churchill, MB. The GPS location of the tailings facility is 61°16' north latitude and 98°30' west longitude.

The mine produced about 100,000 ounces of gold from some 373,000 tonnes of processed ore during its operation for four years, from 1981 to closure in September 1985.

The tailings are either covered by till and revegetated, or submerged under water and saturated to prevent oxidation. The deposit remains frozen for about eight months of the year with only the surface being thawed in the short summer. Potential ARD from the tailings facility on closure was the principal concern of the NWB at the time.

The homogeneous embankments for the tailings dams were constructed in the late 1970s or early 1980s with local silty sand and gravel till. The construction records are limited. Maximum dam height was some 5.5 m above original ground. Unless otherwise noted, all water and embankment surface levels in this report are referenced to a local benchmark and do not indicate actual elevations above mean sea level.

An outline of TP1, as per the 1990 tailings area fieldwork and dam stability assessment report by Trow (1991) to then owner of the facility Corona Corporation, is provided below:

- During mining operations, tailings were deposited along the west and southwest side of TP1.
- Total estimated area of containment was 178,000 m^2 (17.8 ha).
- Volume of water in 1991 in the TP1 was estimated at 290,000 m^3.
- Estimated volume of tailings 233,000 m^3 (373,380 tonnes).
- Average estimated thickness of tailings in the beach area and in the pond was 1,200 mm and less than 450 mm respectively.
- Average estimated annual water surface level was 94.9 m.
- Estimated area of exposed tailings 35,000 m^2 (subsequently covered subsequently by till and revegetated).
- The tailings range from a silty, uniform sand material (west side of the pond) to a fine, clayey silt material (east side of the pond).
- The tailings beach slope to the water's edge of TP1 was at an average of about 1%.

The approximately 300,000 m^2 (30 ha) TP2, which is not within the scope of this review, functioned only as a polishing pond and provided supplementary retention for immediate natural cyanide degradation at the time. Discharge from TP1 to TP2 has not been required since the suspension of operations. TP2 held an estimated 200,000 m^3 of water and average annual water surface level of 89.9 m.

3. SITE INSPECTION

3.1 General

Mr. Jeremy Boswell visited the site on September 3, 2015 to carry out a field inspection. The access to site is normally gained by charter air flights from Thomson, Manitoba. The scheduled site visit on September 2, 2015 was postponed due to bad weather, as northern Manitoba (including Thompson) and southern Nunavut was blanketed in fog. The team was able to land on site by charter flight in the afternoon of September 3, 2015.

It was raining while the team was on site, for approximately five hours. Unfortunately, it was not possible to take any aerial photographs of the site because of low cloud and poor visibility. Photos 26 and 27 in Appendix C show aerial views of the facility, recorded during the August 2014 geotechnical inspection by EXP (2014b). All terrestrial photographs presented in this report (Appendix A) were recorded on September 3, 2015 by Jeremy Boswell unless otherwise indicated.

The engineering personnel who were present during the site visit on September 3, 2015 are listed in Table 1 below.

Table 1. Personnel Present During Site Inspection

Name	Company	Capacity
Mr. Paul Brugger	Barrick Gold	Client representative
Mr. Jeremy Boswell	Thurber Engineering	Dam Safety Review
Mr. Demetri Georgiou	EXP	Annual inspection
Ms. Jane Doucette	Amec FW	Representing INAC

3.2 Site Description

The mine site area features undulating terrain with shallow surficial soils overlying bedrock. The surficial deposits consist mainly of a bouldery glacial till with localized surface organic deposits. The soil matrix of the glacial till is a well-graded, silty sand with no clay to traces of clay (i.e., it exhibits little or no plasticity).

The inspection included TP1 and facilities along the toe, dyke slopes and crest, spillway and immediately upslope area west of the facility.

The primary features of TP1 are shown in the Trow sketch labelled drawing no. 1 and dated 1992 (EXP, 2011), included in Appendix B of this report.

3.3 Walkover Inspection and Photographic Record

Photographs 1 to 25 in Appendix A show the results of the walkover inspection conducted on the afternoon of September 3, 2015. The photographs are a snapshot summary in sequence, of the 221 photos recorded by Jeremy Boswell. The adverse weather and poor visibility were considerably worse than appear in the photographs.

- Photo 1 shows the typical waste rock cladding that was used to cover the till embankment of TP1. This appears to have protected the embankment well, which shows little or no evidence of erosion or weather action.
- Photo 2 shows the extent of progression of vegetative cover over the western edge of the deposit.
- Photo 3 gives a panorama view of the north-eastern embankment of TP1.
- Photo 4 is a view into the pond from the embankment of TP1, showing sheetwash (material eroded from the surface that has deposited below the water surface) and fine material about one metre below the surface.
- Photo 5 shows a branch of the typical pioneer bush species which has made a substantial contribution to the revegetation of exposed surfaces at the site.
- Photo 6 shows the low flow in the spillway (even during rainfall on site) with biotic growth in the stream.
- Photo 7 shows the spillway flow slightly further away from the embankment. The spillway appears to be performing well and the rip rap and waste rock lining of the spillway is working well.
- Photo 8 shows the exposed edge of the HDPE liner which was used in the construction of the spillway.
- Photo 9 indicates a small waste rock pile.
- Photo 10 delineates the path of flow from the spillway of TP1. The flow path is stable, with no evidence of scouring or erosion. Flow from this point enters TP2.
- Photos 11 and 12 show wet areas encountered immediately downstream of the embankment of TP1. The semi-permanent nature of the wet area and associated vegetation indicate that these may be seeps arising from seepage flow through the embankment (Georgiou, 2015).
- Photo 13 shows the remains of an HDPE liner which was transported from TP2 to TP1 when till was used to cover the exposed gold tailings at the time. The waste HDPE pieces thus observed in a few isolated places serve no function today.
- Photo 14 shows the general location of the original thermistors (installed some 15 years ago) and the location of the permafrost depth test pit.

- Photo 15 is a duplicate photo, showing the extent to which the natural regrowth of vegetation is progressively covering the tailings dry cover. This becomes apparent when comparing this photo to earlier inspection records by EXP (2014b).
- Photo 16 shows a remaining exposed patch of the tailings cover, containing silt mixed with waste rock and some till.
- Photo 17 shows the extent to which vegetation has covered the gold tailings originally left exposed when mining was discontinued.
- Photo 18 is an east facing view of the surface of TP1, looking towards the main embankment, from the water's edge.
- Photo 19 is a west facing view showing the difference in vegetation between natural ground (in the distance) and revegetated tailings cover (in the foreground). While the natural ground is richer in biodiversity, it is clear that nature is progressively restoring, over time.
- Photo 20 is a shot in the reverse direction where three environments are clearly visible - natural habitat (in the foreground), revegetated tailings cover in mid-picture, and the water surface of TP1 in the distance.
- Photo 21 shows exposed till on site – a small bare patch of some 8 m by 5 m.
- Photo 22 shows hand excavation in progress of a test pit to determine the depth to the permafrost, which was found to be 1.42 m (56 in). The unoxidized gold tailings (grey in colour) is visible in the spoil pile to the right were found under 900 mm of cover material. It was from this source that a sample of gold tailings was recovered for testing.
- Photo 23 is an indication of type of annual water sampling undertaken by Barrick and their predecessors over the past 30 years.
- Photo 24 shows the spillway flow from TP2 which, although not very strong, was substantially higher than the flow rate from TP1. This is unsurprising, as the catchment areas of the two basins vary quite substantially.
- Photo 25 shows the surface of the contents of TP2, looking north-west towards TP1 (not visible in the photo).

3.4 Condition of Embankments

Waste rock has been used extensively to protect and armour the crest and side slopes of TP1 as shown in Photo 1. On both the upstream and downstream sides of the dam, evidence of small erosion scars were found. However, the scars are not increasing in size according to the previous inspections by Barrick and EXP personnel, and are stabilizing due to accelerating vegetation growth.

The TP1 embankments are of limited height (not more than 5 m), and the depth of water in the pond is estimated to be no more than 2 m. Although new analyses of embankment slope stability were not within the scope of work of the DSR, a review of previous slope stability studies coupled with field observations support the assessment that the embankments are stable. Section 6.2 of this report provides additional detail.

3.5 Spillway Condition

The spillway of TP1 is working well and is in good condition. The waste rock lining is effective in preventing scour and weathering damage from freeze-thaw.

3.6 Seepage

No seepage was observed in the pond located at the downstream side of the spillway channel. A view of the waste rock pile on the downstream slope of TP1 and immediately downstream of the spillway can be found in Photos 9 and 10, respectively. A wet spot was located during the 2010 field inspection and was reported in EXP's annual geotechnical inspection (EXP, 2014b). Photo 11 shows the wet patch on the downstream toe of Dam 1 and photo 12 shows the semi-permanent wet area at the downstream toe. The approximate location of the wet spot is shown in Figure 1 of Appendix B.

Limited seepage continues to occur through the dam, and is within low limits, (for further details please refer to Section 6).

3.7 Offtakes, Drain Outlets and Filter Drains

No filter drain outlets or offtakes were pointed out nor observed during the site inspection; the lack of filter drains in the structure was confirmed by a review of records and by interviews with Mr. Paul Brugger of Barrick, and Mr. Demetri Georgiou of EXP. This is not considered to be unusual given the limited height of the TP1 embankment.

3.8 Monitoring Instrumentation

The locations of old thermistors are shown in Photo 15. They have fallen into disrepair after over fifteen years of life and are no longer relied upon.

No evidence of phreatic surface monitoring (piezometers) or slope stability monitoring (slope inclinometers) was found and, in view of the limited embankment height and restricted site access, such instrumentation was not expected.

3.9 Water and Wind Erosion

As mentioned earlier in this report, some small erosion scars were observed on both upstream and downstream sides of TP1. However, the scars do not appear to be increasing in size compared to the previous inspections performed and recorded by EXP in annual inspection reports. The exposed till mixed with waste rock, with a developing natural vegetative cover, is visible in Photo 16. No evidence of dam internal erosion (piping) was found.

No evidence was found of unsubmerged or exposed gold tailings on site.

3.10 Revegetation

Photographs in BGC (2006) show extensive bare areas of newly sowed till cover on tailings and sowed bare areas on and around TP1 (BGC Photos 20-23, 31, 32, 67, 68 and 78). At the site inspection on September 3, 2015, these bare areas have all but disappeared and are now extensively covered, although not completely (see Appendix A of this report; Photos 2, 14-17, 19 and 20). The revegetation program is observed to be quite successful, despite the short growing season at Cullaton.

It was noted by Mr. Paul Brugger and Mr. Demetri Georgiou that the density of the vegetation has increased gradually, based on their visual observations of previous years and this year. Photo 2 gives the view of the progression of vegetation over the covered tailings. Over all exposed areas, pioneer species of bush that has rapidly accelerated in growth this summer was observed (Photo 5). The areas of previously exposed gold tailings was covered by a layer of till and seeded, and which is now largely restored with a natural growth of vegetation, as can be seen in Photos 15 and 17.

3.11 Unvegetated Areas

A limited number of small isolated bare patches were found across the site. An example is shown in Photo 21.

3.12 Cover and Stabilization

The simple tailings cover (of some 1 metre of till revegetated with sown and natural vegetation) is working well. A new cover design is neither needed nor warranted.

3.13 Observations after Site Inspection

The following observations were made after the walkover inspection:

1) TP1 is stable, in terms of geotechnical stability, as well as resistance to erosion.
2) There is no evidence of physical damage (by wave action, freeze-thaw or weathering) of the structure, and the facility is in good condition, and serving the purpose for which it was intended.
3) The spillway is in good condition and is working well.
4) There is limited seepage passing through the embankment and/or through the foundation.
5) Regrowth of vegetation (accelerated since 2006) across the site is contributing to the return of the site to natural conditions.

4. DAM PERFORMANCE

4.1 Reporting

The condition of the facility is inspected annually in the summer by the owner and geotechnical engineers (EXP), and has been for the past 30 years, since mining was discontinued.

A comprehensive and wide ranging program of annual water sampling and reporting is undertaken by Barrick and reported to the NWB, to meet obligations outlined the water license for the property.

4.2 General Pond Performance

The performance of TP1 is considered to be quite adequate for the purpose it now serves. The embankments are stable and the spillway is operating according to design.

The untroubled long term performance of the facility (30 years since closure) is testimony to the degree of closure that was achieved at the time, and is a confirmation of the closure, surveillance and monitoring measures employed.

4.3 Conformance to CDA Guidelines regarding Dam Safety Management

Compliance of Barrick in dam safety management is considered to be satisfactory based on the DSR team's observations. Specific individuals responsible for the safety, operation, surveillance and maintenance of the dam in this DSR are identified and their reporting methods and paths are clear.

4.3.1 Planning

Since this facility has not been operational for 30 years, no planning is currently taking place. Any new post closure measures would require planning.

4.3.2 Implementation

Procedures for maintenance, surveillance and monitoring as laid down are being implemented.

4.3.3 Corrective Actions

All known and relevant corrective actions as recorded in previous inspections have been diligently implemented and reported.

4.3.4 Records of Construction Documentation

There are limited enduring records of construction, as this was over 30 years ago. The condition of the site has been well documented, as may be observed in the reference documents listed in Section 13.

4.4 Discussion

The DSR team does not have any comments on dam performance, as TP1 is functioning as intended. Comments in regard to decommissioning and long term management are provided in Section 10 below.

5. DAM CLASSIFICATION

5.1 General

The CDA Dam Safety Guidelines (2007 and 2013 Revision) provide guidance on dam classification, and were used for this DSR assignment.

Based on the expected incremental losses associated with a dam failure, a dam should be classified in one of five consequence categories – Low, Significant, High, Very High and Extreme. The appropriate inflow design flood (IDF) for the dam should then be selected based on the classification. Table 2 provides a summary of the dam classification criteria from the CDA Guidelines with recommended IDFs.

Table 2. CDA 2007 Dam Classification (CDA, 2007)

Dam Class	Population at Risk	Incremental Losses			IDF Return Period
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	
Low	None	0	Minimal short-term loss No long-term loss	Low economic losses; area contains limited infrastructure or services	100-year
Significant	Temporary only	Not specified	No significant loss or deterioration of fish or wildlife habitat, Loss of marginal habitat only Restoration or compensation in kind highly possible	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes	100-year to 1000-year
High	Permanent	10 or fewer	Significant loss or deterioration of important fish or wildlife habitat Restoration or compensation in kind highly possible	High economic losses affecting infrastructure, public transportation, and commercial facilities	One-third between 1000-year and PMF[1]
Very high	Permanent	100 or fewer	Significant loss or deterioration of critical fish or wildlife habitat	Very high economic losses affecting important infrastructure or services	Two-thirds between

Table 2. CDA 2007 Dam Classification (CDA, 2007)

Dam Class	Population at Risk	Incremental Losses			IDF Return Period
		Loss of Life	Environmental and Cultural Values	Infrastructure and Economics	
			Restoration or compensation in kind possible but impractical	(e.g., highway, industrial facility, storage facilities for dangerous substances)	1000-year and PMF[1]
Extreme	Permanent	More than 100	Major loss of critical fish or wildlife habitat Restoration or compensation in kind impossible	Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)	PMF[1]

Note 1: PMF stands for Probable Maximum Flood

5.2 Credible Dam Failure Modes for TP1

However remote the possibility of failure (and the probabilities are very low in all cases), part of the function of a dam safety review is to review the extent to which dam failure modes have been identified and assessed. From the documentation provided to Thurber (see references), this has not been performed to date for Cullaton TP1. This is perhaps unsurprising, since the consequences of failure are low in all cases, and the CDA does not require a DSR in this case.

We have briefly considered below what the credible dam failure modes for TP1 might be.

The first question to ask in this regard is what possible events could lead to partial or complete failure of the TP1 dam. (Note that we have only considered failure in terms of dam safety and not in terms of environmental performance nor long term closure).

The credible dam failure modes for Cullaton TP1 are:

1) Overtopping of the embankment after freshet and/or heavy rain in the summer months.

Records obtained from Trow (1991) show the extent of a dam breach which occurred in TP2, and contributed to the decision to introduce a spillway for TP1. The remedial work and report commissioned by Homestake in 1992 provided for a spillway to lower the full supply level of the reservoir. If the spillway were to become blocked (by ice or debris), then the reservoir could rise and lead to an overtopping. The anticipated mode of failure after overtopping is expected to be slow, as a result of rock armouring of the crest and embankment, the very small catchment area supplying the reservoir, and the likely depth of flow over the embankment crest. EXP (1993b, August) estimated the spillway to be capable of discharging more than 100,000 m^3 per month (or around 40 l/s). In our view this is a conservative estimate. The discharge is likely to consist mainly of water, with a limited amount of entrained silt and tailings.

2) Spillway failure.

   In addition to the failure mode described above, the spillway may over a long time be eroded (in the absence of routine inspection and maintenance). This could lead to a sudden or gradual lowering of the water level in the reservoir.

3) Embankment failure through seepage induced by internal erosion (e.g. suffusion, piping), perhaps worsened by freeze-thaw cycles, or continuous melting of permafrost.

   The loosely compacted state of the TP1 embankment fill, along with lack of plasticity of the till of which it was built and long-term weathering effects (such as formation of ice lenses and the gradual removal of material from the thawed layers within the embankment), all favour the development of internal erosion. Breaching of TP1 due to internal erosion through the embankment cannot be ruled out.

   Seepage ponds have been observed on the downstream side of TP1 (see Section 6.2). These ponds indicate that seepage paths may exist within the underlying bedrock foundation. It is conjectured that thawing of pre-existing ice and frozen materials in the fractures of the bedrock has occurred, resulting in these preferred seepage paths. Therefore, breaching of TP1 due to internal erosion through the foundations cannot be ruled out, although less likely to occur, on account that the bedrock material is stronger that the embankment till material.

A formal analysis of failure modes and effects (FMEA) has not been conducted for Cullaton Lake TP1, and is not considered necessary for this dam (embankment height now less than 5 m, tailings depth of 1.4 m and water depth of some 2 m at most, with low consequence of failure for any failure mode).

As shown in this report, all consequences associated with TP1 were found after review, to be low. (In almost all cases they could even be described as very low, or at the lower limit of the table).

The probability of failure may be ruled out as very low in all cases except for the following:

- Internal erosion of the dam (piping failure) – low probability and risk. As shown earlier, the current risk of piping failure is deemed to be low.

5.3 Consequences of Dam Failure

According to Section 1.4 of the CDA Dam Safety Guidelines, the DSR should include a review of the consequences of dam failure. Table 3 summarizes the consequences of dam failure for Cullaton Lake TP1 as per the CDA Guidelines. More detail is provided in the paragraphs below Table 3 as well.

Table 3. Consequences of Dam Failure for Cullaton Lake

Consequence of Failure	Cullaton Lake Dam
Loss of Life	The closest identifiable community from the Cullaton Lake area is the Inuit hamlet of Arviat (population 2318), 237 km distant by line of sight, on the Hudson Bay coastline. Therefore there is no identifiable population at risk.
Infrastructure and Economic Losses	There is no public/third party property, facilities, utilities or infrastructure at or near the Cullaton Lake area. Therefore, there would be very limited economic loss as a consequence of failure.
Environmental Losses	Palmer et al. (2009) in an ecological risk assessment found no evidence on site that fish or water quality were impacted by the site. In the event of dam failure, the associated impact on the environment is expected to be low, as detailed below.
Cultural Losses	There are no known historic or cultural features at the site.

The following sections consider each of the consequences listed in Table 3 and the potential for incremental losses when determining the classification.

5.3.1 Population at Risk

The nearest settlement to Cullaton Lake is Arviat 237 km east of the site. None of the reports document any permanent settlements closer than Arviat. Given the current size of the tailings pond (290,000 m^3) and the distance to Arviat, we believe the population at risk for dam failure is none, as there is no identifiable population at risk, whether temporary or permanent.

5.3.2 Loss of Life

Although a dam breach inundation study is usually required to estimate the incremental losses due to a dam failure, the project documentation does not identify any temporary or permanent settlements, transportation corridors, agriculture or utilities in the vicinity of Cullaton Lake. Consequently, the loss of life for a sunny day dam failure or a flood induced failure is considered to be zero as there is no temporary (or permanent) population exposed to these hazards.

5.3.3 Economic Impact

There is no discernible industry, community or recreational infrastructure exposed to this hazard. Our understanding is that no local communities rely on trapping, hunting or fishing in this area. We are of the opinion that the economic impacts of dam failure would be low.

5.3.4 Environmental Consequences

According to AECOM the water quality in the tailings pond does not exceed any of the Water Licence Limits. Lake Chub and Arctic Grayling were caught in Shear Lake and found to be healthy.

A dam breach could release water and minor amounts of entrained sediment, sheetwash and possibly fine tailings that could impact fish habitat and wildlife habitat for a short time. The ecological risk assessment and the annual water monitoring program have shown that the water quality in TP1 is close to drinking water standards, and is being released into the environment at the moment. Although tundra ecosystems are sensitive to chemical/physical/thermal disturbances and northern locations typically have limited natural attenuation, these impacts would affect a small area of the Kognac River and an unnamed lake around 7 km due east of TP1.

In the unlikely event of a failure of TP1, water and entrained silt and some tailings would likely discharge into TP2. If the failure of TP1 is gradual, TP2 would retain much of the solid material from a breach. If the breach in TP2 were to be sudden (an even more unlikely event), however, a cascade type failure of TP2 cannot be ruled out. The remote possibility of cascading failure of both TP1 and TP2 could release the water contents of both dams of 490,000 m^3 (Trow, 1991) in total.

In view of the high quality of the water in TP1, a release of this water into the environment would not be significant, from a water quality point of view. The water is currently being released albeit gradually, on an ongoing basis. A dam failure would merely release the water in a much shorter period.

The lake described above into which the Kognac River discharges, is estimated to be at least 300 times the areal extent of the combined areas of TP1 and TP2. The increase in water level of this lake if the entire contents of TP1 and TP2 were to enter it, is estimated to amount to an increase in water level of less than 10 mm. The assimilative capacity of the receiving lake is thus substantial. This feature when considered in conjunction with the good quality of the water contained in TP1, leads to the conclusion that potential environmental impact is limited.

Overall we consider the environmental consequences as low.

5.3.5 Cultural Losses

We are not aware of any historic, archeological or cultural features within the potential flood impacted areas; therefore, for the purposes of this DSR, we assess the potential loss at zero.

5.4 Cullaton Lake Dam 1 Classification

After reviewing the various potential losses, it is the considered recommendation of Thurber that the Cullaton Lake TP1 be classified as a Low consequence dam. The only consequence of any consideration at all is environmental, at a low significance level.

6. DAM SAFETY ANALYSIS

6.1 Permafrost and Active Layer Effects

Cullaton Lake is located in the continuous permafrost zone which means perennially frozen ground underlays the natural terrain. The 30-year climate normals (1981-2010) for Arviat give a mean annual air temperature of -9.3ºC (Environment Canada, 2015) that is consistent for a continuous permafrost zone. Construction of TP1 would have altered the thermal regime beneath

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the dam itself and the pond. Ground temperature data from the four instrument sites operating between August 1991 and September 1994 on the west side of TP1 indicate that material below 5 m depth remained at freezing temperatures while temperatures at 4 m depth and above reached above 0ºC temperatures during the summer.

The permafrost exposed at the ground surface undergoes seasonal freezing and thawing and is known as the active layer. Its depth varies with ambient air temperature, vegetation, drainage, soil or rock type, water content, snow cover and degree and orientation of slope (Harris et al., 1988).

Lorax Environmental performed a geochemical sampling program to address the outstanding geochemical issues and questions concerning closure of the Cullaton Lake mine site. The sampling program was conducted from August 5-8, 2008 at the Cullaton Lake mine site. Samples were collected from the TP1 area, the waste rock dump adjacent to Shear Lake and the airstrip. The extent of the active layers, measured (by coring refusal depths) within the sub-aerial tailings was consistent across the TP1 at approximately 1.6 m depth. The active layer depth was confirmed by the presence of frozen tailings.

Since the thermistors installed in 1991 are no longer operational, depth to permafrost has been determined annually since 2007 by hand excavation of a test pit in the tailings, as shown in Photo 22 in Appendix A. The depth to permafrost was determined to be about 1.4 m (56 in) on September 3, 2015.

Although climate is the primary factor controlling the formation of permafrost, the ground thermal regime, permafrost and frost effects also depend on relief, vegetation, drainage, snow cover, and soil/rock exposure. Changes to any of these will alter the ground thermal regime, the distribution and extent of the permafrost and frozen ground, and the behavior or performance of the soils. The most important factors for Cullaton are drainage, vegetation, exposure of soil/rock and snow/ice cover.

The construction of the tailings structures and the impoundment of water have altered the thermal regime of the foundation soils. Impoundment of water will warm the permafrost on the upstream side of the tailings dam and, if seepage through the dam is significant, it will warm the permafrost beneath the dam (Brown & Johnston, 1970). Meanwhile, since the structures are essentially unchanged over decades, the dam has now developed its own thermal equilibrium from the effects of the underlying permafrost, drainage, surface conditions, and the climate at the surface.

Seepage through the TP1 dam suggests there is a perennial conduit for flow through the embankment active layer. However, there is limited information on the active layer thickness and its areal extent through the years. On-going seepage through the tailings dam has the potential to deepen the active layer and can degrade the underlying permafrost.

The impact of vegetation is gradual as it becomes established and grows in extent over the tailings area. Vegetation cover reduces the incoming radiation compared to a mineral soil surface and generally reduces the active layer thickness. The original tailings dam soil surface would have absorbed more solar radiation than a vegetated surface. Areas where the tailings surface is still exposed would develop thicker active layers than comparable vegetated areas.

Snow and ice cover also influence heat transfer at ground surface. Snow is a good insulator and thick snow cover will reduce cooling of the ground in areas compared to wind swept areas. The tailings pond ice cover will grow during winter and, where it reaches pond bottom, can enhance cooling of the ground (when compared to the cooling rate when adjacent to water). Shore-fast ice is an example of ice cover frozen to the ground and with the underlying soils also freezing (Proskin et al., 2011). It is difficult to assess the effect of ice and snow without ground temperature data or site observations during late winter and early spring.

Depending on the ground temperatures, soil gradation, and access to water, permafrost and the active layer soils may develop and accumulate ground ice. The most significant ground ice accumulations occur in soils with substantial fractions of fine grained material and access to water permitting the growth of ice lenses. BGC (2006) noted the potential of frost effects occurring in the fine grained (30-35% silt content) embankment. Significant settlement can occur when ice lenses in the active layer are melted during summer and these can leave remnant fissures in the soil that increase seepage.

The active layer and permafrost within and beneath the tailings dam can change due to thermal disturbances and the time dependent effects of seepage, snow/ice cover, and extent of vegetation cover. The main dam safety geotechnical risks associated with permafrost and the active layer are:

- Ice lensing in the dam fill and subsequent settlement of the fill should the ice lenses melt.
- Seepage through the active layer with potential erosion of ground ice and lowering of the permafrost table.

Previous experience has demonstrated that permafrost and seasonally frozen ground usually contain ice that fills voids and controls seepage and the exposure of tailings at depth to oxidation (Heginbottom, 2000). In extreme cases significant ground ice can occur within frost susceptible soils leading to stability/settlement issues if these thaw. Without some updated information we cannot discuss the potential beneficial or deleterious interactions among seepage, permafrost, active layer and physical/thermal stability of the tailings dam.

In lieu of ground temperature data, we recommend the annual measurement of active layer thickness include three to five measurements to provide better areal coverage of active layer development across the tailings dam. These measurements should be reviewed to see how they vary across the tailings pond and from year to year. Geotechnical observations should continue to watch for signs of fill settlement as an indication of thawed ice lenses as well as monitoring the seepage water quality for fines being washed out from the fill.

6.2 Geotechnical Review

6.2.1 Geological Setting

The Cullaton mine site area features undulating terrain with shallow surficial soils overlying bedrock. At the tailings pond site, the bedrock consists of Precambrian aged volcano-clastic rocks. The surficial deposits consist mainly of a bouldery till with localized surface organic deposits. The soil matrix of the glacial till is a well-graded, silty sand with no clay to traces of clay.

6.2.2 Slope Stability Evaluation

6.2.2.1 Embankment Stability

The embankment slopes of TP1 were observed to be stable, and have been reported stable over the past decade.

Original design drawings for the dams no longer exist and thus were not used in this review. BGC (2006) refers to records of the internal construction of the dam. According to EXP, the tailings dams were constructed predominantly of native till soil scraped from the surrounding ground surface (large boulders removed) and mine waste rock in some places. The embankment of TP1 had an average crest width of 10 m and a maximum height of 5.5 m, with crest elevation of about 97.5 m, and side slopes varying from about 2H:1V on the downstream side to 1H:1V on the upstream side.

Stability analyses of TP1 conducted by Trow in 1991 for the most critical dam section showed that the upstream face was unstable. The results were corroborated at that time by progressive edge failures noted along the pond shorelines of the impoundment area. However, Trow (1991) reported that progressive failures enough to cause dam breaching were unlikely. According to BGC (2006), in 1992 and 1993 the crest of TP1 was lowered and the side slopes flattened for closure, thereby increasing stability relative to the conditions previously analyzed.

On site, we observed no evidence of physical distress of the dam (e.g. cracking, settlement, or displacement of material).

6.2.2.2 Tailings Stability

The gold tailings deposit (which is limited in total areal extent to some 5 ha and in depth to a maximum of 1.4 m) is geotechnically stable.

Based on the reviewed documentation, the tailings ranges from a uniform silty sand on the west side (the point of spigotting or discharge), to a clayey silt at the east side of the pond, the furthest distance from the point of discharge. The maximum thickness of tailings measured by Trow in September 1990 was about 1.42 m in the beach area. The tailings cover beach slopes to the water's edge at an average slope of 1%, which is stable, and does not impart slope stability concerns.

6.2.3 Seepage and Erosion

Based on the A&R Plan (Trow, 1991), TP1 is a homogenous earthfill structure founded on bedrock. It has no internal filters or drains and, as noted by BGC (2006), it probably does not have any foundation seepage cut-off (core trench or grout curtain) – these structures are not mentioned in any report, and there are no details in the available records on foundation preparation for TP1. The pond water behind TP1, therefore, is expected to seep through the dam embankment fill and its foundation, and through the contact between these two.

TP1's embankment fill was likely compacted by construction equipment only, as evidenced by sagging at the edges of the dam, low areas in the crest, and undulations in the crest centerline. The loosely-compacted state of its fill, along with lack of plasticity of the till of which it was built, as well as permafrost effects, favour the development of internal erosion (piping). TP2, which was built in a similar fashion as TP1, breached in 1991, most likely due to internal erosion through a weak zone of poorly compacted fill (Trow, 1991). Breaching of TP1 due to internal erosion through the embankment cannot be ruled out. Nevertheless, this risk seems to be small because of low hydraulic gradients, especially after the lowering of the pond water level (BGC, 2006). Moreover, Barrick carries out routine site inspections every summer, when seepage rates are higher due to seasonal rain and thaw action. These inspections increase the likelihood of detecting early signs of piping, such as boils and sediment laden seepage water, as well as sinkholes or new subsidence on the embankment, and allow for the timely implementation of mitigative measures to prevent dam breach due to piping. It is important to keep in mind that piping erosion might take place even if there is no visible discharge of water, or if the discharged water is not muddy (ASDSO, 2016).

Seepage ponds were observed on the downstream side of TP1 (near the south end of the dam) during our site inspection on September 3, 2015 (see Photo XX) and in previous site inspection. According to BGC (2006), the fact that these ponds exist and were previously associated with a noticeable up-welling flow when TP1 water level was higher indicates that there are seepage paths within the underlying bedrock foundation. BGC further pointed out that these paths have likely found its way through a network of open fractures caused in part by seasonal frost jacking of the bedrock prior to TP1 construction. Some of these fractures may have been filled with ice and/or overburden. BGC added that, after TP1 impoundment, it is possible that thawing of the ice and frozen materials in the fractures has occurred, resulting in preferred seepage paths under the dam foundation. Seepage through the frost shattered zone may or may not increase in the future. Also, breaching of TP1 due to internal erosion through the weathered bedrock foundations cannot be ruled out, although less likely to occur, on account of the higher strength of the bedrock compared to the embankment till material. Based on observations conducted on TP1 by Messrs. P. Brugger and D. Georgiou over the past eight years, it appears that seepage has been steady, and the extent of the seepage ponds has not increased with time.

Small erosion scars were observed on both upstream and downstream sides of TP1 during previous inspections by Trow (and later, EXP). They noted that these scar appear to be stabilizing with vegetation growth, and that the larger rock particles from the dam fill and the mine waste rock have provided a self-armouring protection against the progression of surface erosion. Based on visual comparisons of previous years, the erosion scars do not appear to be increasing.

6.2.4 Seismic Evaluation

The stability of the TP1 embankment under seismic loading conditions was verified by Trow (1991). A cursory assessment of current seismic hazard values for Cullaton Lake area using the 2010 National Building Code's seismic hazard calculator (http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/index_2010-eng.php) confirm the peak ground acceleration (PGA) value used by Trow (0.04g) and the very low seismicity of the area. Moreover, based on surficial geology descriptions, the foundation soils do not contain liquefiable material.

6.2.5 Geotechnical Instrumentation and Monitoring

There are no surviving geotechnical instruments in the dam.

6.3 Hydrotechnical Review

Thurber retained Northwest Hydraulic Consultants Ltd. (NHC) to conduct hydrological and hydrotechnical studies to be incorporated as part of the dam safety assessment.

It is noted that TP1 is classified as a Low consequence dam, in terms of CDA Dam Safety Classification Guidelines CDA (2007, 2013, 2014).

6.3.1 Scope of Work

NHC's scope of work included conducting hydrological analyses including watershed delineation and determining the Inflow Design Flood (IDF) for the Low consequence dam. In addition, hydrotechnical studies included routing the IDF through the spillway and also checking the wind set-up and wave run up for TP1.

6.3.2 Hydrological Analyses

6.3.2.1 Regional Hydrology and Climate

Based on historic Water Survey of Canada (WSC) gauge data and climate station Climate Normals for the region, the hydrology of the Cullaton Lake watershed is typically dominated by snowfall from October through to May, with the main snowmelt period occurring sometime during the months of May and June. Snowpacks melt off quickly and produce rapidly rising flows in streams, with annual maximum peak flows typically occurring sometime between the end of May through to the end of June. It is expected that the largest snowmelt freshet peak flows are augmented by liquid precipitation (rain-on-snow events). Annual precipitation is relatively low (less than 300 mm/year), with a majority occurring as liquid in the June through to October period. Precipitation events during these months can also generate peak flows, but these are typically smaller than during the snowmelt freshet. Climate Normals for Arviat Airport and Baker Lake Airport are provided in Appendix D for reference from Environment Canada (EC). Neither of these stations are an ideal representations of conditions at Cullaton Lake, since Arviat is coastal and Baker Lake is further north, but these provide an idea of monthly precipitation and temperature at the site.

6.3.2.2 Drainage Area of Cullaton Lake

NHC derived the drainage area of TP1 using available Digital Elevation Model data in combination with drainage analysis utilizing GIS. The drainage area is estimated to be 0.74 km^2. This estimate has a degree of uncertainty due to the flat nature of topography in the area.

6.3.2.3 Determination of IDF: Regional Hydrologic Analysis

The Inflow Design Flood (IDF) of interest for a low consequence dam such as Cullaton Lake is one with a 100-year return period. Estimates for Cullaton Lake have been derived from Regional Hydrologic Analysis (regional analysis), and the Rational Method as described in Appendix D.

The estimate of the QPI-100 for Cullaton Lake using the regional analysis approach is 1.01 m^3/s, which is equivalent to 1,368 l/s/km^2. The relation is poor since it relies on only three gauges, resulting in a high level of uncertainty in the estimate. A similar regional analysis conducted by SRK Consulting (2003), as referenced by NHC in Appendix D, for the Jericho Project in Nunavut, which considered 25 WSC gauges, and defined best-fit and upper envelope curves for a plot of estimated QPI-100's for the gauges versus drainage area. A watershed with a drainage area equivalent to the size of Cullaton Lake's is estimated to have a QPI-100 of 800-1,150 l/s/km^2. This appears to indicate that the estimate within this study is too high; however, the smallest gauge in the SRK Consulting analysis was approximately 15 km^2, so there is also a high degree of uncertainty due to the high level of extrapolation to a much smaller watershed. The comparison at least indicates that the current estimate for Cullaton Lake is plausible.

6.3.2.4 Determination of IDF: Rational Method

The Rational Method was also used to assist in refining the estimate of the QPI-100 for Cullaton Lake. This method involves estimating the time of concentration for a watershed, and determining the peak flow that would occur if a rainfall event with a certain return period (and duration equivalent to the time of concentration) were to occur. The assumption is that rainfall return period is equivalent to the peak flow return period, which is not necessarily the case and one of the disadvantages of the Rational Method.

NHC conducted a sensitivity analysis of the Rational Method, with criteria scenarios and results. The QPI-100 for Cullaton Lake using the Rational Method approach is 2.58 m^3/s; it is recommended that QPI-100 estimates from both the Regional analysis and Rational Method be considered in hydrotechnical analyses.

6.3.3 Hydrotechnical Routing of IDF

Hydrotechnical routing was conducted for the IDF as determined by the Regional Analysis (1.01 m3/s) and the Rational Method (2.58 m^3/s). The one dimensional (1D) U.S. Army Corps of Engineers HEC-RAS hydraulic model was utilized to route flow through Spillway 1. In addition, Photos 3-1 and 3-2 contained in the 2014 Tailings Dam Examination (EXP, 2014b) were reviewed when assessing roughness coefficients to be applied for the spillway.

Figure 3-1 in Appendix D shows a section view of the routing of IDF flow over Spillway 1, as extracted from the HEC-RAS model.

Based on the analyses, the routing of the IDF resulted in a water level in TP1 of 93.8 m.

6.3.4 Wind Setup and Wave Runup Analysis

Following the routing of the IDF through Spillway 1, an analysis of wind setup and wave runup was performed following Canadian Dam Association's 2007 Dam Safety Guidelines (CDA, 2007). Normal and Minimum Freeboard requirements were assessed. Normal Freeboard was calculated using reservoir surface elevation at maximum normal level and 1000-year return period hourly wind speed. Minimum Freeboard was determined based on reservoir surface level at IDF with 100-year return hourly period wind speed.

An IDF water surface elevation of 93.8 metres geodetic datum (mgd) was established using averaged Regional Analysis and Rational Method estimates. Maximum normal operating water level was assumed to be at the spillway invert elevation of 93.3 mgd.

Design wind speeds were based on a frequency analysis of weather station data taken 130 km west of the project site. Minimum Freeboard calculations were performed with a 100-year hourly wind speed of 134 km/h at the weather station. For Normal Freeboard, 1000-year hourly wind speed at the weather station was taken to be 149 km/h. Given that the weather station anemometers used for the analyses are located immediately adjacent to a water body (within 500 m) and based on the flat topography with minimum obstructions in the area of the stations; onshore winds did not require adjustment for wind speed over water (RL) (USACE, 1984).

6.3.4.1 Wind Speed Data and Frequency Analyses

The closest location with wind speed data is EC's Ennadai Lake site, which is 130 km west of Cullaton Lake. The height of the wind speed sensor at the latter Ennadai Lake station (1980-2015) was 10 m as per World Meteorological Organization standards. The record at this site consists of two stations with hourly wind speed data, with the record from earlier and recent stations at the site ranging 1953-1979 and 1980-2015, respectively; the sites are close enough to be used as the same station, but the records also contain many data gaps. Hourly values provide an idea of the sustained speed of wind over TP1 for a sufficient duration to be able to generate waves (hourly is also the shortest duration available).

Using EC's "3 and 5" rule as a threshold for inclusion of data with gaps (in the calculation of Climate Normals, months with more than three consecutive days or five total days of missing data are excluded), but on an annual basis, the record was filtered to only include years that met this threshold (essentially 83.3 percent coverage for a year).

An assessment of the filtered data reveals an unusual record in the earlier portion of the dataset (1953-1979) in addition to a significant trend, and the data is considered suspect and was not used. The latter portion of the record (1980-2015) was used in frequency analysis with only 26 years available for analysis (this is the number of years meeting the 83.3% inclusion threshold). Frequency analyses estimate the 100-year and 1000-year hourly wind speeds to be 134 km/h and 149 km/h, respectively.

6.3.4.2 Wind Setup

Wind setup refers to the effect of wind exerting horizontal stress on a body of water, causing the water level to raise at the downwind end and lower at the upwind end (CDA, 2007). A bed elevation in TP1 of 91.3 mgd and 1H: 3V side slopes were assumed in the analyses.

Wind setup was found to be 0.13 m for Normal Freeboard. For Minimum Freeboard, wind setup height was calculated as 0.08 m.

6.3.4.3 Wave Runup

Wave runup is the height that waves attain when breaking against an embankment. Per CDA 2007 Guidelines, the wave runup elevation attained by 95 percent of waves caused by critical wind was calculated. Based on information provided in EXP (2014a, b), a side slope of 1H: 3V was assumed for TP1 side banks. For Minimum Freeboard at 100-year hourly wind speed, wave runup was found to be 1.25 m. At Normal Freeboard with 1000-year hourly wind speed, wave runup was determined to be 1.43 m.

6.3.4.4 Freeboard Requirements

Freeboard requirements were calculated by adding anticipated wind setup and wave runup heights to the water surface elevation. Results for Normal and Minimum Freeboard requirements are summarized in Table 4.1 of Appendix D. Minimum freeboard requirements are the governing conditions. The drawings for the facility currently show a low point on the dam crest at 94.1 m. A dam crest elevation of 95.1 mgd is required to meet freeboard requirements outlined in the 2007 CDA guidelines.

6.3.5 Hydrotechnical Conclusions and Recommendations

The analysis conducted by NHC confirmed that the IDF flow can be safely routed through Spillway 1 within the current design. However, the wind setup and wave runup analyses indicated that the current TP1 does not meet CDA guidelines with respect to freeboard requirements to account for wind setup and wave runup.

Hydrological and hydrotechnical analyses were conducted for the Cullaton Lake Gold Mine Tailings Facility Tailings Pond 1 (TP1). The Inflow Design Flood (IDF) for the low consequence dam (1/100 year flood event) was determined using the Regional Method (1.01 m^3/s) and the

Rational Method (2.58 m^3/s). Routing of the IDF through Spillway 1 was conducted utilizing the HEC-RAS modelling tool developed by the US Army Corps of Engineers. The average of the Regional and Rational Method IDF water levels for TP1 was adopted with a resultant water level of 93.8 m. Wind setup was found to be 0.13 m for Normal Freeboard and 0.08 m for Minimum Freeboard. At Normal Freeboard with 1000-year hourly wind speed, wave runup was determined to be 1.43 m. For Minimum Freeboard at 100-year hourly wind speed, wave runup was found to be 1.25 m. The drawings for the facility currently show a low point on the dam crest at 94.1 m. However, based on these analyses, a dam crest elevation of 95.1 mgd is required to meet freeboard requirements outlined in CDA (2007).

6.4 Structural / Mechanical Review

There is no structural or mechanical equipment installed or required at TP1, and this item is thus not addressed further.

6.5 Ecological Risk Assessment

Barrick retained AECOM in 2008 to document existing environmental conditions and to assess the potential ecological risks associated with the Cullaton Lake mine site at the time and for the future. The 2008 water quality program was conducted during the field visits from May to September (AECOM, 2008). Water samples from different locations across the Cullaton Lake mine area were collected. The study concluded that the overall surface water of the site was not impacted by the mining operations from 1981-1985 or current conditions. The chemical conditions of waste rock and tailings were found to be in an equilibrium condition, without any further changes expected from within the waste rock, tailings deposit and surface water. The key findings of the ecological risk assessment report were:

- Water quality in Shear Lake met the existing Water Licence Limits by NWB. However, the concentrations of heavy metals like Al, Cd, Co, Cu, Fe and Pb exceeded the CCME guideline in some samples. The sediment quality in Shear Lake was found to be generally good.
- Due to leaching from the waste rock pile, the concentrations of metals were elevated in seeps compared to other locations.
- Water quality in TP1 was found not to exceed the Water Licence Limits. The concentrations of some parameters were found higher according to the CCME guideline for the

protection of freshwater. However, there is a debate if this guideline is applicable for a tailings pond.

- Geochemical studies were performed by Lorax in 2009. The study confirmed that the thickness of the tailings cover was below 1 m, which is less than the proposed closure plan, as mentioned in BGC (2006). Therefore, oxidation and AMD were concluded to possibly be occurring.
- The concentration of metals in Shear Lake fish tissues was found comparable to other northern lakes and no evidence of metal accumulation in fish was found.
- A screening level risk assessment was conducted for chemicals of potential concern. Any potential risk from Cd, Co, Cu and Pb concentrations was ruled out. Potential risk for Al and Fe could not be entirely ruled out due to their observed concentrations in Shear Lake. But, the healthy presence of Arctic Grayling fish species in Shear Lake provided evidence that the metals are not bio-available at the total concentrations measured.
- Al is not a typical pollutant from gold tailings or waste rock, and Fe is only mobilized under acidic conditions.

All water samples reported by Barrick (Brugger, 2015) now show essentially neutral pH and are, therefore, unsurprisingly free of heavy metal contamination.

The results of the Ecological Risk Assessment are gratifying, and suggest that in the unlikely event of a dam failure, the ecological impact from any tailings which were to leave TP1, would be limited.

In addition, the work performed by AECOM in 2008 should be considered in developing decommissioning proposals for the site.

6.6 ARD Potential

The DSR team is of the opinion that ARD leaching potential from the tailings deposit is not a risk for the following reasons:

- Limited exposure time per year. Typically, only during July and August can oxidation occur, when the surface has thawed and temperatures are sufficiently high as per CANMET (AECOM, 2006).
- Average annual temperature for the site is -9°C. For more than eight months, the temperature is below freezing, thus limiting ARD leaching and transport.

- Ore mineralogy. SRK (1989) reported that the mining ore mineralogy of eastern Canada is not generally AMD generating, because of low sulphide content and low ambient temperature.
- Very limited amount of sulphur. There exists on site no more than 1.4 m depth of original gold tailings, covering 4 ha. It is difficult to find the deposit now, unless it is pointed out. Even if all the environmentally available sulphur were released from the small tailings body (which is not possible), it would be entirely diluted within a few km of release from the site. The outflow pH at the spillway remains neutral. Sulphate levels at the spillway ranged between 140 and 190 mg/l, (AECOM, 2008) well within drinking water standards (typically 500 mg/l).
- The actual potential to generate ARD. The CANMET tests suggested that in view of the low ambient temperature on site, the potential for generating ARD in the conditions to be expected on site was likely to be low (AECOM, 2008). Dawson & Morin (1996) in the AMD MEND report to INAC confirm that "tailings at the Cullaton Lake Mine do not generate AMD". They add that a short thaw period, seepage dilution, and high ground water table appear to account for the lack of acidity at this site.
- The extent of cover already in place. Tailings are no longer visible on the site, as may be seen from the 25 photos in Appendix A.
- The size of the tailings deposit. The Cullaton Lake TP1 is extremely small when compared to an average international gold mine.

BGC (2006) raised a concern regarding potential ecological impact from suspected ARD and metal leaching (ML) impacts in the Shear Lake mine area and TP1. Accordingly, in 2008 Barrick commissioned AECOM, who retained Lorax Environmental, to conduct a geochemical sampling program to address the concerns raised by BGC (2006). The samples were collected from three areas, described earlier in this report. A summary of the findings from the sampling program, in regard to AMD potential is as follows:

- No tailings samples from the TP1 area were found to be net acid generating. However, significant concentrations of oxygen were found to penetrate the cover. Therefore, the cover systems seemed to be not completely effective in limiting the entry of oxygen to prevent the potential for sulphide oxidation.
- Only Co and U in the submerged tailings of Pond 1 were found to be in excess of the CCME or Provincial Water Quality Objectives for Ontario. However, it is debatable if the

CCME guideline is applicable for a tailings pond. The short-term degradation potential of water quality in the TP1 was found to be low.

In the opinion of Thurber the potential for AMD from Cullaton Lake TP1 is negligible, and this factor should be considered in developing decommissioning proposals for the site.

7. OPERATIONS, MAINTENANCE AND SURVEILLANCE

7.1 General

Cullaton TP1 does not have a formal Operations, Surveillance and Monitoring (OMS) Manual. Instead, the surveillance and monitoring of the dam is subject to actions as laid down by:

1) The NWB water licence, conditions of use, and subsequent administrative requirements.
2) The lease agreement between Barrick and the Crown.
3) Barrick environmental stewardship standards and protocols.

At this long term stage (of monitoring and surveillance of the dam), it is not recommended that a formal OMS manual be developed, as the current manner of working by both Barrick, the mine owner, and the regulators (NWB and INAC), is effective, and no community or environmental concerns have been raised by third parties.

However, any of Barrick's own OMS and DSR procedures for the site should be documented systematically.

7.2 Program Organization, Responsibilities and Dam Inspections

Responsibility for surveillance and monitoring of TP1 within Barrick is under the leadership of Mr. Walter Baumann, Manager, Closure Program, delegated in turn to Mr. Paul Brugger, Barrick Canada and specialists such as Mr. Demetri Georgiou, Specialist Geotechnical Engineer from EXP.

Mr. Brugger is responsible for the annual water sampling and testing program, and Mr. Georgiou is responsible for the annual inspection and report for TP1.

8. EMERGENCY PREPAREDNESS AND PUBLIC SAFETY

These items fall under the responsibility of Barrick.

On account of the extreme remoteness of the site (only humanly accessible by air), the dam classification and the site dormancy, these items were not considered in further detail in this DSR.

9. DECOMMISSIONING OF TP1

The approach recommended for TP1 is to approach closure and decommissioning according to guidance recently compiled in OSTDC (2014).

The objectives for the closure of a tailings facility, and its transformation into a solid earthen structure that qualifies for de-licensing as a dam, are:

1) The structure should be modified in a manner that:
   a) It no longer meets the definition of a dam; and
   b) The probability of the facility ever reverting to a configuration that meets the definition of a dam is extremely low.
2) The resulting structure is considered to have a physical performance that, as a minimum, can be managed as a solid earthen structure (or a conventional waste dump) but that ideally is compatible with the performance of the natural landforms in the region.

We are not persuaded that an approach which assumes a worst or beyond worst inconceivable case is helpful in designing a functional closure scheme for Cullaton Lake TP1.

Instead, we are of the view that the entire area in question is returning to a natural habitat in time, without further untoward human intervention, save for monitoring, albeit on a less frequent basis than annually. There are no downstream or even remotely close human or environmental habitats which appear to be at any risk at all. There are many more substantially contaminated sites in each of our major Canadian cities than may be found at Cullaton Lake. This is not to say that a precautionary approach should not be followed, but rather that it should be a pragmatic one.

The primary author, Jeremy Boswell, in over 35 years of inspection of tailings facilities, has not encountered a tailings facility which offers less risk to the receiving human or natural environment than Cullaton Lake TP1.

This site was inherited from previous lease holders (Corona, Homestake) and previous owners (NWT). A risk based approach is advocated for decommissioning and closure. In other words, where the absence of risk allows, or demonstrated low risk exists, to develop a pragmatic approach to closure which would be unique for this site, but that would be affordable and allow a progressive return of the site to natural or near-natural conditions.

In view of the demonstrated limited potential for AMD, the ongoing cost of monitoring dam safety, and the limited future usefulness of TP1, Thurber recommends that consideration be given to the decommissioning of the dam.

10. RECOMMENDATIONS

1) The approach to management of TP1 is sound and with the exception of recommendation no. 3 below, no improvements to ongoing dam safety management in the short term are considered necessary.
2) The analysis conducted by NHC (Appendix D) as part of this DSR, confirmed that the IDF flow can be safely routed through Spillway 1 within the current design. However, the wind setup and wave runup analyses indicated that the current TP1 does not meet CDA guidelines with respect to freeboard requirements to account for wind setup and wave runup.
3) It is recommended that consideration be given in the short term to reducing the spillway level, to enable TP1 to meet CDA guidelines for wind setup and wave runup.
4) In the longer term, consideration should be given to decommissioning of TP1 as a dam and an investigation of the potential of not storing water at all.
    a) It is not in anyone's interest to continue to operate a dam whose purpose appears to have been served, and where the consequences of failure are low.
    b) The potential for ARD has been demonstrated from specialist opinion and long term monitoring to be very low, and may be dismissed.
    c) The site is very remote. Access to the site and monitoring are challenging.
    d) No dam is completely weatherproof. The longer the dam needs to be maintained, the greater the exposure to the effects of weathering. Freeze-thaw cycles will continue to act on the dyke, and have potential to cause long term deterioration both externally (weathering) and internally (piping). The life of the spillway may also not be indefinite without some maintenance in the long term.

5) While TP1 continues to be operated as a dam, monitoring of TP1 should be more closely aligned with the credible modes of failure as described in this report.
6) General comments.

In view of the long passage of time since closure, there is an abundance of documentation regarding the site, including the detailing of a substantial number of site inspections and site assessments by a broad range of specialists.

In terms of the CDA guidelines, TP1 has been classified (in this DSR) as a low category dam, with low consequence of failure of any credible failure mode.

Closure efforts by Barrick (and others) and ecologically restorative natural processes have largely been successful in restoring the land to near natural condition for this very small tailings deposit (entire extent not more than 1.5 m in depth and area of around 4 ha).

Issues such as permafrost effects, embankment seepage and stability, and ARD have been reviewed based on the information provided and have been found to be of low consequence and probability.

The current routine of continued annual inspections, extensive water sampling and ongoing communication between various parties, now offers seemingly diminishing returns and may preclude more pro-active approaches to addressing specific decommissioning issues.

The risks facing the site have been identified, assessed and addressed by a large number of experts over the years. A risk based approach rather than a prescriptive checklist approach would now be more effective in addressing long term requirements to achieve true decommissioning of TP1, and allowing the closure of the mine site and the return of the land to the Crown.

If this approach is acceptable, then confirming the absence of long term risks and monitoring the site accordingly appears logical.

A once every three years inspection period is recommended in favour of an annual inspection, with more substantial information that can be collected instead. Reference should be made to CDA (2014) in this regard.

If continued monitoring, decommissioning and aftercare is required, some attention should be paid to the maintenance of the access road.

11. LIMITATIONS

None.

12. ACKNOWLEDGEMENTS

The Thurber DSR team would like to acknowledge the support of Barrick personnel Messrs. Paul Brugger, Walter Baumann, Michael Shelbourn and Dan Bornstein, who provided considerable historical documentation to the review team, guided the team on site during the site inspection, provided historical perspectives on the operations of Cullaton Lake gold mine and TP1, and reviewed the draft report.

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13.2 Other Technical References

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d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

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APPENDIX A

Terrestrial Photographs

Date of Photography: September 3, 2015

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Photo 1. Typical waste rock over crest of Tailings Dam

Photo 2. Progression of vegetation cover over tailings and cover

Photo 3. Faint evidence of oxidation of waste rock (yellowing).

Photo 4.Tailings and sheetwash faintly visible below surface.

Photo 5. Pioneer species of bush which has rapidly accelerated in growth this summer over all exposed areas.

Photo 6. Biotic activity in spillway of No. 1 dam.

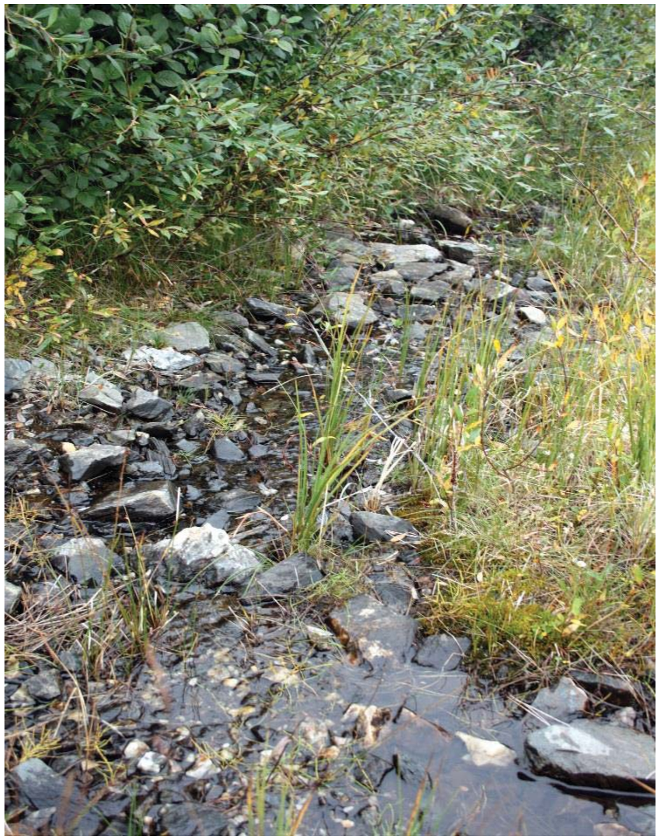

Photo 7. Vegetation cover in lightly flowing spillway of TP1.

Photo 8. Exposure of edge of liner in spillway.


Photo 9. Waste rock pile on downstream slope of TP1.


Photo 10. View immediately downstream of spillway of TP1.

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Photo 11. Wet patch on downstream toe of TP1 with D. Georgiou, P.Eng.

Photo 12. Semi-permanent wet area at downstream toe. (Ref D. Georgiou)

Photo 13. Shreds of liner dumped with spoil obtained from wall of TP2, to cover tailings in TP1.

Photo 15. Area of tailings showing old thermistor locations and location of permafrost test pit.

Photo 15. (same as previous) Note area where till is now being gradually covered with natural regrowth of vegetation.

Photo 16. Till cover mixed with waste rock with natural vegetative cover appearing.

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Photo 17. Area of previously exposed gold tailings, now covered with till and progressively being revegetated naturally.

Photo 18. East facing view of the main embankment of TP1.

Photo 19. View westwards from TP1 showing natural vegetation in distance, reclaimed tailings in foreground.

Photo 20. E facing view from W of TP1 showing progression in revegetation.

Photo 21. Bare patches with some exposed till.

Photo 22. Excavation to permafrost depth showing unoxidized gold tailings (grey colour).

Photo 23. Extensive Water Sampling Program.

Photo 24. Flow from spillway of Dam no. 2.

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Photo 25. View looking NW from no. 2 spillway towards TP1.

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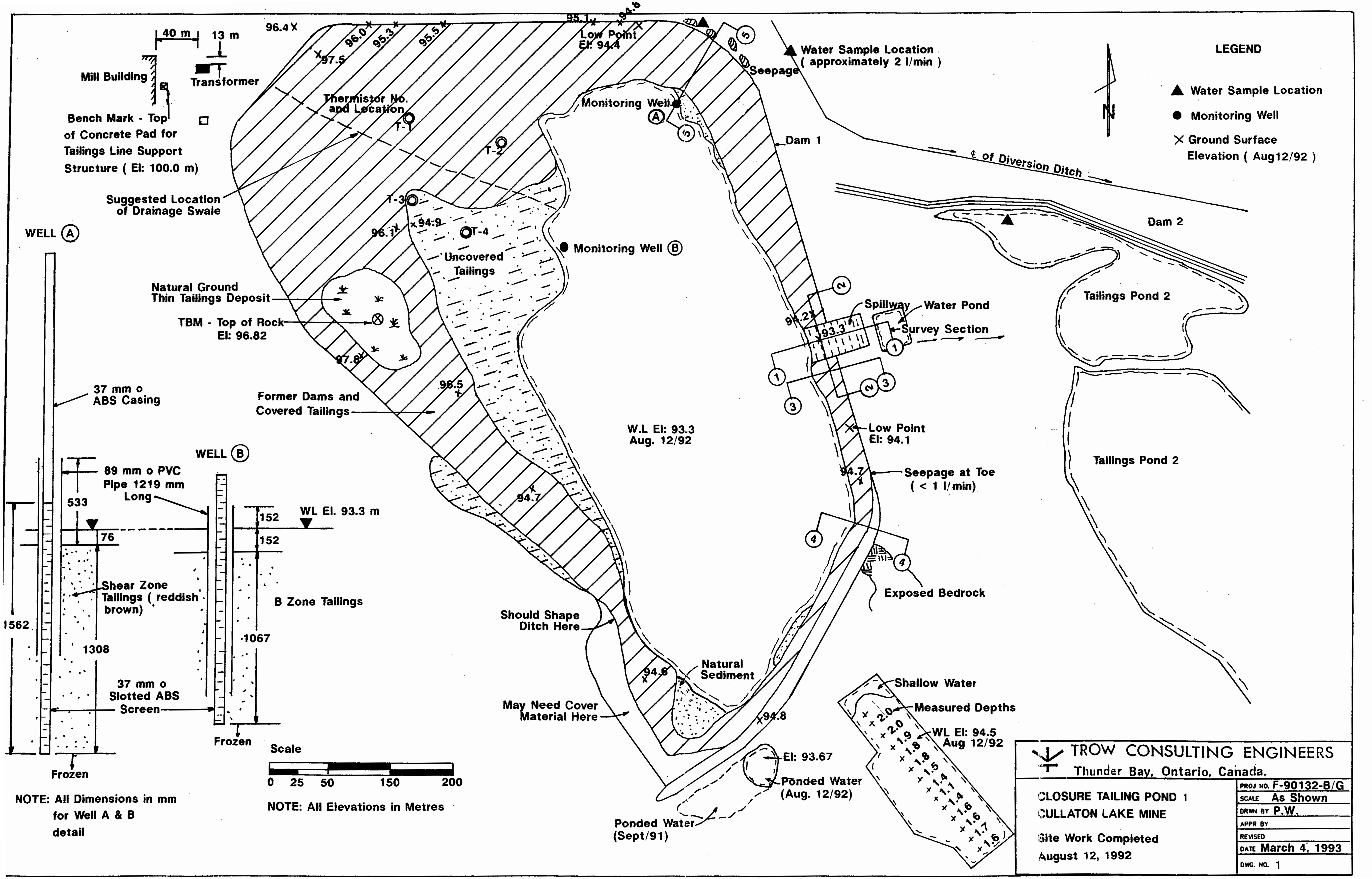
APPENDIX B

Trow Sketch Drawing No.1, dated 1993 (EXP, 2011)



TROW CONSULTING ENGINEERS
Thunder Bay, Ontario, Canada.
CLOSURE TAILING POND 1
CULLATON LAKE MINE
Site Work Completed
August 12, 1992
PROJ NO. F-90132-B/G
SCALE As Shown
DRWN BY P.W.
APPR BY
REVISED
DATE March 4, 1993
DWG. NO. 1
LEGEND
Water Sample Location
Monitoring Well
Ground Surface Elevation (Aug12/92)
N
40 m
13 m
Mill Building
Transformer
Bench Mark - Top of Concrete Pad for Tailings Line Support Structure (El: 100.0 m)
Suggested Location of Drainage Swale
Thermistor No. and Location
T-1
T-2
T-3
T-4
96.4
97.5
96.0
95.3
95.5
95.1
94.8
Low Point El: 94.4
Seepage
Water Sample Location (approximately 2 l/min)
Monitoring Well
Dam 1
℄ of Diversion Ditch
Dam 2
Tailings Pond 2
96.1
94.9
Uncovered Tailings
Monitoring Well B
Natural Ground Thin Tailings Deposit
TBM - Top of Rock El: 96.82
97.8
96.5
Former Dams and Covered Tailings
94.7
W.L El: 93.3 Aug. 12/92
94.2
93.3
Spillway
Water Pond
Survey Section
Low Point El: 94.1
94.7
Seepage at Toe (< 1 l/min)
Exposed Bedrock
Should Shape Ditch Here
May Need Cover Material Here
94.6
Natural Sediment
94.8
El: 93.67
Ponded Water (Aug. 12/92)
Ponded Water (Sept/91)
Shallow Water
Measured Depths
WL El: 94.5 Aug 12/92
2.0
2.0
1.9
1.8
1.8
1.5
1.4
1.1
1.4
1.6
1.6
1.7
1.6
WELL A
37 mm o ABS Casing
89 mm o PVC Pipe 1219 mm Long
533
76
1562
Shear Zone Tailings (reddish brown)
1308
37 mm o Slotted ABS Screen
Frozen
WELL B
WL El. 93.3 m
152
152
B Zone Tailings
1067
Frozen
Scale
0 25 50 150 200
NOTE: All Dimensions in mm for Well A & B detail
NOTE: All Elevations in Metres

APPENDIX C

Aerial Photographs (from EXP, 2014)

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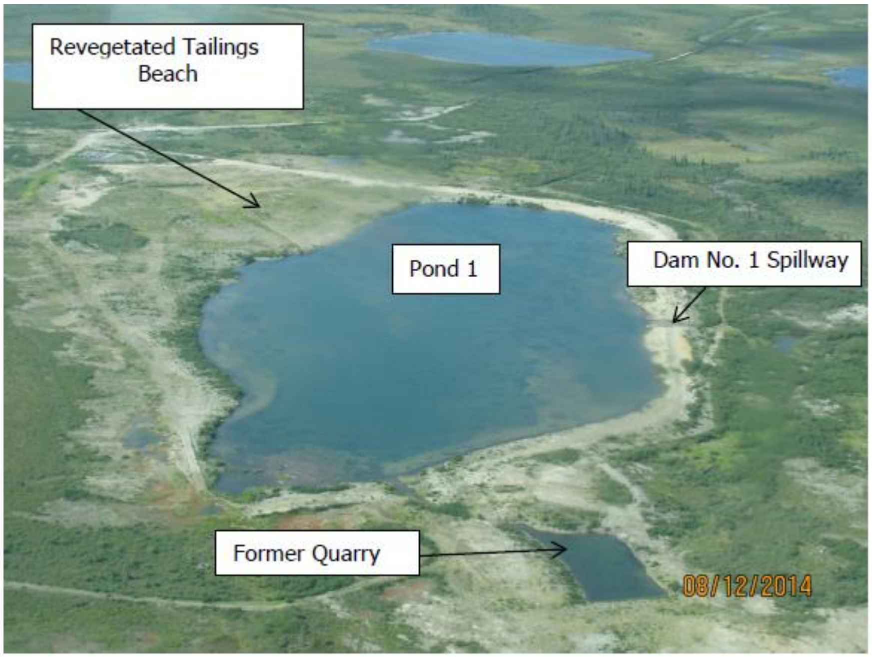

Photo 26. Tailings facility looking north [Reference: EXP 2014 annual geotechnical inspection report]

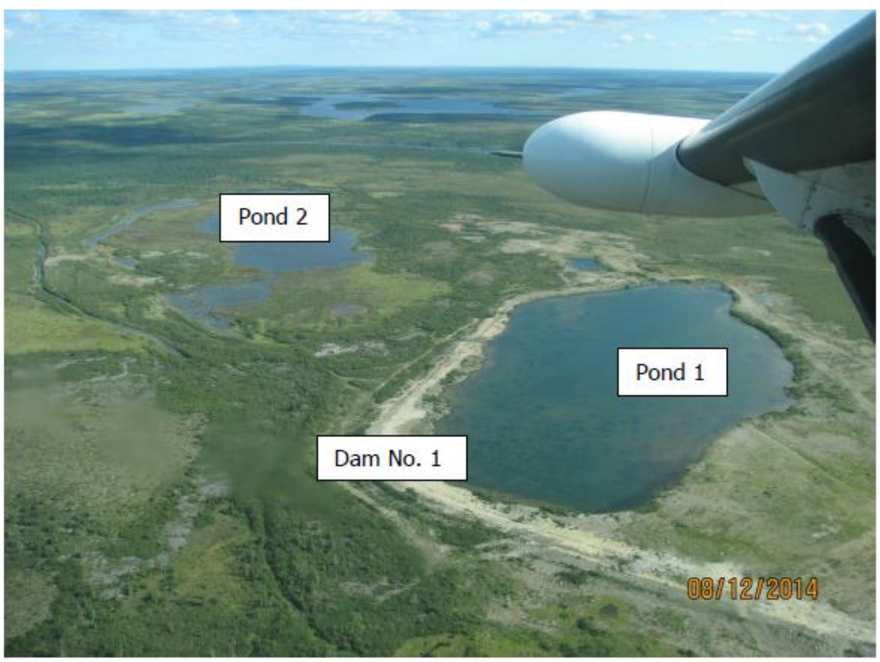

Photo 17. Tailings facility looking southeast [Reference: EXP 2014 annual geotechnical inspection report]

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APPENDIX D

Hydrotechnical Analysis by NHC (July 8, 2016)

nhc
northwest hydraulic consultants ltd

NHC Ref. No. 3001972

08 July 2016

Thurber Engineering Ltd.
180, 7330 Fisher Street SE
Calgary, AB
T2H 2H8

Attention: **Jeremy Boswell, M.Eng., P.Eng.**
Senior Associate / Senior Tailings Engineer

Via email: JBoswell@thurber.ca

Re: **Cullaton Lake Gold Mine Tailings Facility, Tailings Pond 1**
Dam Safety Hydrological and Hydrotechnical Analyses

1 INTRODUCTION

Cullaton Lake Gold Mine Tailings Facility (Cullaton Lake GMTF) is located in Nunavut within the treeline and zone of discontinuous permafrost. The site is located approximately 350 km southwest of Baker Lake; 237 km west of Arviat; 670 km north of Thompson, Manitoba; and 415 km northwest of Churchill, Manitoba. The Cullaton Lake Gold Mine began operating in 1981 and has been closed since 1985.

The Cullaton Lake property comprises a gravel airstrip; gravel access road; waste rock dump; covered subaerial tailings (dry); a tailings pond; and a water pond. Appendix A contains sketches of the facility. Tailings Pond 1 (TP1) contains deposited tailings from the mining operations and Tailings Pond 2 (TP2) provided supplementary retention for natural cyanide degradation at the time.

Thurber Engineering Ltd. (Thurber) is providing Barrick Gold Corporation (Barrick) with tailings and geotechnical services with regards to the dam safety assessment of the Cullaton Lake Gold Mine TP1. It is noted that TP1 is classified as a Low consequence dam. Thurber retained Northwest Hydraulic Consultants Ltd. (NHC) to conduct hydrological and hydrotechnical studies to be incorporated as part of the dam safety assessment.

1.1 Scope of Work

NHC's scope of work included conducting hydrological analyses including watershed delineation and determining the Inflow Design Flood (IDF) for the Low consequence dam. In addition, hydrotechnical studies included routing the IDF through the spillway and also checking the wind set-up and wave run up for TP1.

2 HYDROLOGICAL ANALYSES

2.1 Regional Hydrology and Climate

Based on historic Water Survey of Canada (WSC) gauge data and climate station Climate Normals for the region, the hydrology of the Cullaton Lake watershed is typically dominated by snowfall from October through to May, with the main snowmelt period occurring sometime during the months of May and June. Snowpacks melt off quickly and produce rapidly rising flows in streams, with annual maximum peak flows typically occurring sometime between the end of May through to the end of June. It is expected that the largest snowmelt freshet peak flows are augmented by liquid precipitation (rain-on-snow events). Annual precipitation is relatively low (less than 300 mm/year), with a majority occurring as liquid in the June through to October period. Precipitation events during these months can also generate peak flows, but these are typically smaller than during the snowmelt freshet. Climate Normals for Arviat Airport and Baker Lake Airport are provided below for reference from Environment Canada (EC). Neither of these stations are an ideal representations of conditions at Cullaton Lake, since Arviat is coastal and Baker Lake is much further north, but these provide an idea of monthly precipitation and temperature at the site.

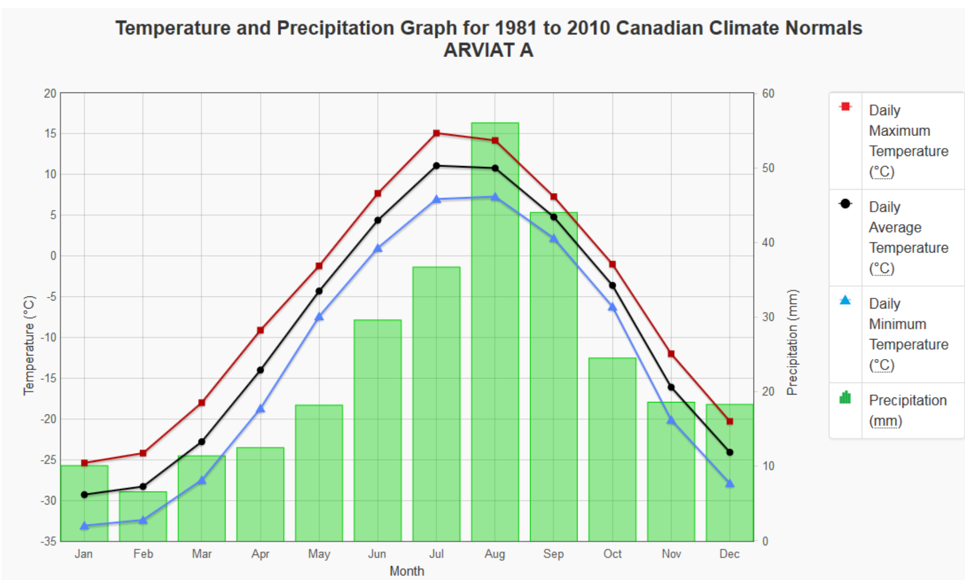

Figure 2-1 EC Arviat Airport station 1981-2010 Climate Normal.

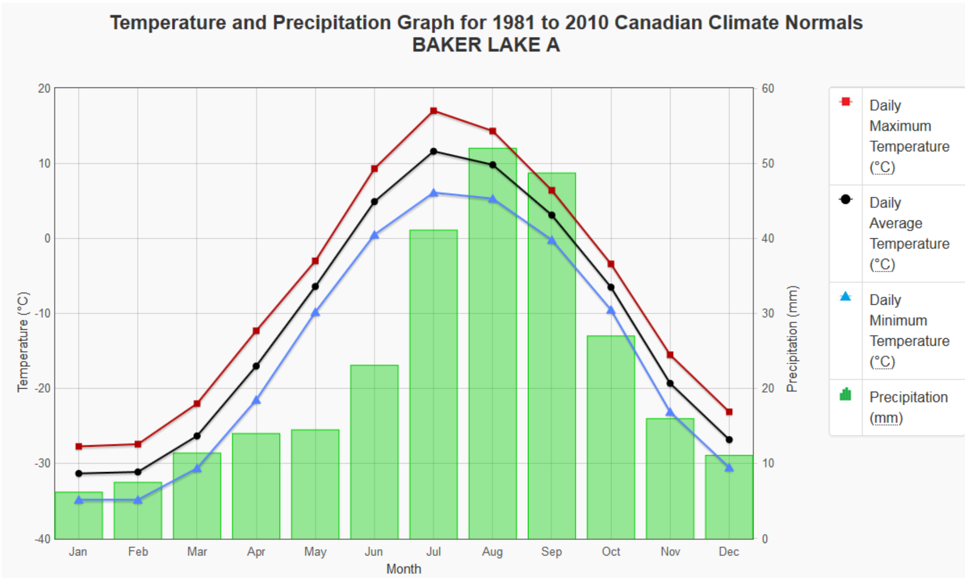

Figure 2-2 EC Baker Lake Airport station 1981-2010 Climate Normal.

2.2 Drainage Area of Cullaton Lake

NHC derived the drainage area of Cullaton lake using available Digital Elevation Model data in combination with drainage analysis utilizing GIS. The drainage area is estimated to be 0.74 km^2, but this estimate has a high level of uncertainty due to the flat nature of topography in the area.

2.3 Determination of IDF: Regional Hydrologic Analysis

The Inflow Design Flood (IDF) of interest for a low consequence dam such as Cullaton Lake is one with a 100-year return period. Estimates for Cullaton Lake have been derived from Regional Hydrologic Analysis (regional analysis), described in this section, and the Rational Method as described in the following section.

WSC gauges in the region with sufficient record periods for estimating a 100-year return period are far and few between:

- Akkutuak Creek near Baker Lake 06MA004 (WSC Akkutuak) with a drainage area of 19 km^2 (350 km north-northeast of Cullaton Lake)
- Sapochi River near Nelson House 05TG006 (WSC Sapochi) with a drainage area of 392 km^2 (600 km south of Cullaton Lake)
- Meadowbank River above Nanau Lake 10RC002 (WSC Meadowbank) with a drainage area of 2,120 km^2 (475 km north-northeast of Cullaton Lake)
- Brown River at the Outlet Of Brown Lake 06OA007 (WSC Brown) with a drainage area of 4,683 km^2 (630 km northeast of Cullaton Lake)

The drainage areas of these sites are much larger than Cullaton Lake, and all would be typically unsuitable for estimating peak flows for such a relatively small site; however, given the lack of available data, considering all gauges at least provide an idea of scaling by drainage area for the region. WSC Brown was excluded from the analysis as it is much too large, and it is also at the outlet of a lake.

The annual maximum peak flow records for WSC Akkutuak (12 years), WSC Sapochi (22 years), and WSC Meadowbank (9 years) were used in frequency analyses to determine the 100-year instantaneous peak flow (QPI-100). Instantaneous peak flows were missing for one and three years at WSC Meadow and WSC Sapochi, respectively, and were estimated using linear relations between daily and instantaneous peak flows. The instantaneous peak flows were missing for all but one year at WSC Akkutuak, and instantaneous peak flows were estimated using the ratio from the one available year (this is not ideal, but no other data exists to assist in estimating ratios for this gauge). The estimates of the QPI-100 for the three gauges were plotted versus drainage area, and the following linear relation (r = 0.993) was developed to estimate the QPI-100 for Cullaton Lake:

$$\text{QPI-100 } (m^3/s) = 1.2198 \times (\text{Drainage Area in } km^2)^{0.6256}$$

The estimate of the QPI-100 for Cullaton Lake using the regional analysis approach is 1.01 m^3/s, which is equivalent to 1368 L/s/km^2. The relation is poor since it relies on only three gauges, resulting in a high level of uncertainty in the estimate. A similar regional analysis conducted by SRK Consulting (2003) for the Jericho Project in Nunavut, which considered 25 WSC gauges, and defined best-fit and upper envelope curves for a plot of estimated QPI-100's for the gauges versus drainage area. A watershed with a drainage area equivalent to the size of Cullaton Lake's is estimated to have a QPI-100 of 800-1150 L/s/km^2. This appears to indicate that the estimate within this study is too high; however, the smallest gauge in the SRK Consulting analysis was approximately 15 km^2, so there is also a high degree of uncertainty due to the high level of extrapolation to a much smaller watershed. The comparison at least indicates that the current estimate for Cullaton Lake is plausible.

2.4 Determination of IDF: Rational Method

The Rational Method was also used to assist in refining the estimate of the QPI-100 for Cullaton Lake. This method involves estimating the time of concentration for a watershed, and determining the peak flow that would occur if a rainfall event with a certain return period (and duration equivalent to the time of concentration) were to occur. The assumption is that rainfall return period is equivalent to the peak flow return period, which is not necessarily the case and one of the disadvantages of the Rational Method. The equation of the Rational Method is copied below from the BC Ministry of Transportation TAC Supplement (2007):

$$Q_p = \frac{CiA}{360}$$

Q_p	is the peak flow, m^3/s
C	is the runoff coefficient
i	is the rainfall intensity = P/T_c mm/hr
P	is the total precipitation, mm
T_c	is the time of concentration, hr
A	is the drainage area, ha

Several methods were used to estimate times of concentration (Tc) for the Cullaton Lake watershed: Kirpich (1.06 hours), Hathaway (1.41 hours), Bransby-Williams (0.85 hours), and the more complex USBR method (0.36 hours).

Rainfall intensities for Cullaton Lake were interpolated from EC Intensity-Duration-Frequency rainfall curves available for Baker Lake Airport (using data 1987-2009, 22 years) and Lynn Lake Airport (using data 1969-2005, 34 years), which is 500 km southwest of Cullaton Lake.

Thurber provided NHC with information on surficial soils:

- Surficial deposits are bouldery till with a well-graded silty sand matrix;
- The range of hydraulic conductivities is expected to be 1 x 10^{-7} m/s to 1 x 10^{-3} m/s, with vertical hydraulic conductivities expected to range 1 x 10^{-7} m/s to 1 x 10^{-3} m/s (could be higher if there are open, vertical fissures in the soil after thaw); and,
- The typical active layer is expected to be to a depth of 1.4 m for August, varying linearly between 0 m and 1.4 m from May to August (due to frost).

In consideration of the above and conditions at site (rocky with well drained slopes and little vegetation), and the likelihood of partially frozen soil during the snowmelt period, the runoff coefficient for natural ground could be expected to be 0.3. This was increased by 0.08 to account for a 100-year return period, as per recommendations in the RTAC Drainage Manual Vol 1 (1982), and further increased by 0.1 to account for snowmelt (i.e. the largest events are expected to be rain-on-snow).

NHC conducted a sensitivity analysis of the Rational Method, with criteria scenarios and results as shown in **Table 2.1.**

Table 2.1 Criteria scenarios and results of Rational Method sensitivity analyses for Cullaton Lake.

Criteria Scenario	QPI-100 (m^3/s)	QPI-100 ($L/s/km^2$)
1. Drainage area as calculated (0.74 km²) and Average Tc (0.92 hours)	**2.58**	**3,498**
2. Drainage area as calculated (0.74 km²) and Lowest Tc (0.36 hours)	4.76	6,470
3. Drainage area half (0.37 km²) and Lowest Tc (0.36 hours)	3.78	10,27
4. Drainage area as calculated (0.74 km²) and Highest Tc (1.41 hours)	1.95	2,652

Scenario 1 was selected in consideration of the large range of Tc (it is better that an average be used), and the unrealistic unit peak flows for Scenarios 3 and 4. **The QPI-100 for Cullaton Lake using the Rational Method approach is 2.58 m^3/s;** it is recommended that QPI-100 estimates from both the Regional analysis and Rational Method be considered in hydrotechnical analyses.

3 HYDROTECHNICAL ROUTING OF IDF

Hydrotechnical routing was conducted for the IDF as determined by the Regional Analysis (1.01 m3/s) and the Rational Method (2.58 m^3/s). The one dimensional (1D) U.S. Army Corps of Engineers HEC-RAS hydraulic model was utilized to route flow through Spillway 1. In addition, Photos 3-1 and 3-2 contained in the 2014 Tailings Dam Examination (EXP, 2014)[1] were reviewed when assessing roughness coefficients to be applied for the spillway. The Manning's n roughness factor sensitivity analysis consisted of varying the roughness factor between 0.03 and 0.05 for the spillway. The modelling indicated that the variation in the factor from 0.03 to 0.05 resulted in a maximum range in water levels of 0.05 m. Based on the spillway properties, a Manning's n roughness coefficient of 0.04 was applied for Spillway 1. **Figure 3-1** shows a section view of the routing of IDF flow over Spillway 1, as extracted from the HEC-RAS model.

[1] EXP. 2014 Tailings Dam Examination, Cullaton Lake Gold Mine, Nunavut, Licence 1BR-CUL1118, Prepared for Barrick Gold Corporation, September 18, 2014.

Photo 3-1 – TP1, Spillway 1 Inlet and Crest (Photo 6 of EXP, 2014)

Photo 3-2 – TP1, Spillway 1 Downstream Channel (Photo 7 of EXP, 2014)

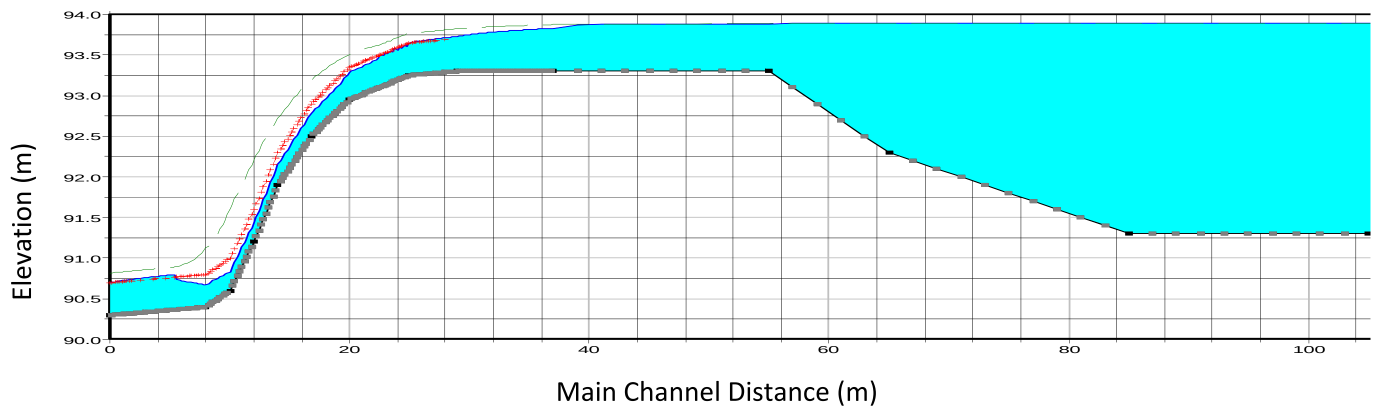

Figure 3-1 – Section View Showing the Routing of the IDF through Spillway 1

Table 3.1 summaries the resultant water levels for conditions with the IDF (Regional and Rational) routed through Spillway 1.

Table 3.1 – Resultant Spillway Water Levels and Freeboard for IDF

	IDF Regional Method 1.01 m³/s	IDF Rational Method 2.58 m³/s	Adopted IDF Flood Levels (Average of Regional and Rational Levels)
Water Level (m)	93.7	93.9	**93.8**
Freeboard (m)	0.4	0.2	**0.3**
Lowest point on dam crest at El. 94.1 m			

Based on the analyses, the routing of the IDF resulted in a water level in TP1 of El. 93.8 m.

4 WIND SETUP AND WAVE RUNUP ANALYSIS

Following the routing of the IDF through Spillway 1, an analysis of wind setup and wave runup was performed following Canadian Dam Association's 2007 Dam Safety Guidelines (CDA, 2007)[2]. Normal and Minimum Freeboard requirements were assessed. Normal Freeboard was calculated using reservoir surface elevation at maximum normal level and 1000-year return period hourly wind speed. Minimum Freeboard was determined based on reservoir surface level at Inflow Design Flood (IDF) with 100-year return hourly period wind speed.

[2] Canadian Dam Association, Dam Safety Guidelines 2007 (2013 Edition).

An IDF water surface elevation of El. 93.8 m geodetic datum (GD) was established using averaged Regional Analysis and Rational Method estimates. Maximum normal operating water level was assumed to be at the spillway invert elevation of 93.3 m GD.

Design wind speeds were based on a frequency analysis of weather station data taken 130 km west of the project site. Minimum Freeboard calculations were performed with a 100-year hourly wind speed of 134 km/h at the weather station. For Normal Freeboard, 1000-year hourly wind speed at the weather station was taken to be 149 km/h. Given that the weather station anemometers used for the analyses are located immediately adjacent to a water body (within 500 m) and based on the flat topography with minimum obstructions in the area of the stations; onshore winds did not require adjustment for windspeed over water (R_L). (Shore Protection Manual Volume 1, 1984)[3].

4.1 Wind Speed Data and Frequency Analyses

The closest location with wind speed data is EC's Ennadai Lake site, which is 130 km west of Cullaton Lake. The height of the wind speed sensor at the latter Ennadai Lake station (1980-2015) was 10 meters as per World Meteorological Organization standards. The record at this site consists of two stations with hourly wind speed data, with the record from earlier and recent stations at the site ranging 1953-1979 and 1980-2015, respectively; the sites are close enough to be used as the same station, but the records also contain many data gaps. Hourly values provide an idea of the sustained speed of wind over TP1 for a sufficient duration to be able to generate waves (hourly is also the shortest duration available).

Using EC's "3 and 5" rule as a threshold for inclusion of data with gaps (in the calculation of Climate Normals, months with more than 3 consecutive days or 5 total days of missing data are excluded), but on an annual basis, the record was filtered to only include years that met this threshold (essentially 83.3 percent coverage for a year).

An assessment of the filtered data reveals an unusual record in the earlier portion of the dataset (1953-1979) in addition to a significant trend, and the data is considered suspect and was not used. The latter portion of the record (1980-2015) was used in frequency analysis with only 26 years available for analysis (this is the number of years meeting the 83.3 percent inclusion threshold). **Frequency analyses estimate the 100-year and 1000-year hourly wind speeds to be 134 km/hr and 149 km/hr**, respectively.

4.2 Wind Setup

Wind setup refers to the effect of wind exerting horizontal stress on a body of water, causing the water level to raise at the downwind end and lower at the upwind end (CDA, 2007). A bed elevation in TP1 of El. 91.3 m and 1H:3V side slopes were assumed in the analyses based on information provided by EXP

[3] Coastal Engineering Research Center, Department of the Army, Waterways Experiment Station, Corps of Engineers, Shore Protection Manual Volume 1, 1984.

(2014). Wind setup was found to be 0.13 m for Normal Freeboard. For Minimum Freeboard, wind setup height was calculated as 0.08 m.

4.3 Wave Runup

Wave runup is the height that waves attain when breaking against an embankment. Per CDA 2007 Guidelines, the wave runup elevation attained by 95 percent of waves caused by critical wind was calculated. Based on information provided in EXP (2014), a side slope of 1H:3V was assumed for TP1 side banks. For Minimum Freeboard at 100-year hourly wind speed, wave runup was found to be 1.25 m. At Normal Freeboard with 1000-year hourly wind speed, wave runup was determined to be 1.43 m.

4.4 Freeboard Requirements

Freeboard requirements were calculated by adding anticipated wind setup and wave runup heights to the water surface elevation. Results for Normal and Minimum Freeboard requirements are summarized in **Table 4.1**. Minimum freeboard requirements are the governing conditions. The drawings for the facility currently show a low point on the dam crest at El. 94.1 m. A dam crest elevation of El. 95.1 m GD is required to meet freeboard requirements outlined in CDA 2007 guidelines.

Table 4.1 - Normal and Minimum Freeboard Requirements based on wind setup and wave runup

	Normal Freeboard	Minimum Freeboard
Weather station wind speed, W (km/h)	149	134
Water surface elevation (m GD)	93.3	93.8
Wind setup (m)	0.13	0.08
Wave runup (m)	1.43	1.25
Required dam crest elevation (m GD)	**94.9**	**95.1**

5 CONCLUSIONS AND RECOMMENDATIONS

Hydrological and hydrotechnical analyses were conducted for the Cullaton Lake Gold Mine Tailings Facility Tailings Pond 1 (TP1). The Inflow Design Flood (IDF) for the low consequence dam (1/100 year flood event) was determined using the Regional Method (1.01 m^3/s) and the Rational Method (2.58 m^3/s). Routing of the IDF through Spillway 1 was conducted utilizing the HEC-RAS modelling tool developed by U.S. Army Corps of Engineers. The average of the Regional and Rational Method IDF water levels for TP1 was adopted with a resultant water level of El. 93.8 m. Wind setup was found to be 0.13 m for Normal Freeboard and 0.08 m for Minimum Freeboard. At Normal Freeboard with 1000-year hourly wind speed, wave runup was determined to be 1.43 m. For Minimum Freeboard at 100-year hourly wind speed, wave runup was found to be 1.25 m. The drawings for the facility currently show a low point on the dam crest at El. 94.1 m. However, based on these analyses, a dam crest elevation of El. 95.1 m geodetic datum (GD) is required to meet freeboard requirements outlined in CDA 2007 guidelines.

DISCLAIMER

This document has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of **Thurber Engineering Ltd.** for specific application to the **Cullaton Creek Gold Mine Facility, Tailings Pond 1 located on Cullaton Lake in Nunavut.** The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic Consultants Ltd.** at the time of preparation, and was prepared in accordance with generally accepted engineering practices.

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Sincerely,

Northwest Hydraulic Consultants Ltd.

Prepared by:

"original signed by"

Daniel Maldoff

"original signed by"

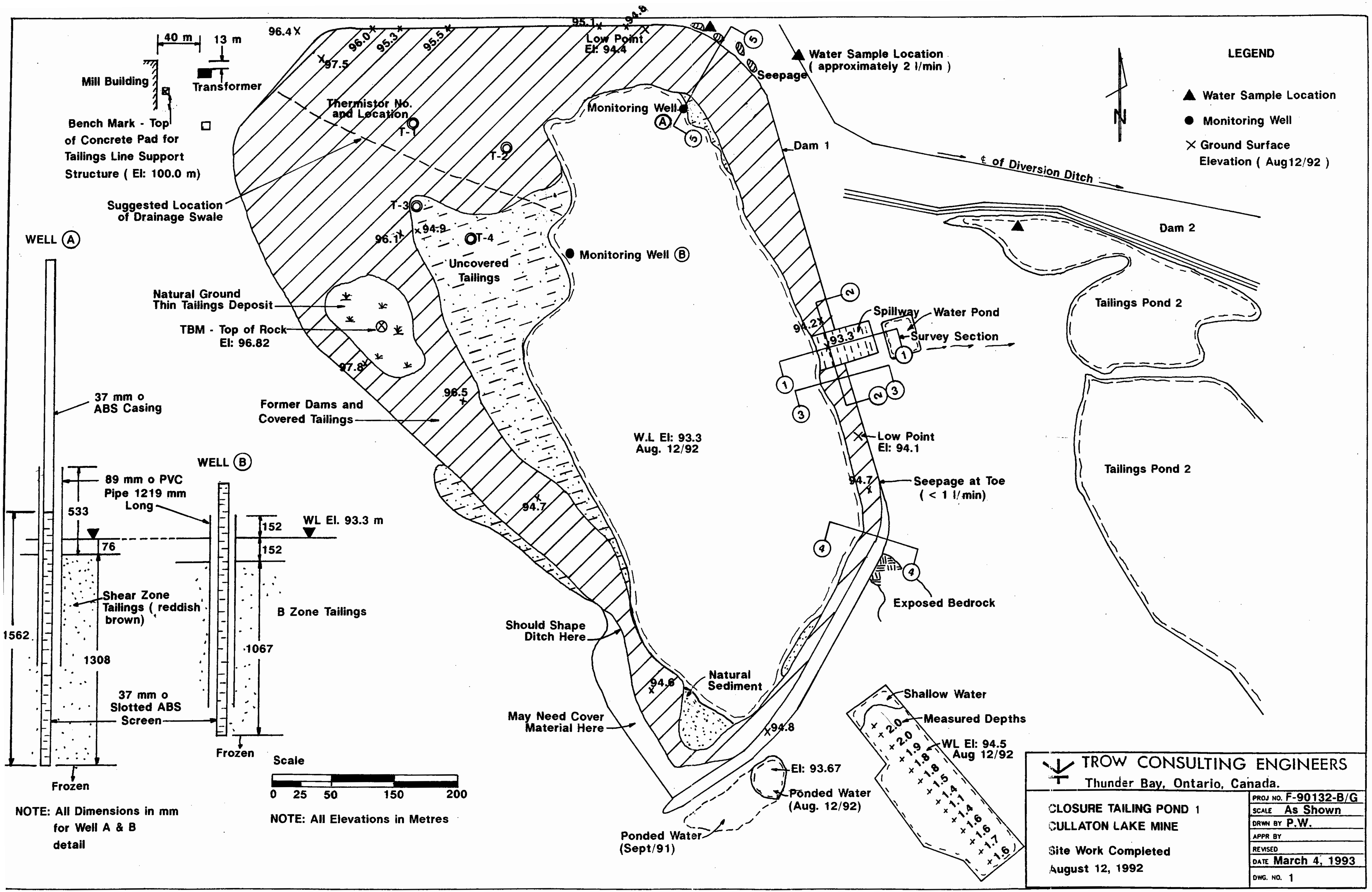
Piotr Kuraś, P.Eng., Senior Hydrologist

Reviewed by:

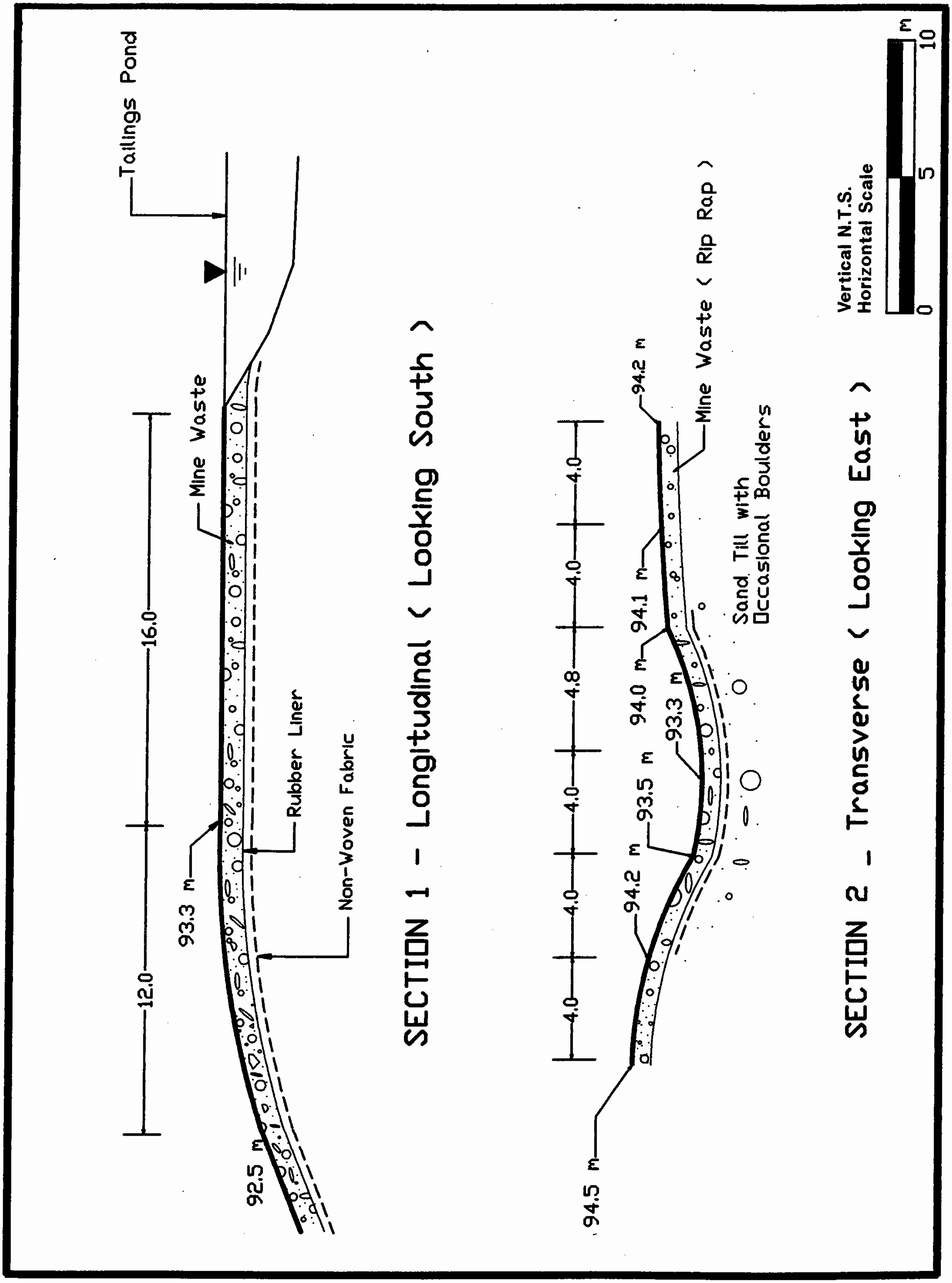
"original signed by"

Nancy Sims, P.Eng., Project Manager

APPENDIX A

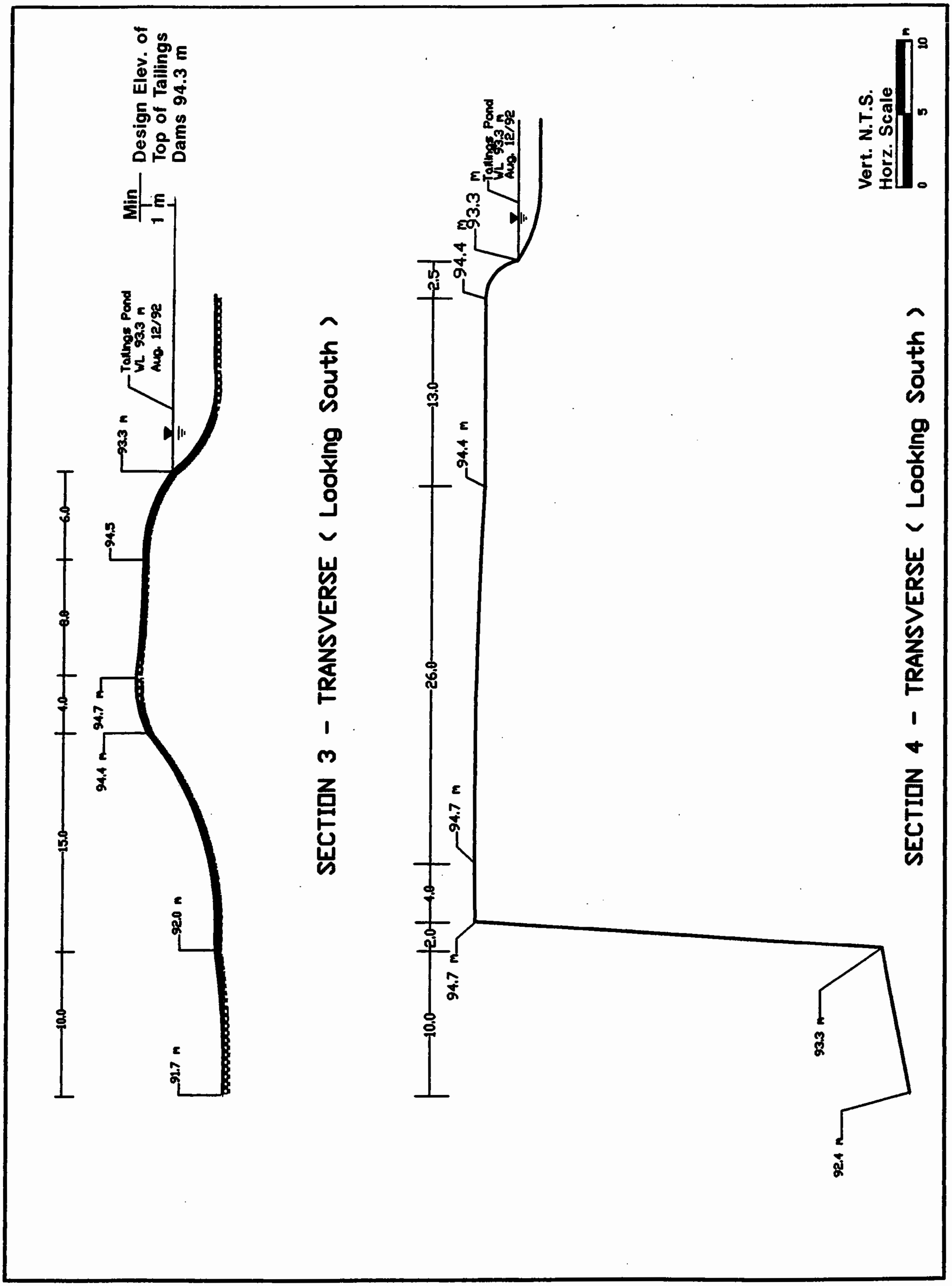


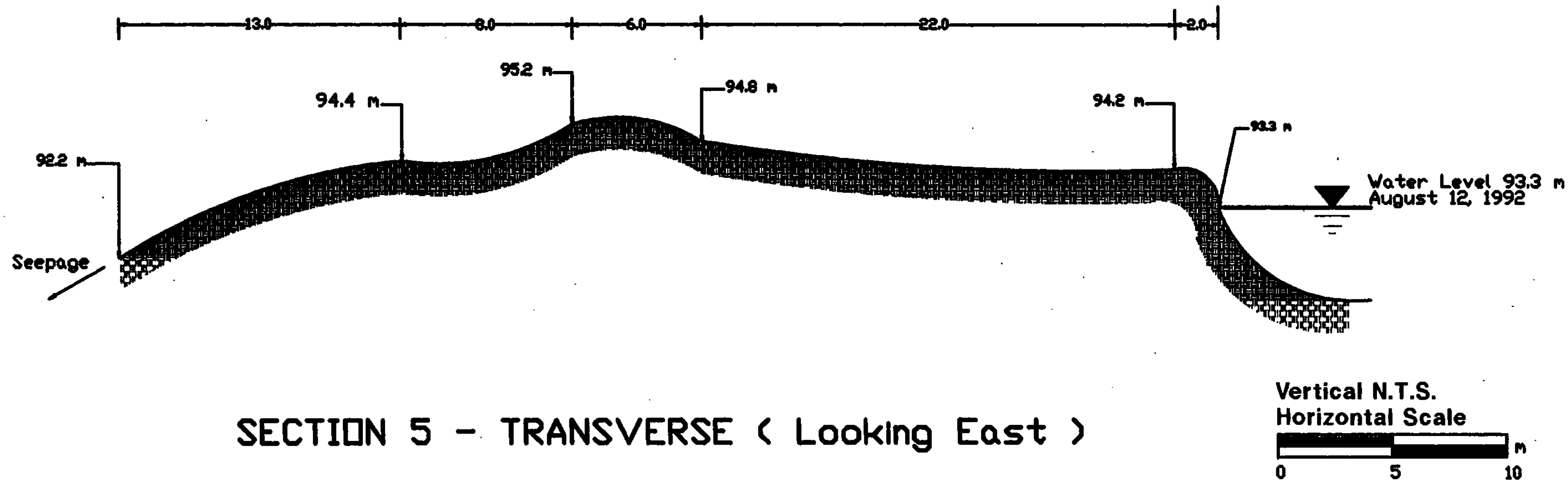
LEGEND
Water Sample Location
Monitoring Well
Ground Surface Elevation (Aug12/92)
N
Mill Building
40 m
13 m
Transformer
Bench Mark - Top of Concrete Pad for Tailings Line Support Structure (El: 100.0 m)
Suggested Location of Drainage Swale
Thermistor No. and Location
T-1
T-2
T-3
T-4
96.4
97.5
96.0
95.3
95.5
95.1
94.8
Low Point El: 94.4
Water Sample Location (approximately 2 l/min)
Seepage
Monitoring Well A
Dam 1
℄ of Diversion Ditch
Dam 2
Tailings Pond 2
Tailings Pond 2
96.1
94.9
Uncovered Tailings
Monitoring Well B
Natural Ground Thin Tailings Deposit
TBM - Top of Rock El: 96.82
97.8
96.5
Former Dams and Covered Tailings
Spillway
Water Pond
Survey Section
94.2
93.3
Low Point El: 94.1
W.L El: 93.3 Aug. 12/92
94.7
Seepage at Toe (< 1 l/min)
94.7
Exposed Bedrock
Should Shape Ditch Here
Natural Sediment
94.6
May Need Cover Material Here
94.8
El: 93.67
Ponded Water (Aug. 12/92)
Ponded Water (Sept/91)
Shallow Water
Measured Depths
2.0
2.0
1.9
1.8
1.8
1.5
1.4
1.1
1.4
1.6
1.6
1.7
1.6
WL El: 94.5 Aug 12/92
WELL A
37 mm o ABS Casing
89 mm o PVC Pipe 1219 mm Long
533
76
1562
1308
Shear Zone Tailings (reddish brown)
37 mm o Slotted ABS Screen
Frozen
WELL B
152
152
WL El. 93.3 m
B Zone Tailings
1067
Frozen
Scale
0 25 50 150 200
NOTE: All Dimensions in mm for Well A & B detail
NOTE: All Elevations in Metres
TROW CONSULTING ENGINEERS
Thunder Bay, Ontario, Canada.
CLOSURE TAILING POND 1
CULLATON LAKE MINE
Site Work Completed August 12, 1992
PROJ NO. F-90132-B/G
SCALE As Shown
DRWN BY P.W.
APPR BY
REVISED
DATE March 4, 1993
DWG. NO. 1


Tailings Pond
Mine Waste
16.0
12.0
93.3 m
92.5 m
Rubber Liner
Non-Woven Fabric
SECTION 1 - Longitudinal (Looking South)
4.0
4.0
4.8
4.0
4.0
4.0
94.5 m
94.2 m
93.5 m
94.0 m
93.3
94.1 m
94.2 m
Mine Waste
Mine Waste (Rip Rap)
Sand Till with
Occasional Boulders
SECTION 2 _ Transverse (Looking East)
Vertical N.T.S.
Horizontal Scale
0
5
10
m

Reference No. F-90132-A/G

Drawing No. 3





SECTION 5 - TRANSVERSE (Looking East)