Supplementary Report
Dam Safety Review (DSR)
Gullbridge Mine, Newfoundland

Report Prepared for:

Government of Newfoundland Labrador
Natural Resources
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1.0 INTRODUCTION

At the request of the Newfoundland and Labrador Department of Natural Resources (NLDNR), Stantec Consulting Ltd. (Stantec) carried out a supplemental geotechnical and hydrotechnical assessment for the tailings dam at the former Gullbridge Copper Mine in central Newfoundland. This review was initiated as a result of NLDNR revising the Dam Hazard Classification of the tailings dam from Low to Significant. Specifically, the purpose of this study was to determine if the change in classification had any impact on the recommended remedial measures for the Gullbridge Dam rehabilitation as provided in the Tender Documents issued by Stantec dated August 9, 2012.

The following report summarizes the approach, methodology, calculations and results conducted by Stantec in order to complete this assessment. The work relies on the general guidelines given in the Dam Safety Guidelines document (CDA, 2007) as well as previous information and data used to complete the previous tailing dam assessments at the site and presented in Stantec's DSR Report dated October 26, 2012.

It is understood that this report is a supplementary report to our October 26, 2012 report and should be read in conjunction with that report.

This report was prepared in general accordance with the requirements of the Canadian Dam Association (CDA) - Dam Safety Guidelines (2007).

2.0 DAM CLASSIFICATION AND CRITERIA

At the request of NLDNR, the Gullbridge Dam was reclassified from that presented in our October 26, 2012 DSR Report from Low to Significant. It is understood that this reclassification was based on NLDNR's internal review of our report and further review of the proximity of the Gullbridge tailings dam and reservoir to the downstream wetland, and tributary (South Brook). From this reclassification, the "environmental loss" is considered to be the main consequence category that is applicable to this reassessment.

The dam class is determined by the highest potential impact for any of the consequence categories. The dam class is used to provide guidance on the standard of care expected by dam owners and designers for management, prioritization, and decision-making. The dam class also provides a basis for design flood (hydrotechnical), and earthquake (seismic) levels used in the deterministic method of analysis. According to the consequences of failure described above, it is understood that NLDNR recommended the following dam class in Table 1.

Table 1 Dam Classification (CDA 2007)

Dam	Highest Consequence Category (Environmental)	Class
Gullbridge Tailings Dam	• No significant loss or deterioration of fish or wildlife habitat. • Loss of marginal habitat only. • Restoration or compensation in kind highly possible.	Significant

2.1 CDA ACCEPTANCE CRITERIA

Based on the dam classification of Significant for the Gullbridge tailings dam, the following acceptance criteria in Table 2 are recommended by CDA, 2007.

Table 2 CDA Acceptance Criteria for Significant Dam Class

Parameters	Suggested Annual Exceedance Probability (AEP)
Inflow Design Flood (IDF)	1/100 to 1/1000 (Selected on the basis of incremental flood analysis, exposure, and consequence of failure)
Earthquake Design Ground Motion (EDGM)	1/1,000
Critical Wind Frequency for Calculation of Freeboard during IDF	1/10

3.0 RESULTS OF ANALYSIS

3.1 HYDROTECHNICAL

The results of the hydrotechnical assessment are provided in Attachment 1. The following findings were highlighted from the hydrotechnical assessment that pertains to the current scope include:

- The present assessment concludes that the Inflow Design Storm (IDF) selected to comply with a dam hazard classification of Significant is the 1:100 year flood event.

- The results indicated that the maximum water elevation that is expected during the passage of the IDF is 152.75 m which is 0.5 m below the top of the dam. The freeboard amounts that are maintained during the passage of the IDF are in agreement with CDA (2007).

- From a hydrotechnical perspective, with the dam reclassified to Significant, the remedial repairs proposed in Stantec's Tender Documents, are adequate and do not require modification.

3.2 GEOTECHNICAL

A slope stability analysis was conducted for the downstream and upstream slopes of the tailings dam using the results of the hydrotechnical assessment and the Significant classification criteria. The analysis considered both static and seismic loading conditions.

From a geotechnical perspective, CDA guidelines provide annual exceedance probability for earthquake design levels for each dam classification. Further to Stantec's DSR report, the initial seismic slope stability analysis completed assumed seismic loading conditions consistent with a Significant consequence dam. This conservative approach was carried out knowing that the static loading condition would govern the remedial design. This is expected considering the relatively low seismicity of the Central Newfoundland region.

The results of the stability analysis using the remedial dam repairs as provided in Stantec's Tender Document, show that adequate factors of safety are maintained and meet the CDA acceptance criteria under the Significant classification.

4.0 CONCLUSIONS

The results of the hydrotechnical and geotechnical assessment of the Gullbridge Mine Tailings Dam using the CDA criteria for a "Significant" dam classification, show that the remedial measures recommended in Stantec's Specifications for the dam repairs are adequate for this classification change and do not require modifications.

5.0 CLOSURE

Use of this report is subject to the Statement of General Conditions provided in Appendix 1. It is the responsibility of Newfoundland and Labrador Department of Natural Resources (NLDNR), who is identified as "the Client" within the Statement of General Conditions, and its agents to review the conditions and to notify Stantec Consulting Ltd., should any of these not be satisfied. The Statement of General Conditions addresses the following: use of the report, basis of the report, standard of care, interpretation of site conditions, varying or unexpected site conditions, and planning, design or construction.

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which is valid for the year 2012

6.0 REFERENCES

Stantec Consulting Ltd. (2012), "Specifications For Department Of Natural Resources Tailings Dam Repairs Former Gullbridge Mine Newfoundland", Report No.: 121613065. Prepared for NLDNR. Dated August 9, 2012.

Stantec Consulting Ltd. (2012), "Dam Safety Review (DSR), Gullbridge Mine, Newfoundland", Report No.: 121613065. Prepared for NLDNR. Dated October 26, 2012.

Attachment 1

Statement of General Conditions

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec Consulting Ltd. and the Client. Any use which a third party makes of this report is the responsibility of such third party.

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INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec Consulting Ltd. at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

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PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec Consulting Ltd., sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec Consulting Ltd. cannot be responsible for site work carried out without being present.

Attachment 2

Hydrotechnical Technical Memorandum

INTRODUCTION

Stantec Consulting Ltd., (Stantec) was retained by the Newfoundland and Labrador Department of Natural Resources (NLDNR) to conduct further hydrotechnical work on the tailings dam at the former Gullbridge Copper Mine in central Newfoundland. Specifically, NLDNR's desire to raise the Dam Hazard Classification from Low to Significant required an assessment of dam breach consequences as described on Table 2-1 of the Canadian Dam Safety Association Dam Safety Guidelines document (CDA, 2007), attached in Appendix A.

Furthermore, the scope of the current study was also to examine the impacts of such increase in the dam hazard classification on the current design recommendations completed by Stantec in the Dam Rehabilitation Package (August, 2012).

The following technical memorandum summarizes the approach, methodology, calculations and results conducted by Stantec in order to complete this dam breach assessment. The work relies on the general guidelines given in the Dam Safety Guidelines document (CDA, 2007) as well as previous information and data gathered to conduct the previous Hydrotechnical Assessment of the former Gullbridge Copper Mine, NL (Stantec, 2012).

METHODOLOGY

Study Approach

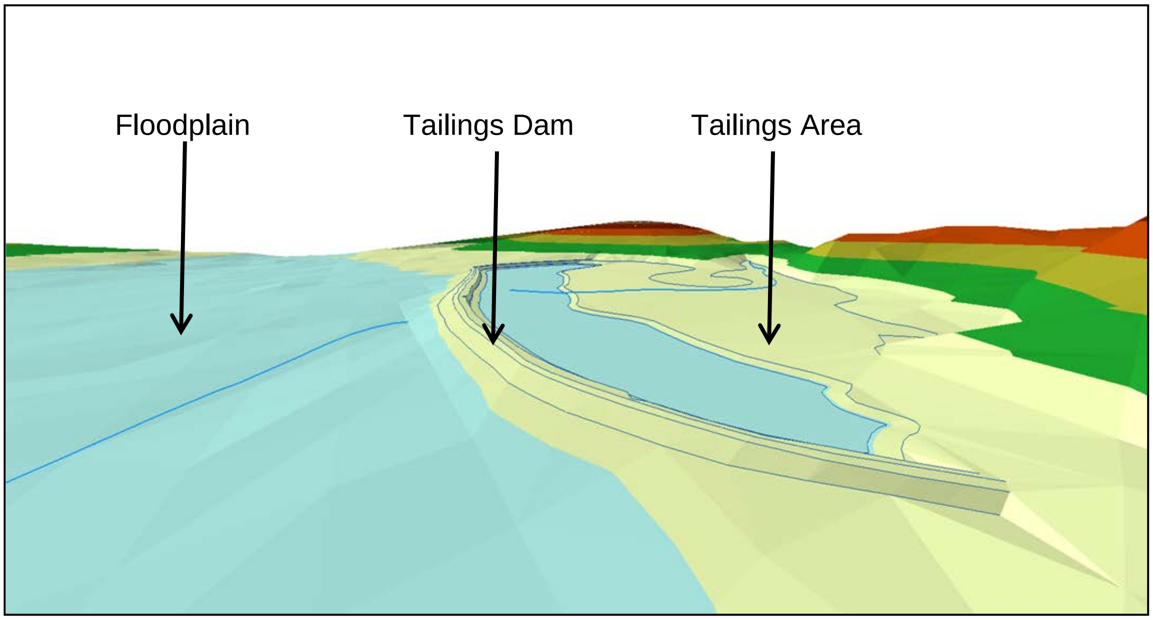
The study approach outlines the Dam Hazard Classification selected for this assessment based mainly on the potential for environmental losses, considering that the receiving watercourse downstream of the tailings dam (South Brook) is a scheduled salmon river. Other factors including loss-of-life potential, and potential for property and cultural loses have been evaluated to be minimal and are not the main driver that determines the hazard classification.

The study approach also defines the conditions of the sunny day and other flood events considered during a dam breach following the guidance from CDA (2007), as well as the development of the digital elevation model and the hydraulic model used in this assessment. Additionally, dam breach parameters as well as model limitations are also discussed.

Digital Elevation Model

The available elevation contours with a resolution of 0.5 m were utilized to create a digital elevation model (DEM) using the GIS software ArcView, version 10. By using the DEM with the GIS extension HEC-GeoRAS, it was possible to create 53 cross-sections along the main reach that covers the tailings area in the upstream section and the downstream floodplain towards South Brook. These cross sections were then imported to the open channel hydraulics software HEC-RAS. HEC-GeoRAS also requires the delineation of the channel centerline, right and left banks and the flow paths for the main channel and the floodplain for all reaches. The DEM is shown in Figure 1 below.

Figure 1 Digital Elevation Model of the Gullbridge Tailings Dam and Tailings Pond



HEC-GeoRAS defines channel cross section coordinates by obtaining the stationing and elevations from the intersection of each cross section line with the elevation features of the DEM, starting always from the furthest point of the cross section on the left bank with a zero coordinate to the end of the cross section on the right bank. Every time an elevation point of the DEM is intersected by the cross section line, a coordinate set is generated. HEC-GeoRAS also measures the distance between one cross section to the next for the center, right and left banks of the channel which in turn define the alignment of each reach. Finally, cross section labels are defined by their stationing starting at zero from the lowest cross section in a reach increasing in the upstream direction.

Determination of Flood Events

According to Table 2-1 of the Dam Safety Guidelines document, a dam hazard classification of significant requires the determination of the inflow design flood (IDF) based on incremental effects between the 1:100 to the 1:1000 year storms (0.01 to 0.001 Annual Exceedance Probability).

The estimated peak flows at the Gullbridge Mine were calculated using normalized maximum stream flow factors obtained from the Water Resources Atlas of

Newfoundland (1992). The data includes normalized factors in $m^3/s/km^2$ that can be applied to adjacent watersheds. In this case, the estimations from Station 02YL001 (Upper Humber River) were utilized based on its proximity to the project site, which is approximately 90 km to the west and using the area of the Gullbridge watershed of 3.65 km^2. The factors are shown in graphical view on Figure B.1 (Appendix B). The resultant peak flows are included Table 1. The values were multiplied by a factor of 20% to account for climate change, based on projected patterns of annual runoff increase for the next century (IPCC, 2007).

Since the normalized factors are only offered between the 1:2 to the 1:100 year storm, an extrapolation method was used to estimate the peak flows for larger storms. A logarithmic equation was selected to best fit the available data with an R^2 value of 0.97. The extrapolation curve is shown in Figure B.2 (Appendix B).

Table 1 Estimated Peak Flows using normalized maximum stream flow values

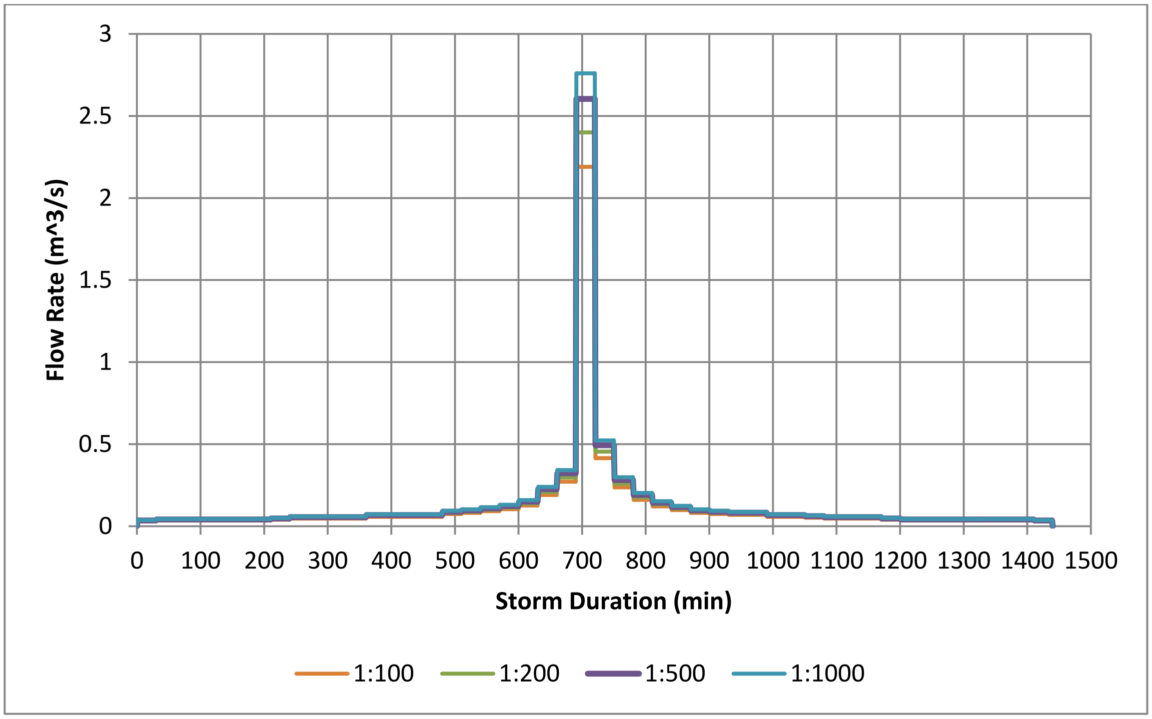
Annual Probability Exceedance (%)	Return Period	Peak Flow Rate (m^3/s)
1	100	2.19
0.5	200	2.40
0.2	500	2.60
0.1	1000	2.76

Synthetic Storms

The required flow hydrographs for flood events with different return periods were generated using a synthetic distribution based on the Natural Resources Conservation Service (formerly the Soil Conservation Service) Type III storm distribution with a total duration of 24 hours (NRCS, 1986). The SCS Type III storm distribution is applicable to Atlantic Coastal areas where typically tropical storms bring large rainfall amounts during a 24 hour period.

For all storm distributions the occurrence of the peak flow was set at 50% of their duration, using the peak flow values included in Table 1. The resultant flow hydrographs for the 1:100, 1:200, 1:500, and 1:1000 return period storms are included in Figure 2.

Figure 2 Flow hydrographs for flood events with different magnitudes



<u>HEC-RAS Hydraulic Model</u>

The computer model selected to conduct this dam breach assessment was HEC-RAS version 4.1.0, which was the latest version available at the time this assessment was conducted. HEC-RAS is the successor of HEC-2 and was developed by the US Army Corps of Engineers. HEC-RAS is a one-dimensional open channel hydraulics model that can perform both steady and unsteady flow simulations in a single river reach or a complex channel network. The program uses channel cross-section stationing and elevation information to determine water elevations, velocities, and flows by solving the one dimensional energy and momentum equations. Energy loses are often calculated with the use of friction coefficients (Manning's) for the main channel and the floodplain as well as contraction/expansion coefficients, which allow HEC-RAS to simulate the presence of hydraulic structures within the reach of interest.

HEC-RAS has the capacity to simulate a range of dam failure scenarios from small to catastrophic (including overtopping and piping phenomena) and predict the flow and stage hydrographs throughout the channel as the transient wave travels downstream. The model can also estimate the combined effects of a large precipitation event and a dam failure occurring simultaneously.

Dam Breach Modeling and Incremental Effects

Sunny Day Dam Break Condition

The sunny day or fair weather condition was included in the analysis. The main assumptions for this scenario are that no precipitation event is occurring at the time of dam failure, the dam reservoir is operating at its highest annual normal operating level and the dam inlet is only conveying what is considered as an annual average flow rate. During the dam breach, a transient wave travels downstream as the reservoir volume decreases. The sunny day condition is expected to have the largest magnitude of effects from the base case (normal flow with no breach) due to the rapid increase from a normal flow to a peak flow condition as a result of the dam breach.

Wet Weather Dam Break Condition

As indicated previously, the flood event that was considered was the 24 hour, 1:100 year storm with dam breach. The 1:200 year event was also modeled under the same assumptions and larger storm distributions were available for analysis. The results were compared to identify any incremental effects that would result from the additional flow associated with both the dam break component and a larger storm.

Model Set up and Limitations

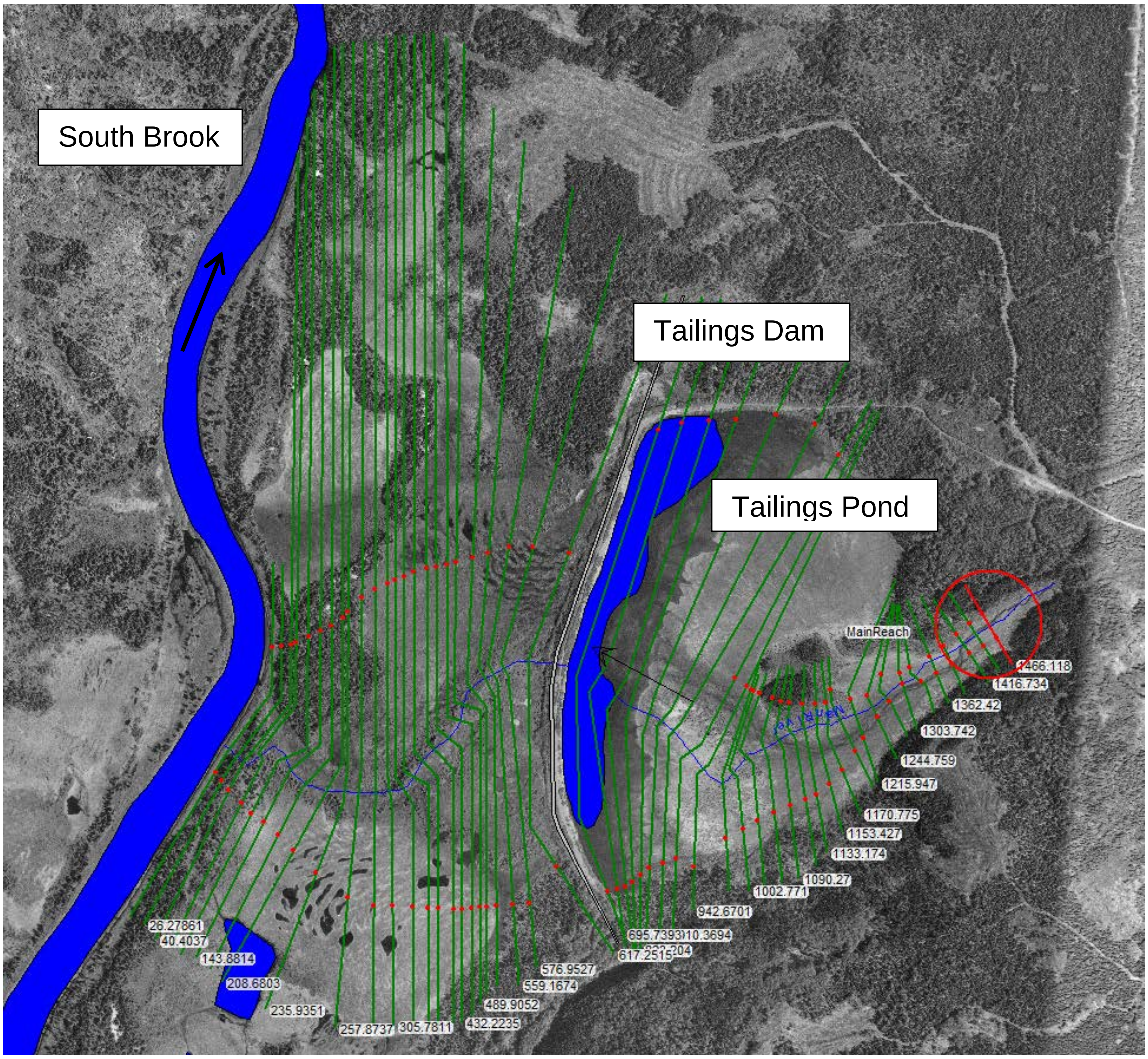
Geometric Data

Geometric data to setup the open channel model in HEC-RAS was obtained from the digital elevation model mentioned previously. A total of 53 cross-sections were imported into HEC-RAS for analysis. The cross sections are mostly straight lines where channel geometry allows and perpendicular to the channel center line following model requirements, however, in some sections of the tailings pond and the floodplain the cross sections were bent to allow for closer distances between them. This is allowed by the model as long as the cross sections do not overlap.

The cross sections were labeled with consecutive numbers that represent the stationing within the study reach from an arbitrary datum located at the downstream boundary. The cross sections range from ID 12.08 at the downstream boundary to 1466.11 at the upstream boundary, therefore, the entire study reach has a total length of 1454.03 m. A plan view of all cross sections is included in Figure 3.

Reference: Supplementary Hydrotechnical Assessment
Former Gullbridge Mine Tailings Dam

Figure 3 Cross Sections along the model domain

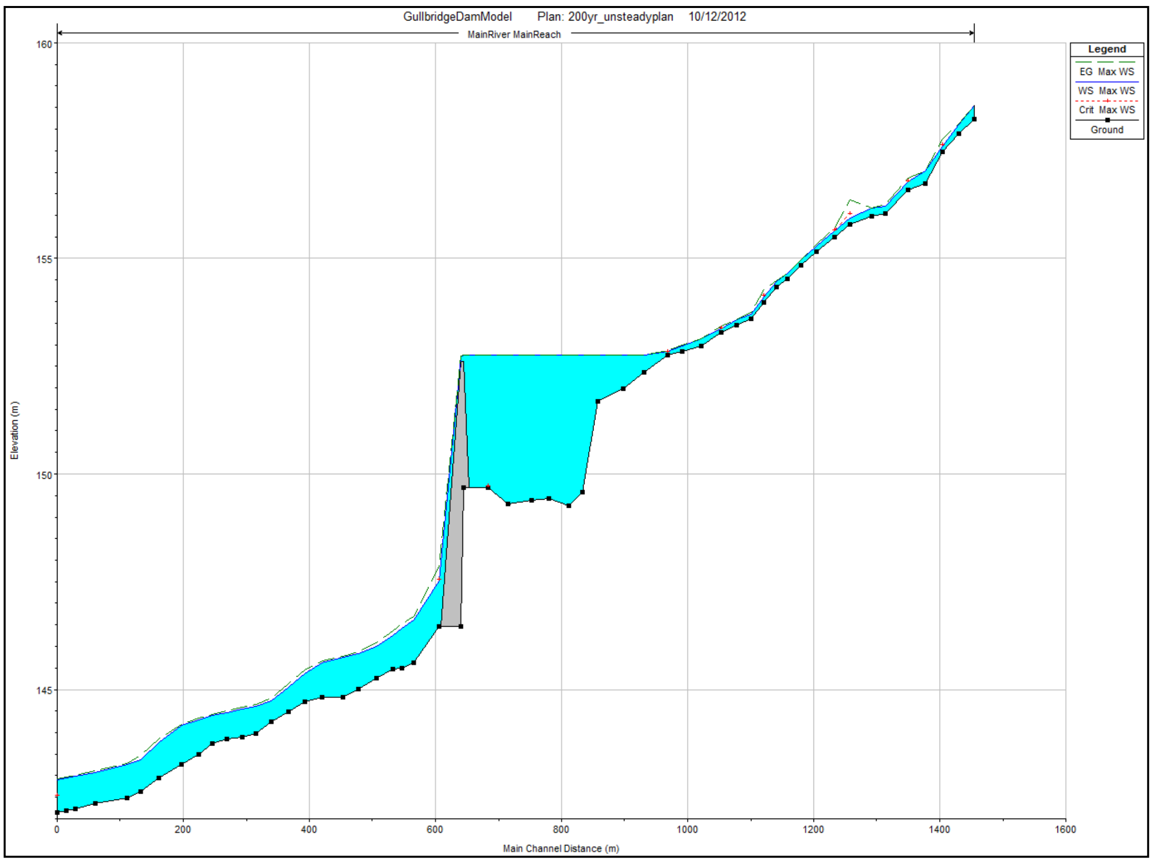


Contraction and expansion coefficients were set based on information presented in the HEC-RAS User's manual (Version 4.1, January 2010). Contraction and expansion coefficients were set with values of 0.1 and 0.3, respectively. No ineffective flow areas were set at any location within the model domain. The longitudinal channel profile of the model domain is shown in Figure 4.

The configuration of the tailings dam also included the details of the emergency spillway as per the Dam Rehabilitation Works issued for tender by Stantec on August 2012. The spillway geometry is triangular with an invert elevation at 152.6 m and a total width of 38 m, with a top elevation of 153.25 m and side slopes in the order of 3.4%. The spillway has been designed to be fordable during the passage of most storms and to provide extra conveyance to ensure the maintenance of freeboard requirements as per CDA

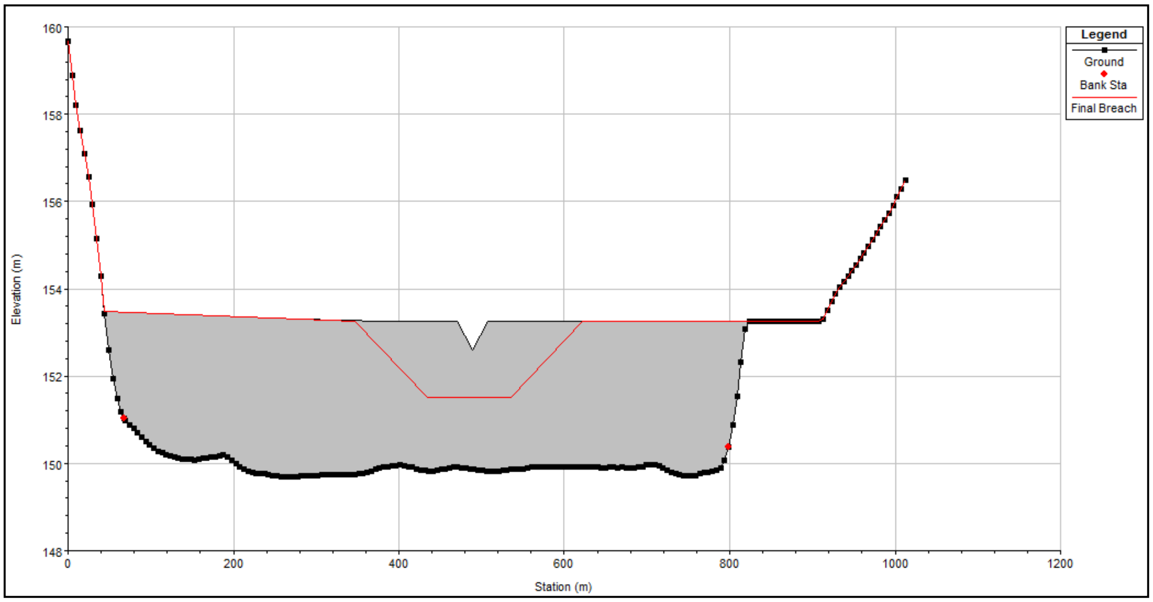
(2007) guidelines. According to the Dam Rehabilitation Package, two existing Corrugated Steel pipe culverts (CSP) with a diameter of 900 mm will be upgraded with two 1,200 mm High Density Polyethylene (HDPE) culverts with the same invert elevation and slope. These culverts were not included in the model to account for a more conservative scenario. Furthermore, it is assumed that regular inspection and maintenance will be provided as well as measures will be in place to avoid culvert and spillway blockage by beaver action.

Figure 4 Longitudinal Profile of the model domain



Additionally, the geometry of the dam breach geometry was selected based on geotechnical parameters and what is considered as a feasible catastrophic breach condition. The breach geometry was set with a width at the base of 100 m and at the top of 275 m and a total height of 1.75 m. The time for the progression of the breach to reach a full opening was set at 0.5 hours and the assumed failure mechanism was selected to be overtopping, all failures where set at a fixed time when storm effects are maximized (i.e. during the passage of the peak flow). The breach geometry is shown in Figure 5.

Figure 5 Breach Geometry of the Gullbridge Tailings Dam



Roughness Coefficients

The required Manning's roughness coefficients for the main channel and the floodplains were estimated by comparing site characteristics with predefined values provided in French (1985). The estimated Manning's coefficients for the tailings area in the floodplain below the tailings dam were estimated to be 0.03 and 0.05 respectively.

Boundary Conditions

Boundary conditions are required by HEC-RAS to effectively estimate water depths and velocities along the study reach. There are many options that the model accepts as boundary conditions including flow hydrographs, stage hydrographs, normal depth, critical depth, and rating curves. In this particular case, all scenarios were set up with a flow hydrograph at the upstream boundary representing the flood event and a normal depth for the downstream boundary condition, which is based on the available elevation data. For the sunny day condition a fixed flow of 0.5 m^3/s was selected. A summary of all boundary conditions are included in Table 2 for all considered storms.

Table 2 Summary of Upstream and Downstream boundary conditions

Scenario	Upstream	Downstream
Sunny Day	Constant flow of 0.5 m^3/s	Normal Depth S = 0.002 (based on elevation contours)
1:100 year storm with dam break	Flow hydrographs for the tailings area with the following peak flow rates respectively: 1:100 yr = 2.19 m^3/s 1:200 yr = 2.4 m^3/s	
1:200 storm with dam break		

<u>Model Numerical Instabilities</u>

There are two main components that pertain to numerical instabilities; one is related to numerical sensitivity and the other to physical parameter sensitivity. The objective of this analysis is to adjust model parameters to qualitatively analyze the uncertainty of model results and minimize model instabilities.

For the numerical sensitivity there are two main elements that must be considered, these are the distance between cross sections and what is known as the Courant Condition which estimates the appropriate time step interval to run the simulations. The maximum distance between cross sections can be estimated with the Samuel's Equation as follows:

$dx < 0.15\ D / S_o$,

where: dx = distance between cross sections

D = average full bank channel depth (ft)

S_o = average bottom channel slope

Therefore, based on the hydraulic model calculations D = 2.95 ft and So = 0.004, the estimated dx is 110.6 ft or 33.7 m which is higher than the maximum cross section distances used for the model domain, with an average of 27.6 m.

The Courant Condition can be evaluated with the following formula:

dt = dx / Vw,

where: dt = model time step (seconds)

dx = average cross section distance (27.6 m)

Vw = velocity of the flood wave (1.06 m/s from model results)

By solving the previous equation the value of dt is 26 seconds which is higher than the time step required for all scenarios of 5 seconds, for which no numerical instabilities were found in the model. Therefore, in this case the model parameters related with numerical sensitivity were satisfactory.

With respect to physical parameter sensitivity, the modification of a few parameters will have a larger effect on model results. These are the Manning's roughness coefficients, cross section distance and stationing, and hydraulic structure parameters and coefficients. Other related parameters are also the upstream and downstream boundary conditions. For this case, the sensitivity analysis was limited to the numerical instability check presented previously and no analysis for physical parameters was completed due to deficiencies in the available data.

RESULTS

Floodplain Mapping

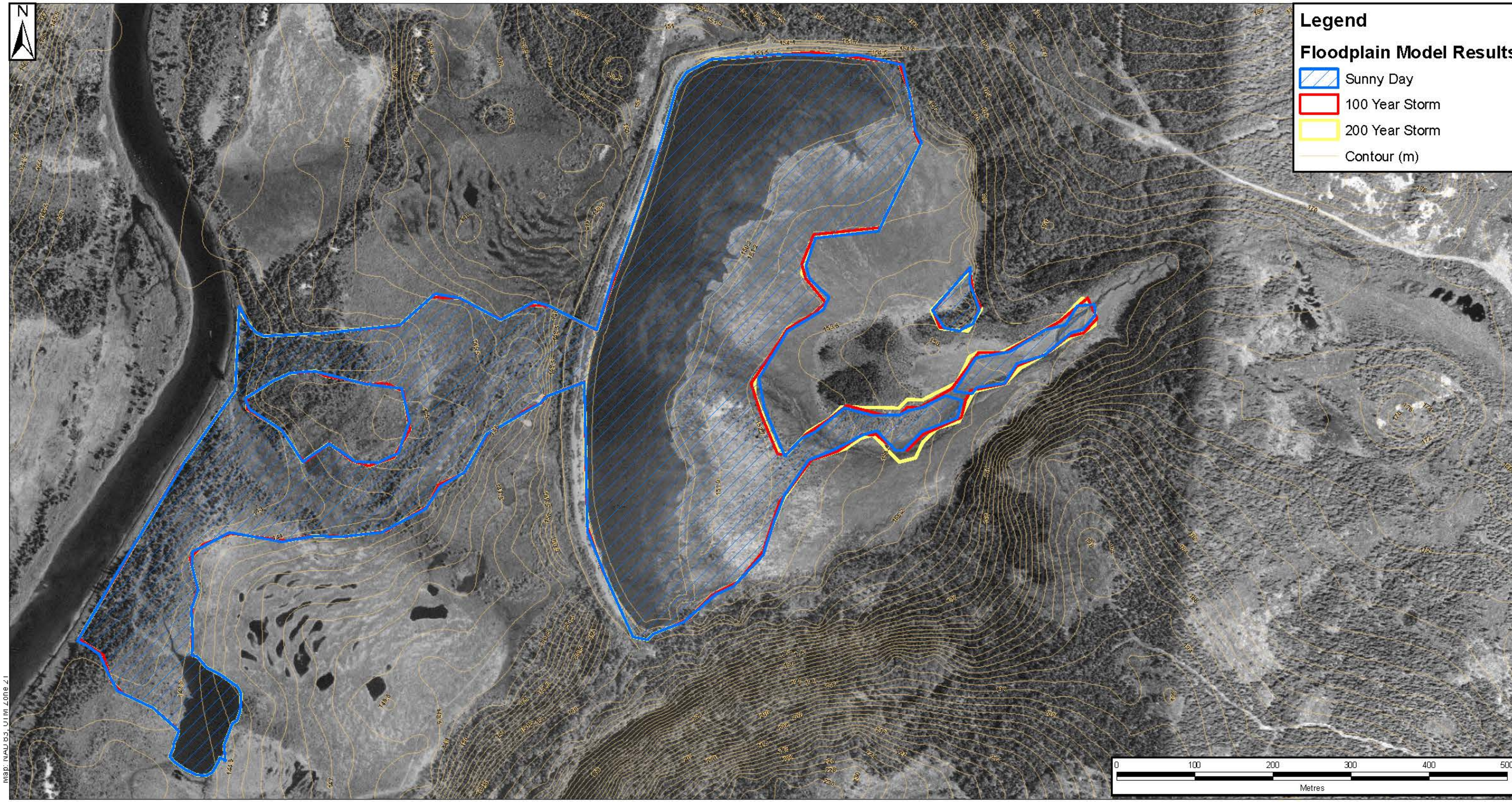
Floodplain maps were generated using the calculated maximum elevations along the channel during the pass of the transient wave, since the transient wave travels downstream rapidly the maximum elevations occur at different times for each location of the floodplain. These maps indicate the maximum expected water levels for each considered scenario, including the sunny day, 1:100 and 1:200 year storms with dam break. The floodplain delineation map in Figure 6 includes all considered scenarios mentioned previously. By comparing the floodplain extents it is possible to estimate the incremental effects that each dam breach has on the base condition.

Determination of Inflow Design Flood

For the cases considered it was noted that the floodplain delineation boundaries have negligible increase with increasing storm magnitude, therefore the Inflow Design Flood (IDF) was selected to be the 1:100 year event, however, due to a reassessment of potential effects the dam hazard classification was upgraded from Low to Significant.

Reference: Supplementary Hydrotechnical Assessment
Former Gullbridge Mine Tailings Dam

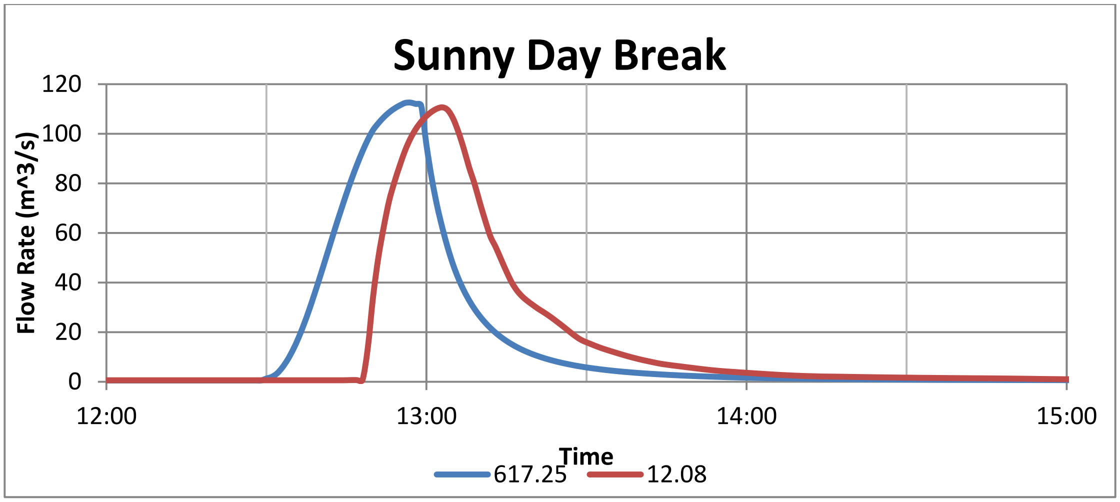
Figure 6 Floodplain Model Results

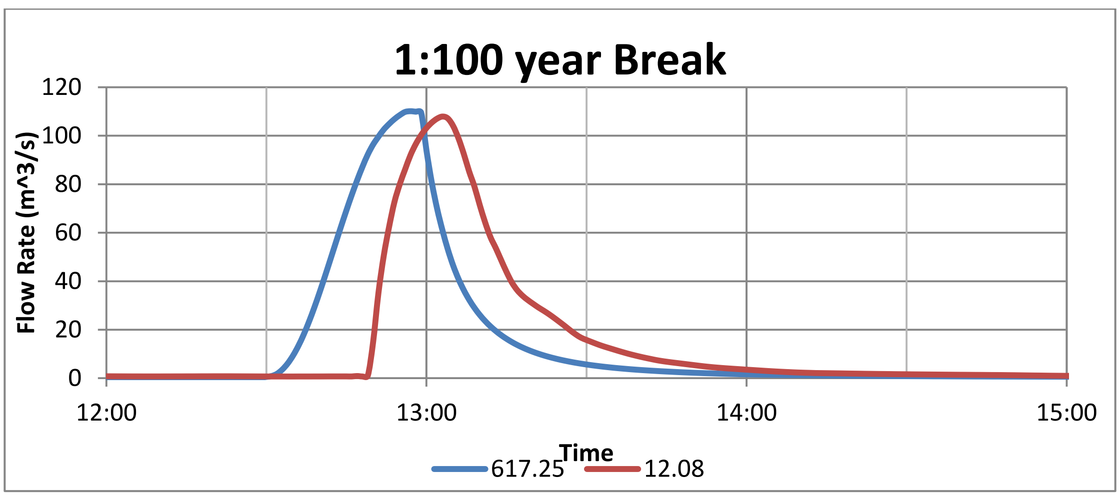


Flow Hydrographs

The peak flow hydrographs at cross sections located in the upstream and downstream reaches of the floodplain (Cross sections 617.25, and 12.08) are shown in Figure 7.a, and 7.b for the sunny day and the 1:100 year storms with dam breach respectively. Cross section 617.25 is located just downstream of the tailings dam and cross section 12.08 is located just upstream of South Brook. The flow hydrographs indicate that the floodplain storage capacity between the dam and South Brook is negligible, and therefore the flow rate associated with the transient wave that reaches South Brook has no attenuation.

Figures 7 a & b Flow Hydrographs during dam break for different event magnitudes





The model results also indicate that the dam breach and release of tailings pond water govern peak flow rates with a small contribution from the wet weather events.

A summary of model results is provided in Appendix C for the sunny day condition and IDF storm with dam break.

Maximum Water Elevation during the passage of the IDF

The water maximum elevation at the tailings pond during the passage of the IDF which is the 1:100 year storm was estimated by the model to be 152.75 m, which is 0.50 m below the top of dam (153.25 m). This elevation was obtained using only the conveyance capacity of the emergency spillway and without accounting for the conveyance capacity of the two proposed 1,200 mm diameter HDPE culverts as per the Dam Rehabilitation Design Package (Stantec, 2012). Therefore, the actual water elevation with fully functioning culverts during the passage of the 1:100 year storm is expected to be lower than model predictions.

Estimated Travel Time of the Transient Wave

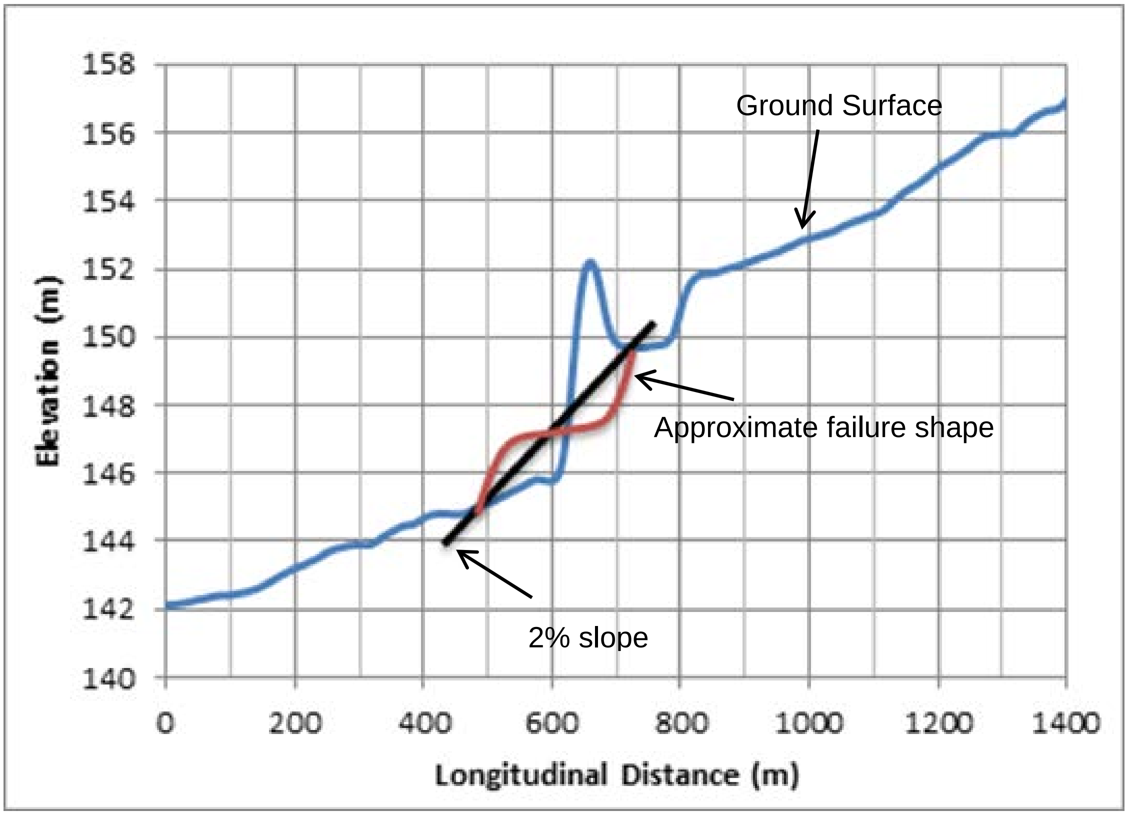
Based on the time of occurrence of peak flows during the tailings dam breach for the sunny day and wet weather events, the approximate travel time of the transient wave from the dam structure to South Brook is in the order of 2 to 5 minutes, which results in an average velocity of the transient wave in the order of 2 m/s. These values assume a broad flow across the floodplain. For a scenario where the peak flows are concentrated along existing channels or naturally occurring troughs, the travel velocities will be faster than 2 m/s, resulting in a decreased travel time.

Preliminary Analysis of Tailings Migration

An estimation of the tailings release distance from the tailings dam during modeled dam breaches is also included in this analysis. To conduct this assessment the saturated tailings angle of repose was assumed to be 2%.

Since HEC-RAS is unable to model the movement of a mixture of water and saturated tailings along the channel, a GIS assessment was conducted to determine the extent of tailings migration. The channel elevation profile was generated and a 2% slope line was defined approximately 50 m upstream of the tailings dam, which is assumed as the starting location of failure in the submerged tailings mass. Tailing materials will then slide downstream and stabilize when their angle reaches a 2% slope, determined to be the approximate angle of repose, and the intersection of this slope with the ground marks the boundary of the tailings migration extents, as shown in Figure 8.

Figure 8 Estimated extent of tailings migration



The results indicate that the expected travel distance of the tailings is approximately 120 m downstream of the tailings dam toe and 440 m upstream of South Brook. Therefore, it can be concluded that the coarser portion of the tailings material will not reach South Brook under any of the scenarios considered in this assessment.

Dam Freeboard Requirements

A minimum freeboard is recommended to be maintained at all times and especially during large precipitation events. Dam overtopping is not recommended at any given time because this could lead to erosion and eventually local failure.

By increasing the dam hazard classification to significant, the freeboard requirements due to wind action required the tailings dam to safely comply with the two following conditions:

- No overtopping by 95% of the waves caused by the most critical wind with a frequency of 1:1000 year when the reservoir is at its maximum normal elevation; and

- No overtopping by 95% of the waves caused by the most critical wind (AEP of 1:10 year) when the reservoir is at its maximum extreme level during the passage of the IDF.

Based on the results of the wind analysis obtained on the Hydrotechnical Assessment of the former Gullbridge Copper Mine, NL (Stantec, 2012); an updated freeboard analysis is required only for the second case where the wind AEP is decreased to the 1:10 year wind.

The wind velocity for this condition is in the order of 30.5 m/s (110 km/h). The fetch was maintained at 500 m based on the predominant wind direction (N – NE) and the average water depth was also maintained at 1.5 m.

The maximum height of the waves due to wind action is 0.55 m, which is only 5 cm higher than the expected freeboard during the passage of the IDF (0.50 m at elevation 172.75 m). These calculations do not take into account the conveyance capacity of the new 1,200 mm HDPE culverts that will replace the old 900 mm diameter CSP culverts

Conveyance Structures

As mentioned previously, the IDF is defined as the 1:100 year storm with tailings dam break. For a dam hazard classification of Significant, the hydraulic structures in the dam must be able to safely convey the flows while maintaining the required freeboard.

Based on model results, the emergency spillway and two 1,200 mm diameter HDPE culverts are able to provide conveyance while allowing the dam to maintain the required freeboard amounts, provided that these structures are fully functioning without any blockages (i.e. debris, beaver action, ice jams).

DISCUSSION

Loss of Life Potential

Loss of life potential is specifically examined for non-transient persons within the floodplain during a flood condition and both non-transient and transient persons during a sunny day failure. Examples of non-transient occupation of the floodplain include residents of habitable dwellings, overnight campground users, and workers in buildings in the floodplain. Transient users include workers and visitors to the site for which it is assumed that safety practices will be in place, unauthorized visits should be discouraged with proper signage.

Based on the examination of downstream uses, non-transient groups were identified approximately 15 km downstream of the tailings ponds on a few structures located on the banks of South Brook, which are likely seasonal campgrounds. Therefore, potential effects in the downstream reaches of South Brook are feasible and must be considered.

However, based on their distance to the tailings pond and the size of South Brook, it is considered the floodplain can minimize the potential flooding effects for these users.

Transient users should be aware of the hazards present at the site and apply safety measures to mitigate these hazards.

Property Losses

Property loss effects relate to certain direct and indirect losses incurred to third parties as a result of dam failure and/or inadequate operation of the tailings dam and conveyance structures. Even though there is infrastructure within the mine site (i.e. culverts and tailings dam), these are located within the site and therefore not considered as third party property. Currently the assessment indicated that the potential for third party property loses is mostly focused on the existing structures located on the banks of South Brook. However, based on the distance that exists between these features and the tailings pond (15 km) it is expected that the majority of the transient wave will dissipate and be attenuated in the floodplain of South Brook before it reaches these features.

Environmental Effects

Environmental effects were examined from the perspective of erosion and sedimentation potential and breach release water quality on sensitive downstream salmon habitat (i.e. South Brook).

Tailings pond water receives no treatment other than detention to facilitate sedimentation. During all breach conditions tailing pond water quality may not meet regulatory criteria due to insufficient residence time.

Flooding is an important function in the sustainability of aquatic and riparian habitat. Flushing flows remove accumulated debris and provide important sediment transport. Floods also bring sediment and nutrients to the floodplain. This assessment focuses on potential effects of dam break on the dam reservoir and receiving environment as well as the ability of the riparian system to restore itself after the flooding event.

For all considered scenarios, the tailings dam breach has a large effect on floodplain depths and velocities due to the volume that is accumulated and released at the tailings pond prior to the occurrence of the breach. However, model results indicate that the incremental effects of flooding between the sunny day break and the 1:100 year storm are minimal.

Both scenarios have the potential to generate a flow peak in the order of 110 m^3/s which can reach South Brook in about 2 to 5 minutes from the time of breach, with an associated volume release in the order of 70,000 m^3. The incipient mobility of the transient wave moving at 2 m/s is a particle ≤ 20 mm, which is assumed to be all tailings particle size classes. Thus all assessed breach scenarios have the potential to transport tailings to South Brook.

It is difficult to determine the exact volume of tailings sediment which would reach South Brook during a breach, especially due to its relatively shallow water depth and surface roughness across the floodplain. The finer fraction of the tailings and dam construction materials would likely be subsequently deposit downstream of the dam in South Brook and its floodplain areas.

For the scenario where the tailings sediment reaches South Brook, turbid condition may perpetuate for extended periods if South Brook's water velocities have the potential to carry tailings material for extended distances downstream. As such the turbidity effects of a tailings dam breach have the potential to last for several months if South Brook can carry tailings sediments during higher flows and deposit them during lower flows repeatedly until the tailings sediment is sorted to areas of sand-silt zones in the Brook. Thus the effects of tailings sediment deposition and transport in South Brook are expected to have environmental effects.

Cultural – Built Heritage Effects

Cultural – built heritage effects refer to damage sustained to designated cultural heritage sites, however, at present time there is no information available regarding any designated cultural – built heritage sites near the former Gullbridge Mine or the lower sections of South Brook.

CONCLUSIONS AND RECOMMENDATIONS

The present assessment concludes that the Inflow Design Storm (IDF) selected to comply with a dam hazard classification of Significant is the 1:100 year flood event.

Based on the examination of downstream uses, non-transient groups were identified approximately 15 km downstream of the tailings ponds on a few structures located on the banks of South Brook, which are likely seasonal campgrounds. For a dam hazard classification of Significant the population at risk is defined as temporary, which includes seasonal cottage use, transportation routes and recreational activities. This is in agreement with the conditions encountered in the area of the Gullbridge mine and the downstream sections of South Brook. Transient users should be aware of the hazards present at the site and apply safety measures to mitigate these hazards.

Currently the assessment indicated that the potential for third party property loses is mostly focused on the existing structures located on the banks of South Brook. However, based on the distance that exists between these features and the tailings pond (15 km) it is expected that the majority of the transient wave will dissipate and be attenuated in the floodplain of South Brook before it reaches these features.

The most critical component during a dam breach determined in this assessment is related to environmental effects. The assessment of environmental effects during a dam breach concluded that the receiving environment (South Brook) downstream of the dam would experience short-term erosion and sedimentation.

The model results indicated that the maximum water elevation that is expected during the passage of the IDF is 152.75 m with the emergency spillway in operation and assuming that the HDPE culverts are blocked. This is considered to be a more conservative approach and takes into account the possibility of culvert blockage due to different factors.

These conveyance structures are vital to the proper operation of the tailings dams and measures must be in place to minimize potential hazards including beaver action which has been reported in the past as well other potential vulnerabilities (i.e. seepage, stability, ice jams, debris).

The freeboard amounts that are maintained during the passage of the IDF are in agreement with CDA (2007) requirements for a dam hazard classification of Significant. The maximum estimated wave height is 0.55 m produced by the most critical wind with an AEP of 1:10, and the freeboard amount is 0.50 m during the passage of the IDF. This scenario is conservative because the culvert conveyance capacity is not included and 95% of all waves should be retained by the tailings dam, decreasing the required freeboard to 0.52 m.

Based on this assessment the tendered dam repairs (Stantec 2012) are able to accommodate the “Significant” classification and the 1:100 year storm

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APPENDIX A

Table 2-1, Canadian Dam Safety Guidelines (CDA, 2007)

Table 2-1: Dam Classification

Dam class	Population at risk [note 1]	Incremental losses		
		Loss of life [note 2]	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
Significant	Temporary only	Unspecified	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
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
Very high	Permanent	100 or fewer	Significant loss or deterioration of *critical* fish or wildlife habitat Restoration or compensation in kind possible but impractical	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)
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)

Note 1. Definitions for population at risk:

None—There is no identifiable population at risk, so there is no possibility of loss of life other than through unforeseeable misadventure.

Temporary—People are only temporarily in the dam-breach inundation zone (e.g., seasonal cottage use, passing through on transportation routes, participating in recreational activities).

Permanent—The population at risk is ordinarily located in the dam-breach inundation zone (e.g., as permanent residents); three consequence classes (high, very high, extreme) are proposed to allow for more detailed estimates of potential loss of life (to assist in decision-making if the appropriate analysis is carried out).

Note 2. Implications for loss of life:

Unspecified—The appropriate level of safety required at a dam where people are temporarily at risk depends on the number of people, the exposure time, the nature of their activity, and other conditions. A higher class could be appropriate, depending on the requirements. However, the design flood requirement, for example, might not be higher if the temporary population is not likely to be present during the flood season.

Reference: Supplementary Hydrotechnical Assessment
Former Gullbridge Mine Tailings Dam

APPENDIX B

Figure B.1 Normalized Factors to estimate Peak Flows with different recurrence intervals in $m^3/s/km^2$ – Station 02YL001

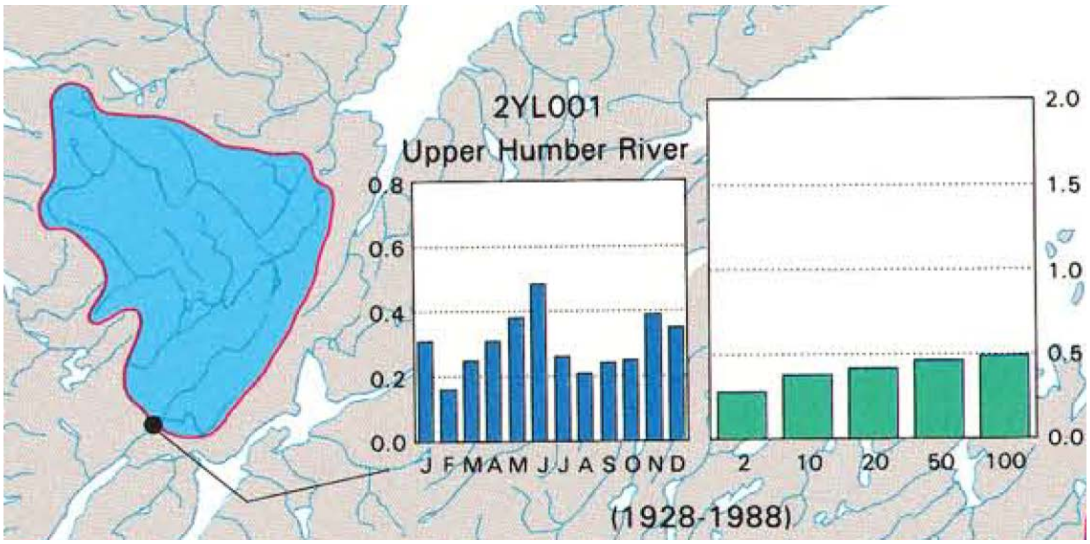

Figure B.2 Extrapolated Maximum Peak Flows for large storm events