APPENDIX U

TAILINGS MANAGEMENT AREA FAILURE AND WATER QUALITY ASSESSMENT

TAILINGS MANAGEMENT AREA FAILURE AND EFFECTS ASSESSMENT
RAINY RIVER GOLD PROJECT

Submitted by:

AMEC Environment & Infrastructure
a Division of AMEC Americas Limited
160 Traders Blvd., Suite 110
Mississauga, Ontario
L4Z 3K7

On behalf of:

Rainy River Resources Limited
1111 Victoria Avenue East
Thunder Bay, Ontario
P7C 1B7

June 2013
TC111504

EXECUTIVE SUMMARY

A catastrophic tailings dam failure is an extremely unlikely event, and the results presented in this report are not in any way intended to reflect upon the integrity of the dam, or the likelihood of such a failure. They are merely intended to demonstrate the consequences of such an extreme event, were such an event to occur under worst case assumptions. The expected environmental impact of a "credible worst case" dam failure was examined as part of the Rainy River Gold Project (RRGP) environmental assessment process. A credible worst case dam failure, for the purpose of this exercise, is defined as a full breach of the dam to its toe, releasing a large volume of tailings water into the Pinewood River, at a time when the river is in a zero flow late summer condition. The purpose of the undertaking was to demonstrate the level of expected overall impact of such a failure, and to identify reasonable measures in the design and operation, as appropriate, to mitigate the potential risk to the downstream environment. Material transport in the Rainy River was modelled for the most conservative case, 7Q20 low flow condition. Greater mixing potentials would result in lower parameter concentrations in the Rainy River under higher river flow conditions.

The assessment was carried out in two parts: the dam failure assessment with flood wave routing along the Pinewood River; and plume dispersion modeling within the Rainy River.

The TMA dam was assumed to fail as a foundation failure. The HEC-RAS hydraulic software package was used to simulate discharge of water and the down-river flood flow from the dam failure.

The simulated peak discharge leaving the TMA was modelled at approximately 500 cubic metres per second, declining to approximately 40 cubic metres per second at the Pinewood River terminus (confluence with the Rainy River). The simulated peak flow would reach the Pinewood River terminus in about one day following a TMA failure. The total simulated quantity of water released by the breach is approximately 3.3 million cubic metres.

The run-out of tailings solids from a simulated breach from a dam section vertical failure of 23.5 metres is at projected at 4.6 kilometres, based on a simplified regression analysis of similar failures. The 4.5 kilometre value exceeds the 3.5 kilometre distance between the dam toe and the Pinewood River, indicating that were this very unlikely event to occur, tailings solids could potentially reach the Pinewood River. The Constructed Wetland complex would help to partially contain tailings solids run-out in the event of such a failure.

Plume dispersion within the Rainy River was modeled using the AQUASEA flow and transport model. Results of model application indicated that parameter concentrations in the Rainy River would be reduced by dilution and hydrodynamic mixing. At any point in the study reach greater than 15 km downstream on Pinewood River the modelled parameter concentration does not exceed 30% of the source concentration. During low flow, at the end of the reach (Lake of the Woods), the plume's maximum parameter concentration was predicted to be less than 27% of the initial source concentration.

The modeling indicated that Provincial Water Quality Objectives for the protection of aquatic life (or equivalent values) would be expected to be met, or approximately met, in the Rainy River downstream of the Pinewood River inflow point, except for a comparatively short exposure zone along the north side of the river closer to the Pinewood River inflow. The potential for adverse effects within this zone, if realized, would therefore be minor and transient.

Due to the conservative modelling assumptions, actual parameter concentrations in the Rainy River during flood water discharge (excluding background additions to the computed values), would be expected to be lower than those predicted by the modelling. Modelling also assumed that all parameters behaved conservatively. Parameters which are not conservative (i.e., which will react, degrade or otherwise be lost from the system, especially in open water conditions) have been over-estimated by this modelling. These non-conservative parameters include free and total cyanide, un-ionized ammonia, cyanate and thiocyanate.

TABLE OF CONTENTS

LIST OF TABLES

PAGE

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

This report presents the assumptions, methodology and results of an assessment carried out by AMEC Environment & Infrastructure, a Division of AMEC Americas Limited (AMEC), of the potential effects of a catastrophic tailings dam failure at the Rainy River Gold Project (RRGP), on Rainy River and Lake of the Woods. This assessment was conducted in support of the broader RRGP Environmental Assessment Report being prepared by AMEC for Rainy River Resources (RRR).

The Tailings Management Area (TMA) for the RRGP is to be located in the upper Pinewood River watershed (total Pinewood River watershed area of approximately 575 km^2), which flows into the Rainy River (watershed area at the Pinewood River confluence of approximately 51,140 km^2), which in turn flows into the Lake of the Woods (Figure 1). A catastrophic tailings dam failure could conceivably release a large volume of water and possibly tailings solids that would flow down the Pinewood River and enter into the Rainy River, possibly impacting water and/or sediment quality. The Rainy River and Lake of the Woods are both international waterways.

The expected environmental impact of a credible worst case dam failure has been examined as part of the Environmental Assessment process. A credible worst case dam failure, for the purpose of this exercise, is defined as a full breach of the dam to its toe, releasing a large volume of tailings water into the Pinewood River, at a time when the river is in a zero flow late summer condition. The purpose of this undertaking is to demonstrate the level of expected overall impact of such a failure, despite its unlikely occurrence, and to identify reasonable measures in the design and operation of the TMA to mitigate the potential risk to the downstream environment.

To complete the undertaking, a conservatively based assessment was carried out with the objective of providing a representation of the magnitude and extent of the potential impact. The results of this assessment are considered appropriate to identify the upset risk of such a tailings dam failure, given the conservative assumptions used in the assessment.

2.0 SCOPE OF WORK

The assessment has two parts and four components:

Part 1: Failure Assessment:

1. Flood Wave Evaluation - Evaluation of the flood wave resulting from a catastrophic tailings dam failure, and its routing and dissipation along the Pinewood River to its confluence with Rainy River.

2. Tailings Solids Evaluation - Evaluation of the potential for tailings solids associated with a tailings dam failure to reach the Pinewood River (tailings run-out).

Part 2: Rainy River Water Quality Evaluation:

3. Hydrologic Evaluation - Evaluation of flow rates in the Rainy River and its major tributaries for application in water quality assessment of the Rainy River in terms of contaminant loading from a tailings dam failure flood wave from the Pinewood River.

4. Water Quality Evaluation - Evaluation of the spatial extent and concentration of a plume in the Rainy River that may result from contaminant loading from a failure flood wave entering the Rainy River from the Pinewood River. This analysis provides a mechanism for estimating potential water quality impacts along the Rainy River downstream of the confluence with the Pinewood River.

This report provides a summary of the approach, methodology and results for all four tasks of the assessment.

3.0 PART 1: FAILURE ASSESSMENT

3.1 Flood Wave Evaluation

3.1.1 Introduction

The TMA dam was assumed to breach in a "sunny-day" failure mode (i.e., a foundation failure to the TMA dam under late summer zero flow conditions in the Pinewood River). This scenario was perceived to represent the highest potential upset water quality loading to the receiver.

It should be noted that this selection was not based on the likelihood of a foundation failure generating a catastrophic tailings dam failure. A catastrophic TMA failure is an extremely unlikely event. The results presented in this report are not in any way intended to reflect upon the integrity of the dam, or the likelihood of such a failure. They are merely intended to demonstrate the consequences of such an extreme event, were such an event to occur under worse case assumptions.

In fact, a number of design and procedural measures have been, or will be, implemented to prevent the possible occurrence of a catastrophic dam failure, including:

- Geotechnical investigations to fully understand tailings dam foundation conditions, and the nature of materials that will be used to construct the dams;

- Tailings dam designs that meet or exceed prescribed factors of safety for long-term stability;

- Third party review of dam designs, to be supported by government review of the designs;

- Spillways designed to pass the Probable Maximum Flood;

- Allowance for sufficient operational freeboard to accommodate extreme precipitation events;

- Provision of chimney filter drains in the tailings dams to dissipate tailings dam pore pressures and protect against potential cracking;

- Use of instrumentation to measure tailings dam pore pressures and settlement;

- Construction supervision to ensure quality control and assurance; and

- Regular inspections of the tailings dams by a qualified geotechnical engineer, once the dams have been completed.

In cases where tailings dams do fail, it is often during an extreme precipitation event, or early in the dam construction sequence. In the first instance, there would be considerable flow in the downstream river systems to dilute the effluent release. The dry period failure condition assumed in this analysis is therefore conservative, in that extreme low flow conditions are assumed for downstream waters. In the second instance, dam heights would be considerably less than the maximum design height, such that tailings solids run-out would be less than defined herein.

3.1.2 Methodology

The HEC-RAS hydraulic software package (version 4.1.0), released by the United States Army Corps of Engineers, was used to simulate discharge of water resulting from the failure. This modelling was carried out in unsteady mode in two phases:

- Generation of the failure hydrograph; and

- Routing of the failure hydrograph through the Pinewood River to its confluence with the Rainy River.

3.1.3 Topographic Data

The following topographic data were used to support the TMA failure modelling:

- Within the TMA, the stage-storage relationship was based on the modelled tailings surface as shown in the Feasibility Study (BBA 2013). The tailings dam was coded in as a lateral structure, with a final dam crest elevation of 379.5 metres above sea level (masl) as shown in the Feasibility Study.

- The topography downstream of the TMA was derived from available provincial Digital Elevation Models (DEM; Ministry of Natural Resources 2006).

3.1.4 Input and Simulation Parameters

The final stage TMA dam crest elevation (379.5 masl) was used in combination with the stage-storage relationship for year 8.9 of operations. The initial water elevation was assumed to be at the normal operating level of 368.5 masl. The TMA was simulated in HEC-RAS as a storage area connected to the river via a lateral structure (the tailings dam) located between sections XS38000 and XS37011 (Figure 2). This location represents the approximate location of Loslo Creek where the tailings dam will be located.

A total of 39 cross sections, spaced approximately 1,000 m apart, were created along the length of the Pinewood River from contours developed from the provincial DEM. Cross sections were extended up to 1,500 m on either side of the river centerline to capture sufficient floodplain to model a failure scenario with potentially large peak flows. For purposes of model stability, cross sections were interpolated throughout the reach with sections positioned at distances no larger than 250 m apart.

Breach parameters (elevation, initial width, side slopes and related parameters) were calculated using the method of Froehlich (1987). The failure model was run at a one second simulation time step for purposes of model stability.

3.1.5 Simulated Peak Discharge at Dam and at Confluence with Rainy River

The simulated peak discharge leaving the TMA for the modelled dam failure mode directly downstream of the dam is approximately 500 cubic metres per second (m^3/s). At the confluence with the Rainy River, the simulated Pinewood River peak discharge for the modelled dam failure mode attenuates to approximately 40 m^3/s. The simulated peak flow reaches the Pinewood River confluence with the Rainy River about 1 day following the simulated failure, and the majority (95%) of the discharge hydrograph is discharged within about 1.5 days following the peak.

The discharge hydrograph is graphically illustrated in Figure 3 and is presented in tabular format in Appendix A, Table A1. The total simulated quantity of water released by the breach is approximately 3.3 million cubic metres (Mm^3).

3.2 Tailings Solids Evaluation

3.2.1 Methodology

Following a breach of a tailings dam, a portion of tailings stored at the dam may be released. This outflow volume is difficult to estimate as it depends on several variables. These variables include:

- Sediment load;
- Fluid behaviour (Newtonian or Binghamplastic) which depends on the type of failure (e.g., seismic action, static liquefaction, slide, etc);
- Particle-dependent rheology of the suspension;
- Topography and valley gradient; and
- The presence of obstacles impeding the slurry flow, among others.

The tailings outflow volume from a potential failure incident depends on the liquefaction process, breach time, breach size and the amount of water in the pond at the time of failure. In most failure cases, tailings ponds never empty completely and only a limited portion of the tailings solids are released. The height difference between the crest of a tailings dam and the decant surface, known as freeboard, is generally small, and essentially the dam height equals the thickness of the tailings deposit. Accordingly, dam height provides a good approximation of the tailings thickness and its potential energy during a dam failure.

For this assessment, the extent of tailings solids run-out was estimated based on a research paper by Rico et al. (2008) containing a survey of incidences and related data on 29 historic tailings dam failures with the purpose of establishing a simple correlation between tailings pond dam height and the run-out distance of spilled tailings solids.

Figure 4 shows a plot of dam height (H) for the known historical tailings dam failures versus the outflow run-out distance (D_{max}). The graph shows considerable dispersion of data and a poor relationship between these variables, described by the following regression equation:

$D_{max} = 0.0528 \times H^{1.413}$ ($r^2 = 0.16$) ....Equation 1

The low correlation shows that run-out distance depends on other factors not considered in the equation, such as outflow mine waste volume, gradient and the topography into which the tailings flow.

The envelope curve for run-out distance from all the tailings dams has the equation:

$D_{max} = 0.008 \times H^{3.23}$...Equation 2

3.2.2 Predicted Tailings Run-out

Based on the maximum dam crest elevation of 379.5 masl and minimum ground elevation at the dam toe of 356 masl, the maximum dam height is 23.5 m. Based on regression equation 1, the run-out distance is about 4.6 km. This exceeds the 3.5 km distance between the dam toe and the Pinewood River, implying that the tailings solids could potentially reach the Pinewood River, and be mobilized further downstream by stream flow. Based on regression equation 2 (envelope curve), the run-out distance would exceed 100 km, implying that the tailings would reach the Rainy River. It should however, be noted that this is an extremely conservative scenario, assuming that tailings run-out would follow the behaviour of those historical cases with the longest recorded run-out distances.

3.2.3 Discussion

The described regression method provides a simplified approximation of tailings solids outflow characteristics, which is of importance for risk analysis purposes. It indicates that in the case of a catastrophic tailings dam failure, there is a reasonable potential that tailings solids could reach the Pinewood River.

Application of the described regression equations for prediction purposes should be treated with caution due to the very low correlation of run-out distance with dam height. Also, the proposed Constructed Wetland complex would be expected to impede and retain a portion of the tailings solids run-out.

4.0 PART 2: RAINY RIVER WATER QUALITY EVALUATION

4.1 TMA and Receiver Water Quality

Predicted TMA and receiver background water quality data for key parameters are shown in Table 1. The second column in Table 1 (CND Test Time – 0) shows expected process plant effluent following cyanide destruction and heavy metal precipitation using the SO_2/Air process. Column 3 of Table 1 shows these same data after a further approximately 60-day aging period in the laboratory under simulated natural conditions at room temperature. Aging tests were carried out in containers holding a layer of treated tailings solids covered by a thin, approximately 6 cm thick layer of liquid effluent. Both data sets are for filtered samples. The fourth column of Table 1 represents the expected quality of stored process plant effluent in the TMA pond that would be released under a catastrophic dam failure. Column 4 values are rounded averages of Column 2 and 3 values, except for cadmium, zinc and hardness where more conservative values were used. The TMA pond has a retention time of several months, such that Column 4 values are considered conservative, recognizing that seasonal variations in TMA water quality will occur, especially for cyanide.

Cadmium and zinc are neutral soluble metals and the aging test work indicated some tendency for these metals to come into solution following effluent aging. The 60-day aging test values were therefore used for these two metals as the more conservative case. Test work showed that concentrations of both metals had levelled off by 60 days. The hardness value of 300 mg/L shown in Column 4 of Table 1 was reduced from the average of Columns 2 and 3, to account for precipitation and general site runoff that would be added to the TMA basin. This value is conservative.

Baseline water quality values shown for the Pinewood River and Rainy River are 75th percentile values calculated from monthly sampling data collected since June 2010. The Ministry of the Environment (MOE) requests that water quality effects to receiving waters be calculated on the basis of 75th percentile values. The only exception is hardness where a median hardness value has been used. Median hardness values are more conservative than 75th percentile values for this parameter, as hardness is a metal toxicity modifying factor, wherein higher hardness values result in reduced toxicity for metals where toxicity is affected by hardness.

4.2 Hydrologic Evaluation

4.2.1 Introduction

All available daily flow data for the Rainy River and its main tributaries in the study area were downloaded and analyzed, to determine average and low flow conditions.

Long term Rainy River daily flow records are available for two Water Survey of Canada stream flow stations:

- Rainy River at Fort Frances (05PC019, 38,600 km^2, available data 1905 to 2010); and
- Rainy River at Manitou Rapids (05PC018, 50,200 km^2, available data 1928 to 2010).

For the water quality evaluation, flows were also estimated at three points further downstream:

- Rainy River at Pinewood confluence (51,140 km^2);
- Rainy River at Rapid River confluence (53,660 km^2); and
- Rainy River at Lake of the Woods (54,820 km^2).

Average and low flows at these points were estimated by pro-rating flows obtained from the Rainy River at Manitou Rapids (05PC018) by the ratio of drainage areas raised to the exponent 0.87. This exponent was found to give the best prediction of flows for the Rainy River at Manitou Rapids (05PC018) from recorded flows for the Rainy River at Fort Frances (05PC019).

Significant tributaries into the Rainy River within the study area are:

- Pinewood River (574.5 km^2); and
- Rapid River (1,406 km^2).

Table 2 summarizes the catchment areas and mean annual discharges for the various points that were evaluated.

4.2.2 Evaluation of Annual Mean and Low Flows

The Rainy River is a regulated system and consequently the low flow periods are determined by a combination of seasonal runoff patterns and water management effects. A study of daily flow records over the period of record 1928 to 2010 at the nearest gauge to the Pinewood River (Rainy River at Manitou Rapids, 05PC018) shows that although the highest flows typically occur during spring freshet, with lower flows during the rest of the year, the year-to-year flow patterns are quite variable. A review of the stream flow data indicates that high flows and low flows can occur in any season.

Two low flow conditions are presented, the 7Q20 flow, defined as the lowest 7 day average flow based on a 20 year return interval; and the 10 year monthly low flow, defined as the lowest monthly average flow based on a 10 year return interval.

Regarding 7Q20, in cases when low flow is an issue only during a particular season (e.g., for navigation or fish passage) a seasonal 7Q20 is determined, in which case the consecutive seven-day periods are limited to the season of interest. However, for the present evaluation the expected water quality effects from a failure would be of relevance whenever they occurred and are not limited to a particular season. For this reason a seasonal 7Q20 was not considered and the 7Q20 values were determined for annual flow.

Table 3 presents a summary of annual and low flow statistics at the various points of interest in the Rainy River and the Rapid River.

4.3 Water Quality Evaluation

4.3.1 Introduction

River dispersion modelling was undertaken by AMEC to assess the potential effect of a catastrophic TMA dam failure on the Rainy River and Lake of the Woods. This part of the report summarizes results of analyses to evaluate the extent and concentration of a plume in the Rainy River that may result from contaminant loading from the flood wave entering the Rainy River from the Pinewood River. This analysis provides a mechanism for estimation of potential water quality impacts along the Rainy River downstream of its confluence with the Pinewood River (i.e., parameters potentially exceeding Provincial Water Quality Objectives for the protection of aquatic life; PWQO).

4.3.2 Methodology

The assessment was carried out with the intent of providing a conservative indication of the magnitude and extent of impact. Accordingly, available data were interpreted and analyzed based on simplified, conservative assumptions of a more complex process. Average Rainy River channel depth required for the analysis was estimated from average flow and channel width and gradient data, cross correlated with river bathymetry data available from Lakemaster (2008).

The plume dispersion and dilution calculations were performed with the help of a numerical flow and transport model for the 7Q20 case only, as this is the most conservative case. Dispersion modelling was not carried out for average river flow conditions, as these conditions would yield reduced in-river water quality parameter concentrations compared with the 7Q20 condition. The 7Q20 condition for the Rainy River at its confluence with the Pinewood River was calculated at 80.9 m^3/s (Table 3). Annual and low flow statistics for the Rainy River are given in Table 3. A 41 km length of the Rainy River reach, between points extending from 1 km upstream of Pinewood confluence, to Lake of the Woods, was modelled. The variable geometry of the river reach was simplified to a rectangular channel with bottom elevations varying from 315 to 319.5 masl for the study reach, corresponding to river depths of from 8.0 to 3.5 m.

The river flow model was calibrated for the average flows in the Rainy River initially. Flow and transport were both simulated in the Rainy River in transient mode by coupling the flood hydrograph joining from Pinewood River.

Parameter concentration estimates for the Rainy River, associated with the dam failure flood water discharge, were determined in the river reach downstream of the Pinewood River confluence by assuming an initial parameter concentration of 100% in the Pinewood River flood hydrograph. These 100% parameter concentrations correspond to Column 4 values in Table 1, as Pinewood River flows in the 7Q20 condition were considered to be zero. The residual volume in the Pinewood River available for mixing in a zero flow condition was considered to be negligible compared with the approximate 3.3 Mm^3 dam failure release volume.

For ease of presentation, the initial flood water parameter concentration was presented as 100 percent in the Pinewood river flood discharge water to the Rainy River used in the analysis. The results are directly proportional to the initial concentrations and can be used to assess the concentrations of any of the conservative substances contained in the flood water. Parameters which are not conservative (i.e., which will react, degrade or otherwise be lost from the system, especially in open water conditions) will be over estimated by the modelling. These non-conservative parameters include free and total cyanide, un-ionized ammonia, cyanate and thiocyanate.

4.3.3 Model Description

The model used in the analysis was AQUASEA (1992). AQUASEA is a two-dimensional, depth averaged flow and transport model using a mixed (staggered) Galerkin finite element method with triangular elements. It is designed to simulate hydraulic flow in estuaries, rivers, lakes and coastal areas. The flow model is based on the solution of two-dimensional shallow water equations including bed resistance, wind stress and nonlinear convection terms. The transport model includes sources, decay, and convective and dispersive transport.

Assumptions used for modelling the mixing of Pinewood River flood water discharge with the Rainy River were the following:

- Differences between the model averaged and actual river depths are small and will not change the flow regime at the larger scale, will not affect overall results obtained through the modelling.

- The average flow rate in the Rainy River is 31,968,000 m^3/day (370 m^3/s).

- The 7Q20 low flow rate in the Rainy River is 6,990,000 m^3/day (80.9 m^3/s).

- Average Rainy River channel depth was estimated from average river flow and width, cross correlated with detailed river bathymetry data available from Lakemaster (2008).

- The bottom friction coefficient is estimated during the flow model calibration, and is based in part on other studies carried out for the river and other river reaches with similar morphology.
- Other flow and transport parameters, such as transverse and longitudinal dispersion coefficients were estimated from published data for similar river reaches.

- The effluent discharge is chemically conservative.

- The flow in the river is uniform; the effects of rapids and secondary currents on the flow regime and mixing are ignored.

- The river velocities govern mixing in the river with initial mixing due to momentum of the Pinewood River inflow being neglected. The Pinewood River flood enters the Rainy River through an approximately 50 m wide channel located at the northern river bank at a variable rate, and is completely mixed with river water in the vertical water column.

- The variable inflow rate from Pinewood River was calculated in Part I. Failure Assessment (Section 3). The dam breach hydrograph at the TMA dam and at the confluence of the Pinewood River with the Rainy River is presented in Table A1 in Appendix A.

- Salinity concentrations in the plume are small so as not to create significant density gradients in any direction.

- Tributaries or streams entering the study reach (Rapid River, Baudette, etc.) were simulated using their estimated inflows prorated to the low flows calculated for the Rainy River (Table 3).

In general, it should be noted that the assumptions used to construct the model are conservative.

Bathymetric information, based on previously collected data including field observations, was used to estimate the average depth and the river bed elevation and incorporated into the finite element grids constructed. The study reach was simplified to a rectangular channel with bottom elevations varying from 315 to 319.6 masl.

The finite element model grid contains 10,940 triangular elements and 5,991 nodes. The element sizes vary from approximately 15 m near the river confluences to 100 m near Lake of the Woods. Separate flow scenarios were analyzed for the river with and without the Pinewood River flood inflow during model calibration and simulation stages.

Considering the assumption of uniform flow in the simulated river channel, and ignoring small head losses through the reach, hydraulic gradients in the model were estimated to be small (less than 0.0001). The hydraulic gradient for the upper half of the reach (0.0001) was greater due to the shallower depths, compared with the hydraulic gradient for the deeper lower half of the reach which was estimated at 0.00003. Hydraulic gradients were adjusted during the calibration of flow simulations.

The Manning roughness coefficient for the river reach was estimated from values available in the literature for similar channels. Roughness coefficients used in the hydrodynamic model for Rainy River upstream of the dam at International Fall / Fort Frances were also reviewed (ARC-CNRC 2010).

The river bottom friction constant (Chezy's coefficient - *C*) was calculated using the Pavlovskii formula (Chow 1960):

$$C = 1.5 \frac{R^y}{n}$$

Where: *n* = the Manning roughness coefficient
R = the hydraulic radius calculated as a ratio of area of cross section to the wetted perimeter

and:

$$y = 1.5\sqrt{n} \qquad \text{for } R<1.0 \text{ m}$$

In the model grid, flow and mass flux calculation boundaries were installed along the river reach at 500 m, 2 km and at 5 km intervals downstream from the outfall location. Also, several time series nodes were selected at similar grid locations for both flow and transport models. Time series flow and concentration data accumulated at these calculation boundaries, and at the selected time series nodes, were used to check model variables at the end of each calibration and simulation run.

4.3.4 Model Calibration

The flow model was run to generate the observed average flow rate in the Rainy River (370 m^3/s at Pinewood River confluence) by varying the Chezy's friction coefficient and comparing the simulated flow rates throughout the river reach with the observed values. The estimated low flow rate of 80.9 m^3/s corresponding to the 7Q20 flow condition, was achieved in the model using Chezy's friction coefficients of 18 $m^{1/2}/s$ and 30 $m^{1/2}/s$ for the upstream and downstream portions of the river reach, respectively.

At the end of calibration, the simulated velocities for low flow in the river varied from 0.040 to 0.075 m/s. In the areas closer to the river banks the velocities would be much smaller.

4.3.5 Transport Model Simulations

The transport model was designed to use the same grid as well as the velocities generated in the flow model. Transport runs for the Rainy River were performed simultaneously with the flow runs, in transient mode. The flows and velocities in the reach were generated at every time step for the period of the flood wave passing through the 40 km reach of the Rainy River which was approximately 10 days. The flood wave entering the Rainy River was simulated as a continuous source with a variable discharge rate, tracing parameter percentage concentration changes with time.

The following assumptions were used in simulating the flood wave transport in the Rainy River:

- The Pinewood River discharges the flood water near the north bank of the Rainy River at Pinewood confluence, where average water depth is greater than 3.4 m during the low flow;
- The flood hydrograph peaks at 39 m^3/s discharge rate approximately 9 hours after its first appearance in the Rainy River and reduces gradually to 1.0 m^3/s after 56 hours;
- The parameter concentration discharged from the Pinewood River to the rainy River is the initial Pinewood River influx concentration (i.e., 100% of the influx concentration); and
- The background concentration of the nominal parameter in the Rainy River is zero.

The modelling investigated plume migration in the Rainy River downstream of the Pinewood River confluence for low flow conditions for 240 hours (10 days). The upstream boundary condition was assigned a specified concentration of zero. The downstream boundary was assigned a zero concentration gradient. The source boundary was selected on the model grid to coincide with the Pinewood River confluence as shown on Figure 5. Parameter concentrations in the inflows entering the Rainy River from tributaries were assigned a value of zero.

The main parameters required in the transport model (the longitudinal and transverse dispersion coefficients) were estimated from the literature for similar channels having uniform flows and low velocities as 1.0 and 0.2 m^2/s, respectively. The representative transverse dispersion coefficients, as determined by field tests and laboratory experiments, were summarized in Sumer (1976) and Beltaos (1978). The transverse dispersion coefficient is typically 5 to 10 times smaller than the longitudinal dispersion coefficient for straight channels. Due to the meanders and river morphology in the actual river, a slightly larger transverse dispersion coefficient was used for the river reach.

Transport simulations were conducted relative to the initial parameter concentration (100 percent) existing in the flood water discharge from the Pinewood River to the Rainy River at the confluence of the Pinewood River with the Rainy River. For the purposes of modelling, parameter percentage concentrations were again conservatively assumed to be resistant to decay, sorption or other processes that would remove them from solution in the river water.

Figures 6 through 17, pertaining to the 7Q20 low flow condition, illustrate nominal parameter concentration changes estimated along the Rainy River downstream of the Pinewood River confluence. Plume concentrations are shown at various time snapshots, progressing downstream from the source to the end of the modelled river reach (to the entrance of Lake of the Woods). Results indicate that higher concentrations will initially occur along the northern bank of the Rainy River and closer to the source outlet.

Based on the results of transport simulations for the low flow condition, the parameter plume generated by the flood wave initially follows the north shore of the Rainy River, and at the end of 6 hours expands transversely to approximately 196 m with the plume front reaching 1,900 m along the north river bank. At the end of 12 hours the plume reaches to the south river bank of the Rainy River with a concentration of 2 percent of the initial Pinewood River influx concentration and its front reaching 4,250 m along the north river bank. At the end of the first day (24 hours) the plume reaches 8,300 m downstream along the north Rainy River bank, and the maximum concentration along the south river bank reaches 15 percent of the initial Pinewood River influx concentration. Concentration versus time plots (breakthrough curves) for points A and B on the north and south river bank, 5 km downstream of the Pinewood River (Figure 5) are shown on Figure 18. Percent concentration breakthrough curves at points along north Rainy River riverbank are shown on Figure 19.

At the end of two days, the plume front along the Rainy River reaches 14,400 m distance, and shows maximum concentrations within the plume of 35 percent and 28 percent of the initial Pinewood River influx concentration (at a point located approximately 10,000 m downstream of the Pinewood River inflow) along the north and south banks of the Rainy River, respectively. Plume concentrations in the Rainy River at the end of each day and/or half day are illustrated in Figures 9 through 17. Although the parameter source concentration stays constant at 100 percent for the duration of flood wave (56 hours), the flood flow reduces significantly after the first day (to approximately one third); hence the mixing power (dilution) of the Rainy River increases resulting in lower parameter concentrations at the plume tail. The plume front travels at an average velocity of approximately 180 metres per hour (m/h), attaining the end of the Rainy River reach (40.0 km) in about 230 hours (about 9.5 days).

The mass flux entering and leaving the reach was computed in the model at flux boundaries installed into the model grid at various transects, to verify that no significant loss of parameter mass occurred in the reach during model simulations. Conservation of the total amount of the nominal parameter flowing in and out of the study reach was checked to verify model reliability against numerical dispersion and convergence in time. There is a small dilution effect around the entrance of the Rapid River joining in to the Rainy River (Figure 13). Review of the time series data accumulated in a file at the end of the low flow transport simulations indicated that the total mass flux entering Lake of the Woods spreads over a period of approximately four days, following Gaussian distribution with a peak mass flux rate of approximately 2.3 kilograms per second (kg/s). The mass flux near the Pinewood River confluence and Lake of the Woods in the Rainy River is shown in Figure 20.

Modelling has demonstrated that the parameter concentration entering into the Rainy River would be immediately diluted (assuming instant mixing in model element) by river water to approximately 62% at the Pinewood River inflow concentration during the 7Q20 low flow condition. It should be noted that the model does not solve for near field (turbulent jet) dispersion, and that parameter concentrations in the river in close proximity to the source are approximate. The parameter plume concentration along the north river bank at a point 500 m downstream of the Pinewood River confluence would exceed 90 percent of the source inflow concentration for approximately 12 hours during the passage of the plume travelling through this point. At a point 2,000 m downstream, the parameter concentration near the north river bank would exceed 60 percent of the initial Pinewood River influx concentration for approximately 12 hours as shown on Figure 18. At any point in the Rainy River study reach greater than 15 km downstream of Pinewood River inflow the parameter concentration would not exceed 30% of the source inflow concentration (Figure 19).

During low flow, at the end of the reach (Lake of the Woods), the plume's maximum concentration was predicted to be approximately 27% of the initial Pinewood River influx parameter concentration. The duration of exposure of any point at the end of the Rainy River reach to a parameter concentration of 20 percent or more of the initial Pinewood River influx concentration would be shorter than 20 hours. While the lateral (across channel) concentration gradient would be as large as 0.26 percent of the the initial Pinewood River influx concentration per lateral m of the river (80 percent / 310 m near the Pinewood River inflow point), the cross-channel gradient would be approximately zero at the end of the reach.

Breakthrough curves at points A (north riverbank) and B (south riverbank) around 5 km downstream of the Pinewood River inflow, and the concentration contours presented in Figures 6 through 17, indicate that the nominal parameter concentration never exceeds 50 percent of the initial Pinewood River influx concentration along the north bank of the Rainy River and 25 percent of the initial Pinewood River influx concentration along the south river bank downstream of these points.

4.3.6 Low Flow Water Quality Simulations

Based on the data presented in Figure 19, once the flood wave reaches the 15 km downstream point on the Rainy River, the flood wave plume from the Pinewood River is diluted to a maximum value of not greater than 30% of the original concentration. Applying this percentage to the parameters listed in Table 1 generates maximum parameter concentrations shown in Table 4. Comparisons with PWQO values show that only free cyanide, copper, zinc and un-ionized ammonia concentrations would be expected to exceed PWQO values downstream from this point in the river, and only for a relatively brief period (less than 40 hrs) as the flood wave passes.

In viewing these four parameters, free cyanide and un-ionized ammonia are not conservative parameters (i.e., they are reactive and volatile). Hence there would be additional loss of these parameters from the system. Taking into consideration the comparatively low levels of these two parameters (only marginally above PWQO values), their reactive state, short exposure times, and conservative nature of the model and the 7Q20 condition, downstream adverse effects to aquatic life from exposure to free cyanide and un-ionized ammonia would not be expected.

With regard to copper and zinc both metals are shown to exceed their respective PWQO values. The PWQO value for copper does not however, fully consider hardness effects, as the 0.005 mg/L PWQO value is based on hardness values greater than 20 mg/L. If United States Environmental Protection Agency (US EPA) equations are applied to copper and zinc, the calculated river values do not exceed the calculated US EPA long-term thresholds for the protection of aquatic life (US EPA 2009). Taking into consideration hardness effects, short exposure times, and the conservative nature of the model and the 7Q20 condition, adverse effects to aquatic life related to copper and zinc would not be expected.

Upstream of the 15 km point, parameter concentrations would be greater than those shown in Column 4 of Table 4, especially during the first 24 hour exposure period close to the north side of the river. There is some potential for adverse effects within this zone, but any such effects, if any, would still be considered minor and transitory.

5.0 SUMMARY AND CONCLUSIONS

The expected environmental impact of a "credible worst case" dam failure was examined as part of the RRGP environmental assessment process. The purpose of this undertaking was to allow RRR to demonstrate the level of expected overall impact of such a failure, and to identify reasonable measures in the design and operation, as appropriate, to mitigate the potential risk to the downstream environment. The assessment was carried out based on conservative assumptions. Contaminant transport in the Rainy River was modelled for the most conservative case, 7Q20 low flow condition. Greater mixing potentials would result in lower parameters concentrations in the Rainy River under higher river flow conditions.

The simulated peak discharge leaving the TMA for the modelled dam failure mode directly downstream of the dam is approximately 500 m^3/s, declining to approximately 40 m^3/s at the Pinewood River terminus (confluence with the Rainy River). The simulated peak flow would reach the Pinewood River terminus in about 1 day following a failure. The total simulated quantity of water released by the breach is approximately 3.3 Mm^3.

The run-out of tailings solids from a simulated breach from a dam section vertical failure of 23.5 m is projected at 4.6 km, based on regression analysis of similar failures (Figure 4), recognizing that the base data are highly variable. The 4.5 km value exceeds the 3.5 km distance between the dam toe and the Pinewood River, indicating that were this unlikely event to occur, tailings solids could potentially reach the Pinewood River. The Constructed Wetland complex would help to partially contain tailings solids run-out in the event of such a failure.

Based on a low flow rate of 80.9 m^3/s corresponding to the 7Q20 flow condition, flow and transport modelling indicated that parameter concentrations in the Rainy River would be reduced by dilution and hydrodynamic mixing. The parameter plume concentration along the north bank of the Rainy River at a point 500 m downstream of the Pinewood confluence would exceed 90 percent of the initial Pinewood River influx concentration for approximately 12 hours during the passage of the plume travelling through the point. At no point in the study reach, greater than 15 km downstream of Pinewood River confluence, would the modelled parameter concentration exceed 30% of the source concentration.

During low flow, at the end of the reach (Lake of the Woods), the plume's maximum parameter concentration was predicted to be less than 27% of the initial source concentration, with exposure of any point at the end of the reach to a parameter concentration of 20 percent or more of the source concentration being shorter than 20 hours. These results indicate a negligible potential for toxicity to aquatic life in the lower reaches of the Rainy River and in Lake of the Woods.

Based on the data presented in Figure 19 and in Table 4, PWQO or PWQO equivalent values are expected to be met, or approximately met, in the Rainy River downstream of the Pinewood River inflow point, except for a comparatively short exposure zone along the north side of the river closer to the Pinewood River inflow. The potential for adverse effects to aquatic life within this zone, if realized, would be minor and transient.

Due to the conservative modelling assumptions as specified in Section 3, it should be noted that actual parameter concentrations in the Rainy River during flood water discharge (excluding background additions to the computed values), would be expected to be lower than those predicted by the modelling. The reason for this is that any features that influence the flow path (rapids, islands, meanders, etc.), the effects of which were ignored and/or averaged during modelling, would increase turbulence, initiate secondary currents and promote mixing. These factors would further contribute to reducing overall predicted parameter concentrations. Also a number of the parameters considered, namely free and total cyanide, un-ionized ammonia, cyanate and thiocyanate, are not conservative parameters and would be expected to show some level of degradation within the system.

6.0 REFERENCES

AQUASEA. 1992. *Tidal Flow in Estuaries and Coastal Areas Lake Circulation Transport Modelling*. Vatnaskil Consulting Engineers. Reykjavik, Iceland.

BBA. 2013. NI 43-101 Feasibility Study of the Rainy River Gold Property, Ontario Canada. Prepared in collaboration with AMEC, Golder Associates, SGS, Merit Consultants International and SRK Consulting.

ARC-CNRC. 2010. Rainy River 2D Hydrodynamic Model Conveyance Study, Prepared for International Joint Commission. Controlled Technical Report CHC-CTR-112. September 2010.

Beltaos, S. 1978. *Transverse Mixing in Natural Streams.* Report No. SWE-78/01, Transportation and Surface Water Engineering Division, Alberta Research Council, 99 pp.

Chow V. T. 1960. Open Channel Hydraulics. McGraw-Hill Book Company, Inc. New York, Tokyo.

Froehlich, D. C., 1987. Embankment Dam Breach Parameters. Proceedings of the 1987 National Conference on Hydraulic Engineering, ASCE, New York.

Lakemaster. 2008. Contourelite. Woods/Rainy Edition. DVD PC Software Version 3 (Rainy River bathymetry data collected Nov 2007).

Ontario Ministry of Natural Resources (MNR). 2006. Digital Elevation Model – Version 2.0.0 – Provincial Tiled Dataset. 300 Water Street, Peterborough, ON K9J8M5.

Rico, M.[1], Benito[2], G., Díez-Herrero, A.[3] 2008. Floods from tailings dam failures. ([1]CSIC – Instituto Pirenaico de Ecología, Zaragoza, Spain; [2]CSIC – Centro de Ciencias Medioambientales, Madrid, Spain; [3]Geological Hazards Unit, Spanish Geological Survey (IGME), Madrid, Spain). J Hazard Mater. 2008 Jun 15;154(1-3):79-87.

Sumer, S. 1976. *Transverse Dispersion in Partially Stratified Tidal Flow.* Report WHM – 20. National Science Foundation Grant No. GI 34932. Hydraulic Engineering Laboratory College of Engineering, University of California, Berkeley, California, 218 pp.

United States Environmental Protection Agency (US EPA). 2009. National Recommended Water Quality Criteria.

7.0 CLOSING

The investigations and activities presented in this report were conducted in accordance with generally accepted environmental assessment principles and practice. The report has been compiled by AMEC based on information assembled by AMEC.

Should any questions arise concerning the preparation of this report or its conclusions, the undersigned should be contacted.

Yours truly,
AMEC Environment & Infrastructure

Prepared by:

Sukru Sumer, Ph.D., P.Eng.
Senior Associate Environmental Engineer

Prepared by:

Peter Nimmrichter, P.Eng., M.Eng.
Senior Water Resources Engineer

Reviewed by:

David A. Simms, Ph.D.
Principal, Environmental Assessment and
Resource Development

Table 1: Predicted TMA Pond and Baseline Receiver Water Quality for Tailings Dam Failure Analysis

Parameter	CND Test Time 01 (mg/L)	CND Test 60-day Aging Test Results2 (mg/L)	TMA Water Quality for Dam Failure Analysis[3] (mg/L)	Pinewood River Background Station SW 3 - 75th Percentile (mg/L)	Rainy River Background Station SW 17 - 75th Percentile (mg/L)	PWQO[4] (mg/L)	PWQO modified by Application of US EPA Hardness Equations
Free cyanide	0.07	<0.01	0.04	0.0	0.0	0.005	
Total cyanide	0.2	<0.01	0.1	0.0	0.0	-	
Antimony	0.07	0.036	0.05	0.00053	0.0005	0.02	
Arsenic	0.004	0.003	0.004	0.003	0.001	0.005	
Barium	0.023	0.029	0.03	-	-	-	
Boron	0.04	0.05	0.05	0.037	0.02	0.2	
Cadmium	0.00002	0.0015	0.0015	0.0001	0.0001	0.0005	
Chromium	0.0008	<0.0005	0.0007	0.005	0.005	0.0089	
Copper	0.055	0.012	0.03	0.002	0.002	0.005	0.011
Lead	0.0002	0.0005	0.0004	0.001	0.0006	0.005	0.004
Mercury	<0.00001	0.00001	0.00001	0.0001	0.0001	0.0002	
Nickel	0.003	0.003	0.003	0.003	0.002	0.025	0.06
Selenium	0.009	0.002	0.006	0.002	0.002	0.1	
Zinc	0.004	0.086	0.09	0.006	0.005	0.02	0.138
Un-ionized Ammonia	0.044	0.153	0.1	<0.0010	<0.0010	0.02	
Cyanate	130	85	100	<1	<1	-	
Thiocyanate	24	25	25	<1	<1	-	
Hardness as $CaCO_3$	475	490	300	-	40	-	

Notes:

1 Process plant effluent concentration immediately following cyanide destruction / heavy metal precipitation (filtered samples)

2 Process plant effluent following cyanide destruction and a further 60-day aging period in simulated natural conditions (filtered samples)

3 Rounded average of Column 2 and 3 results, except for cadmium, zinc and hardness values, showing partially treated values

4 PWQO (Provincial Water Quality Objective) values represent the more stringent of existing or interim values

Table 2: Catchment and Mean Annual Flow Summary

River and Location	Gauge Name	Catchment Area (km^2)	Flow Data from	Mean Annual Discharge (m^3/s)	Notes
Pinewood River at Highway 617	WSC 05PC023	232.67	2008 to 2010	1.79	Published data
Pinewood River near Pinewood	WSC 05PC011	461	1952 to 1998	2.90	Published data available from March to October, other values were estimated
Pinewood River at Rainy River	n/a	574.5	n/a	3.51	Pro-rated from 05PC011
Rapid River near Baudette, MN	USGS 05134200	1,406	1956 to 2012	9.35	Published data
Rainy River at Fort Frances	WSC 05PC019	38,600	1905 to 2010	277	Published data
Rainy River at Manitou Rapids	WSC 05PC018	50,200	1928 to 2010	366	Published data
Rainy River at Pinewood Confluence	n/a	51,140	n/a	370	Pro-rated from 05PC018
Rainy River at Rapid River Confluence	n/a	53,660	n/a	386	Pro-rated from 05PC018
Rainy River at Lake of the Woods	n/a	54,820	n/a	393	Pro-rated from 05PC018

Notes:
n/a: not applicable

Table 3: Annual and Low Flow Statistics in Rainy River

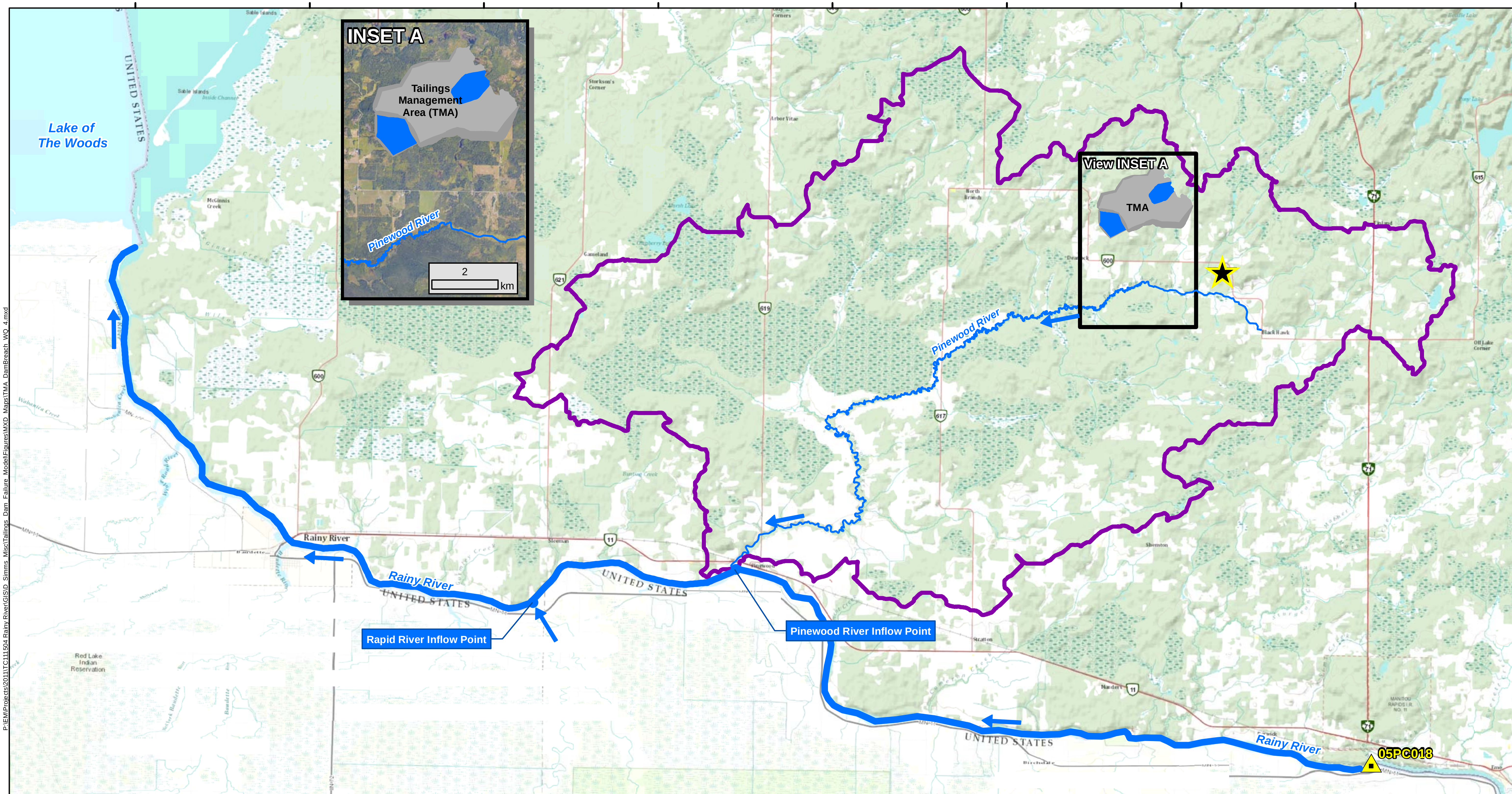
	Rainy River at Fort Frances (05PC019)	Rainy River at Manitou Rapids (05PC018)	Rapid River Near Baudette, MN (USGS Gauge 05134200) Daily Flow Summary	Rainy River at Pinewood Confluence	Rainy River at Rapid River Confluence	Rainy River at Lake of the Woods
Catchment Area (km^2)	38,600	50,200	1,406	51,140	53,660	54,820
Flow Data Source	Measured Flows 1905 to 2010	Measured Flows 1928 to 2010	Measured Flows 1956 to 2012	Pro-rated from Rainy River at Manitou Rapids (05PC018) based on Catchment Area		
Flow (m^3/s)						
Mean	277	366	9	370	386	393
Maximum	614	689	20	784	817	832
Minimum	100	131	3	128	133	136
7Q20	n/a	79.6	0.03	80.9	84.4	86.0
10 Year Low Month	76.8	108.9	0.06	110.7	115.4	117.6

Note: 7Q20 in Pinewood River at Rainy River is considered to be zero, based on the historical data at Pinewood River Near Pinewood (WSC 05PC011) in which 14 months from 1952 to 1998 show zero mean monthly discharge.

Table 4: Predicted 7Q20 Rainy River Water Quality (Maximum Concentration) Downstream of the 15 km Point

Parameter	Pinewood River Flood Wave Concentration (100 % Parameter Concentration) (mg/L)	Rainy River Background Station SW 17 - 75th Percentile (mg/L)	Maximum Predicted Parameter Concentration Downstream of the 15 km Point in the 7Q20 Condition at 30% Plume Strength[1] (mg/L)	PWQO[2] (mg/L)	PWQO modified by Application of US EPA Hardness Equations
Free cyanide	0.04	0.0	**0.012**	0.005	
Total cyanide	0.1	0.0	0.032	-	
Antimony	0.05	0.0005	0.016	0.02	
Arsenic	0.004	0.001	0.002	0.005	
Barium	0.03	0	0.008	-	
Boron	0.05	0.02	0.028	0.2	
Cadmium	0.0015	0.0001	0.0005	0.0005	
Chromium	0.0007	0.005	0.0037	0.0089	
Copper	0.03	0.002	**0.011**	0.005	0.011
Lead	0.0004	0.0006	0.001	0.005	0.004
Mercury	0.00001	0.0001	0.00007	0.0002	
Nickel	0.003	0.002	0.002	0.025	0.06
Selenium	0.006	0.002	0.003	0.1	
Zinc	0.09	0.005	**0.031**	0.02	0.138
Un-ionized Ammonia	0.1	<0.0010	**0.030**	0.02	
Cyanate	100	<1	30.7	-	
Thiocyanate	25	<1	8.1	-	
Hardness as $CaCO_3$	300	40	118.000	-	

Notes:
[1] Bold values exceed PWQO (Provincial Water Quality Objective)
[2] PWQO values represent the more stringent of existing or interim values



LEGEND

- RRGP Site
- Water Survey of Canada Flow Monitoring Station (05PC018)
- Pinewood River Watershed
- General Flow Direction

NOTES:
- Base data outside of Ontario extracted from ESRI DeLorme World Basemap

Datum: NAD83
Projection: UTM Zone 15N

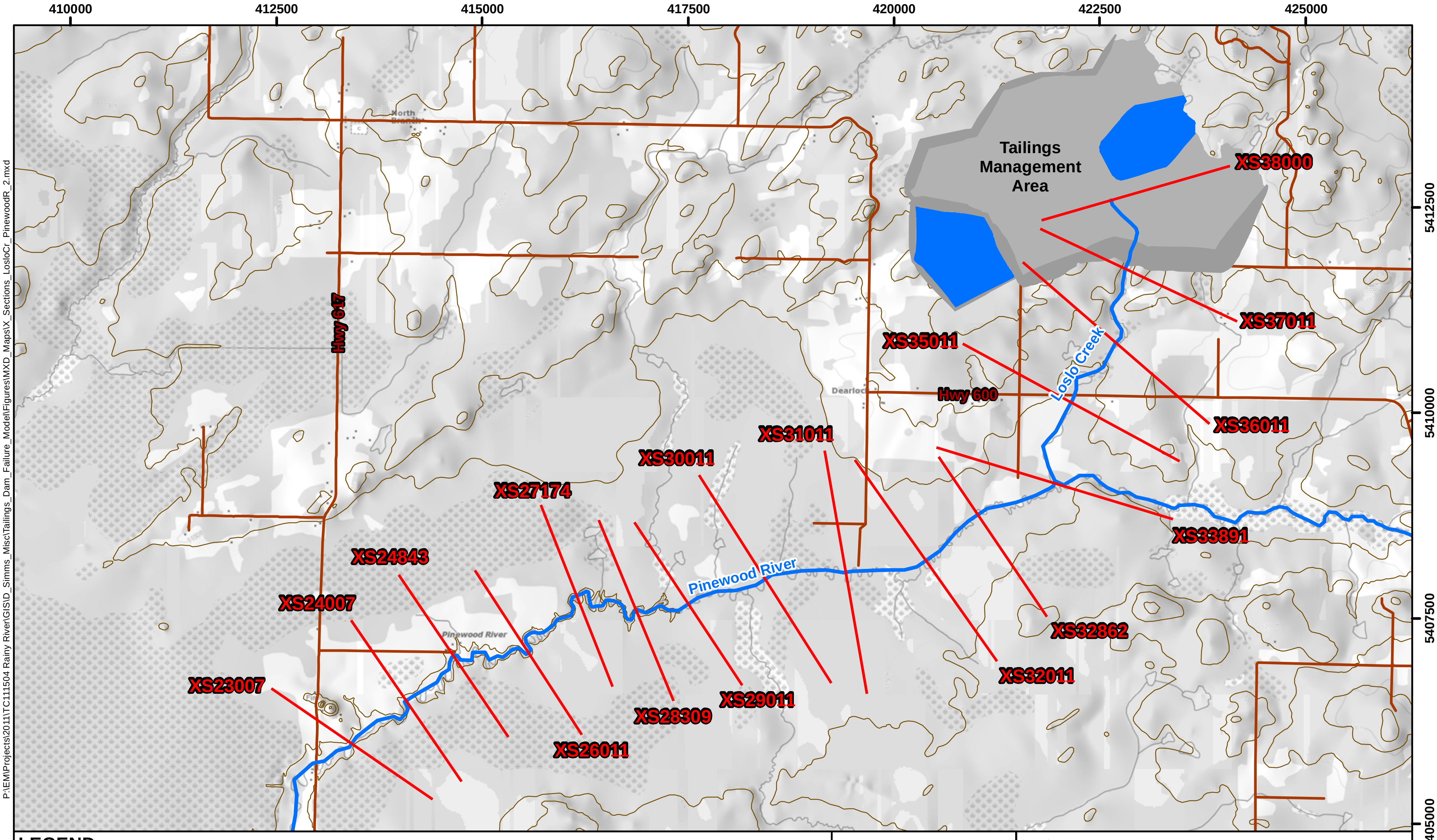
0 5 10 20 30 40 Kilometres

RAINY RIVER amec

RAINY RIVER GOLD PROJECT

Dam Failure and Effects Assessment Regional Map

PROJECT N°: TC111504	FIGURE: 1
SCALE: 1:170,000	DATE: July 2013



P:\EM\Projects\2011\TC111504 Rainy River\GIS\D_Simms_Misc\Tailings_Dam_Failure_Model\Figures\MXD_Maps\X_Sections_LosloCr_PinewoodR_2.mxd

LEGEND

- Cross Section (labelled with ID)
- Existing Roads
- Contours, 10 m interval

NOTES:
-

Datum: NAD83
Projection: UTM Zone 15N

0 1 2 4 6 8 Kilometres

N W E S

RAINY RIVER

amec

RAINY RIVER GOLD PROJECT

Cross Sections Located Along Loslo Creek and Pinewood River

PROJECT N^{o}: TC111504	**FIGURE: 2**
SCALE: 1:64,000	DATE: July 2013

Figure 3: Dam Breach Hydrograph at the Tailings Dam and at Confluence with the Rainy River

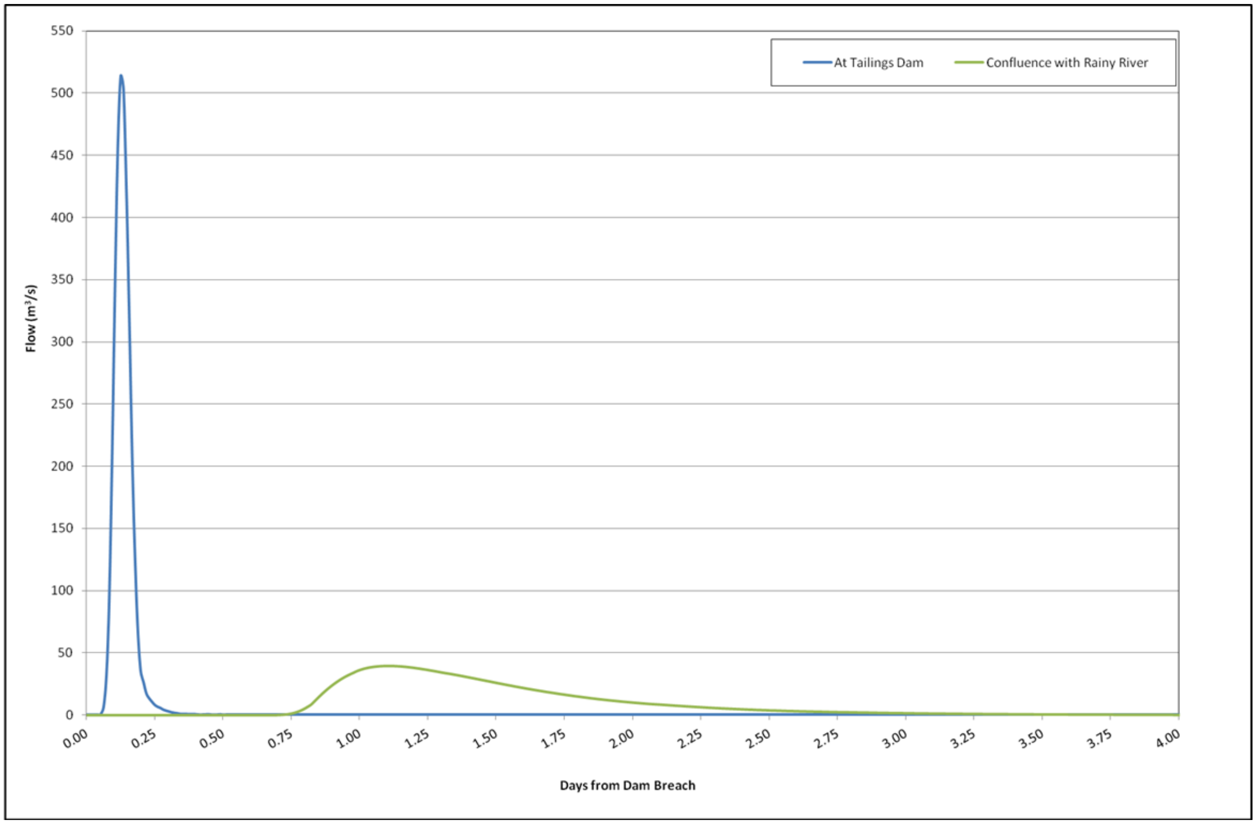


Figure 4: Historical Tailings Run-out Distances for Tailings Dams

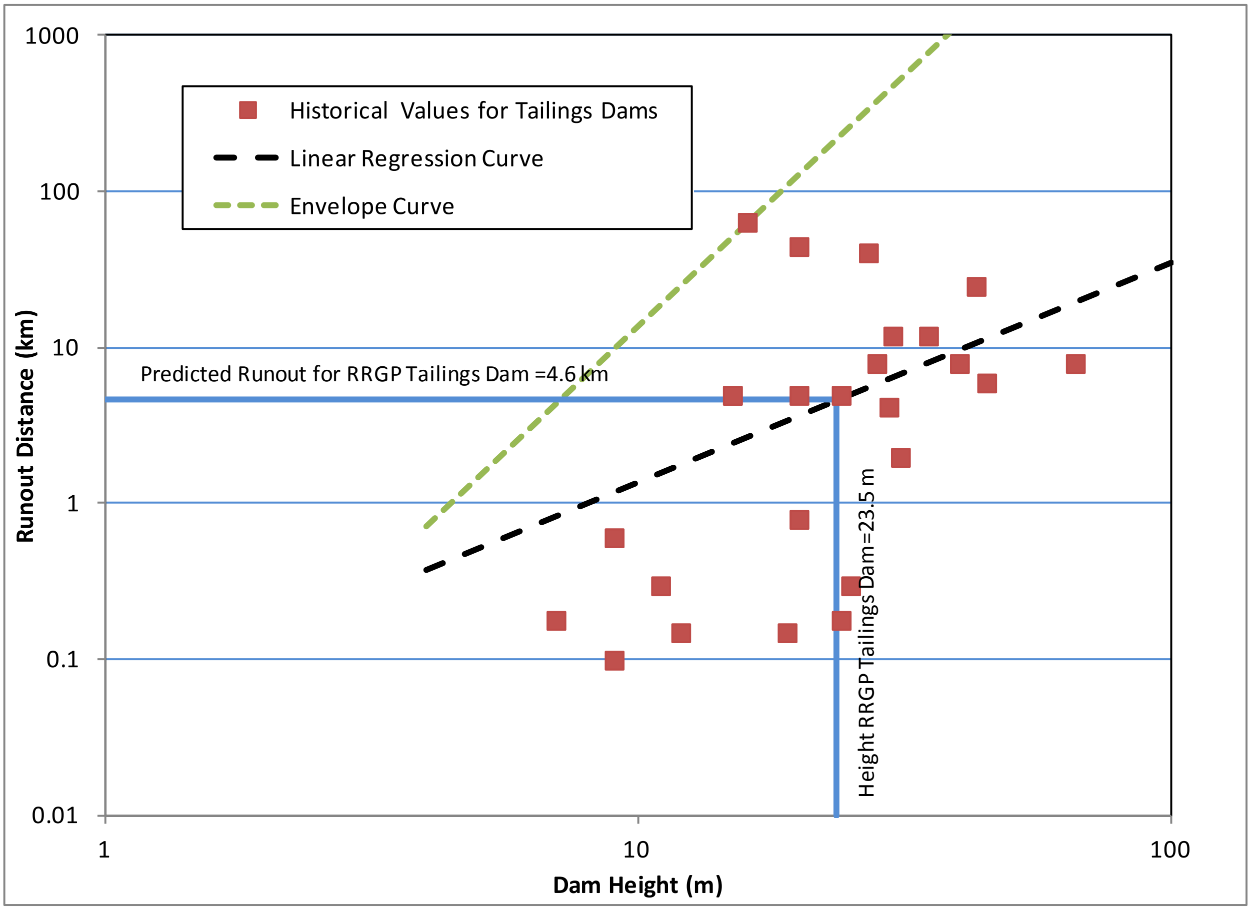


Figure 5: Model Grid and Boundaries of the Study Reach in Rainy River

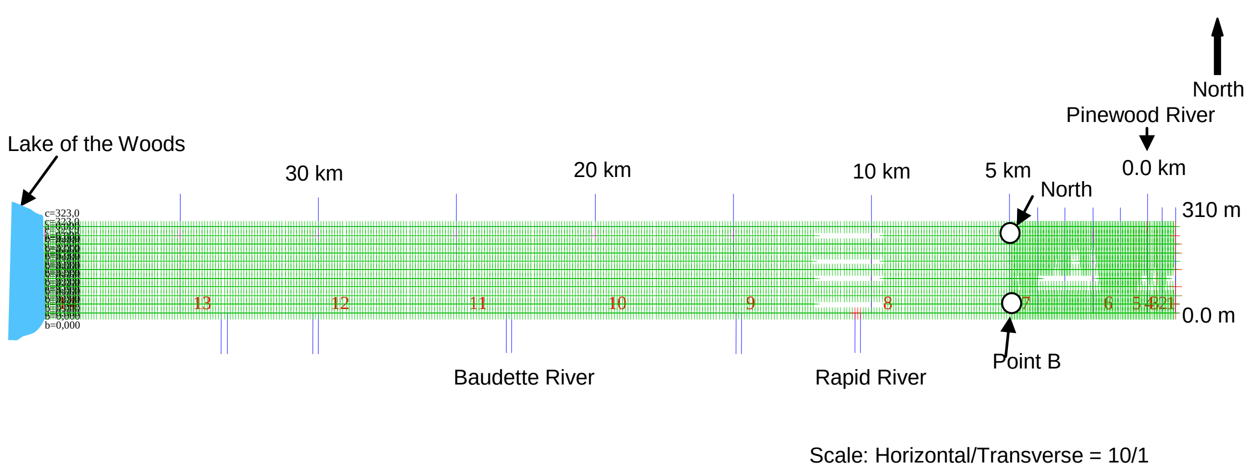


Figure 6: Percent Concentrations at the end of 6 hours

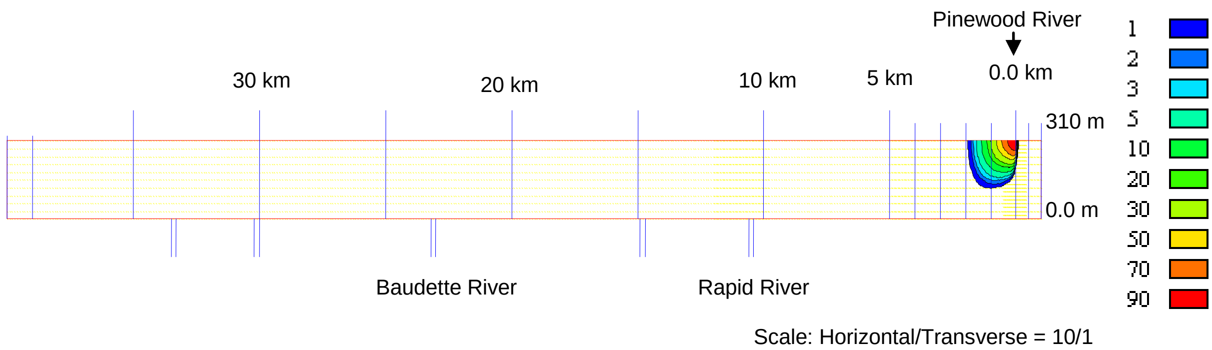


Figure 7: Percent Concentrations at the end of 12 hours

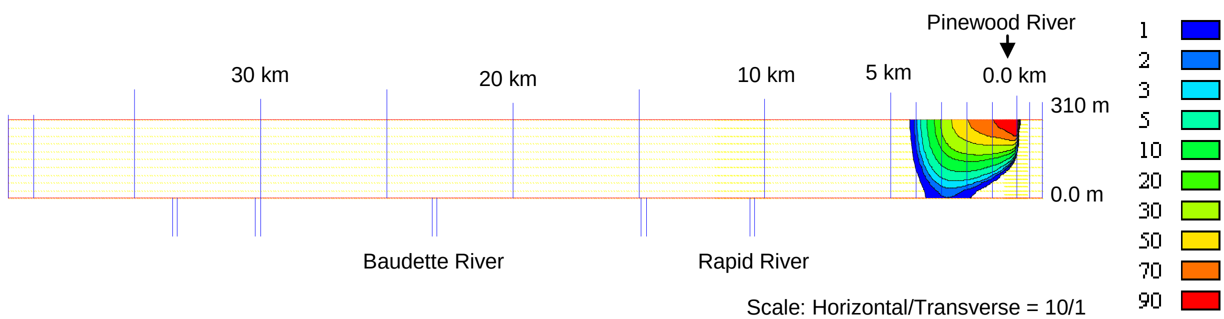


Figure 8: Percent Concentrations at the end of 18 hours

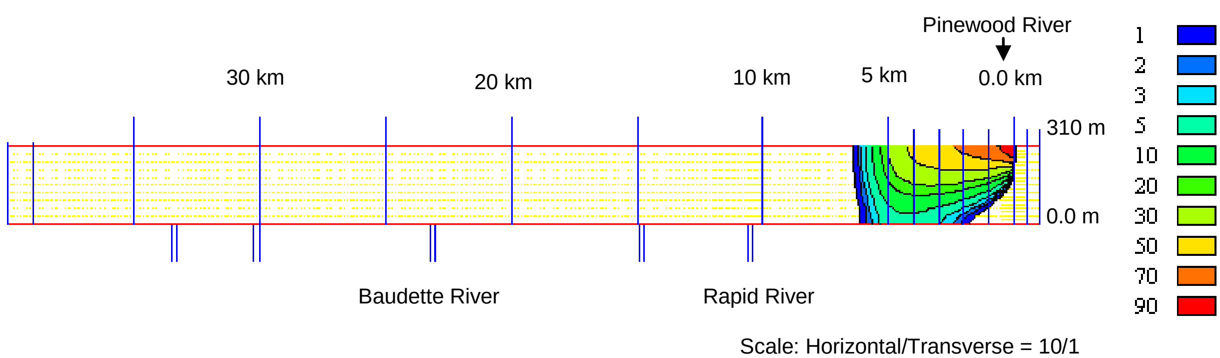


Figure 9: Percent Concentrations at the end of 24 hours

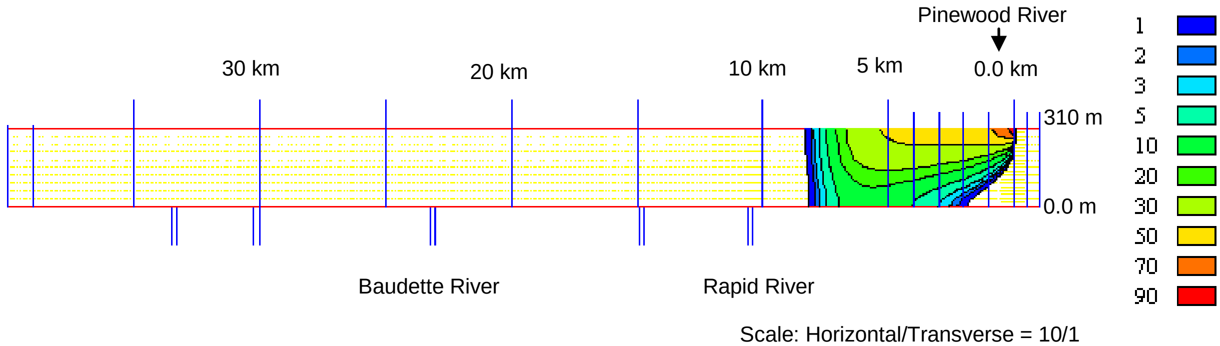


Figure 10: Percent Concentrations at the end of 36 hours

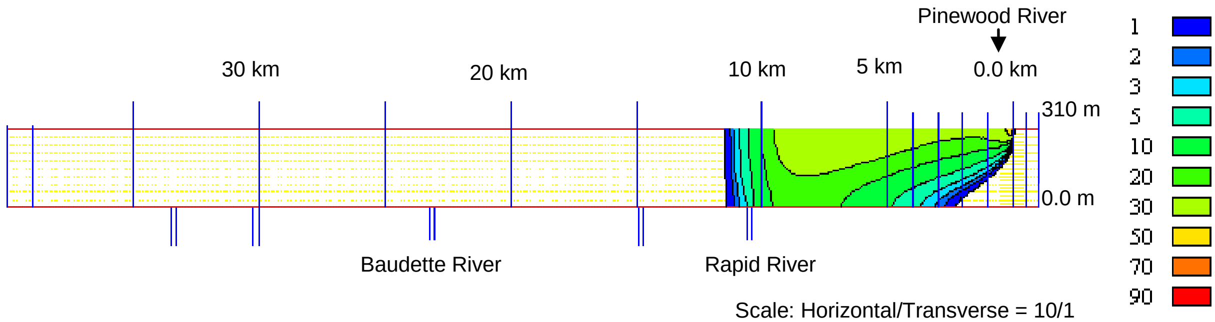


Figure 11: Percent Concentrations at the end of 48 hours (2 days)

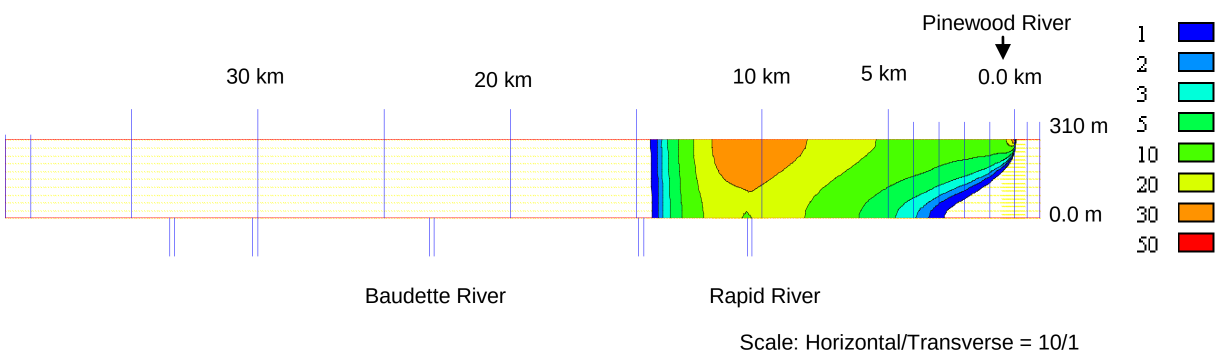


Figure 12: Percent Concentrations at the end of 72 hours (3 days)

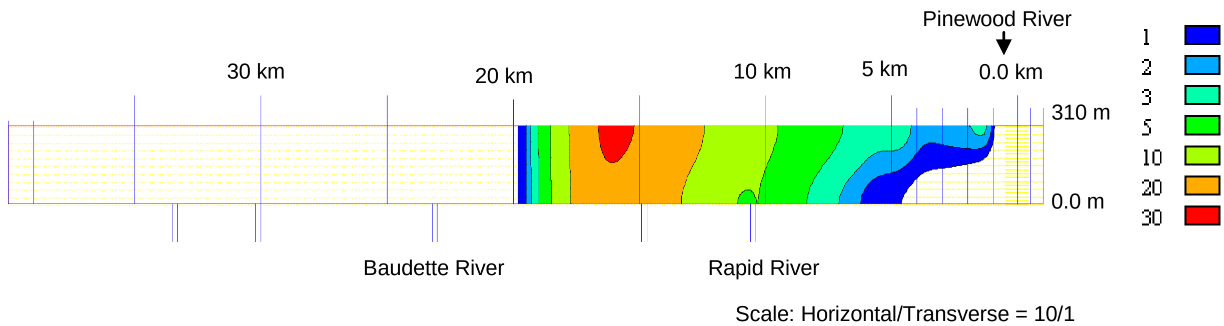


Figure 13: Percent Concentrations at the end of 96 hours (4 days)

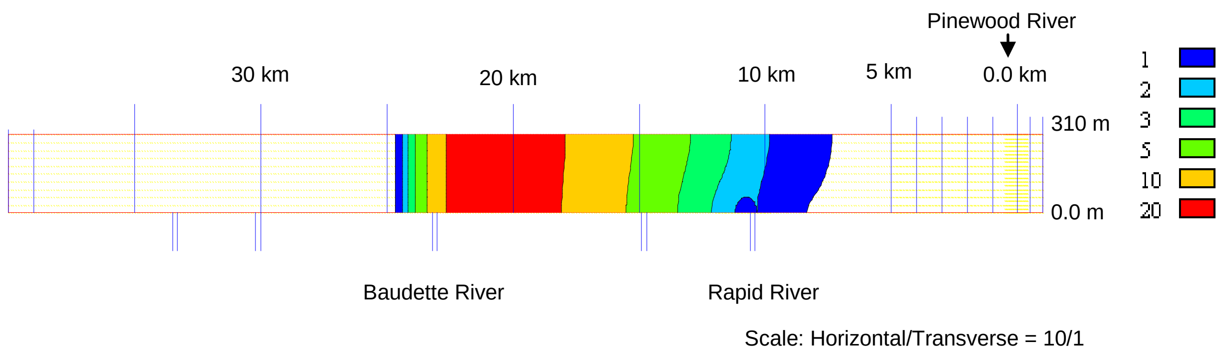


Figure 14: Percent Concentrations at the end of 120 hours (5 days)

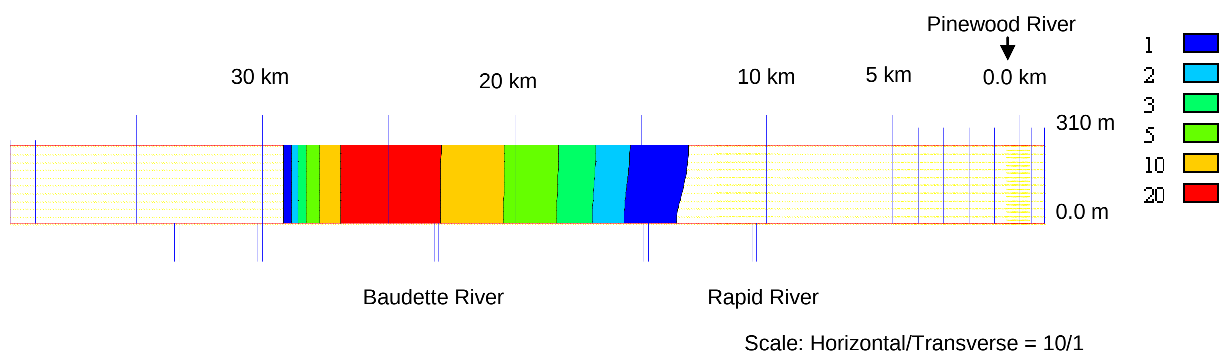
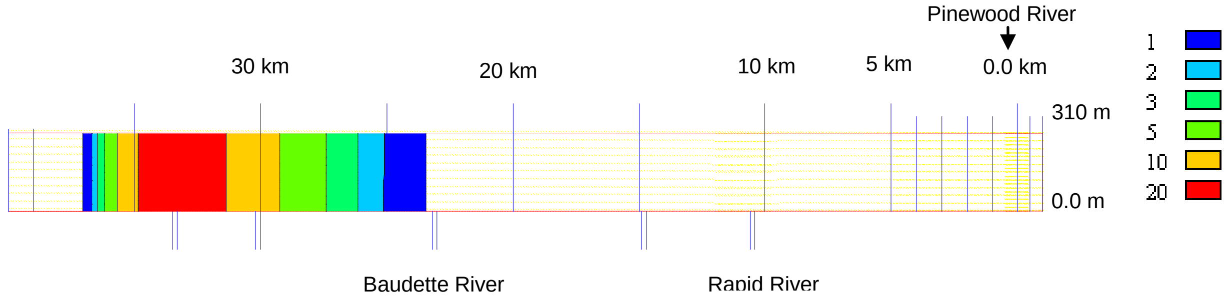
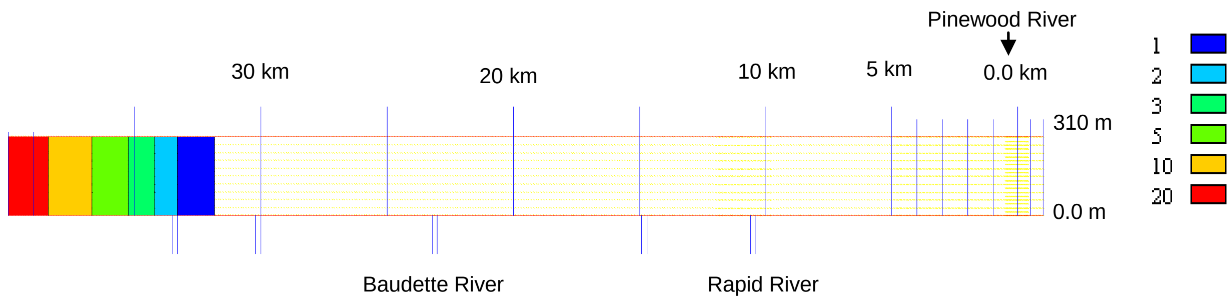


Figure 15: Percent Concentrations at the end of 168 hours (7 days)



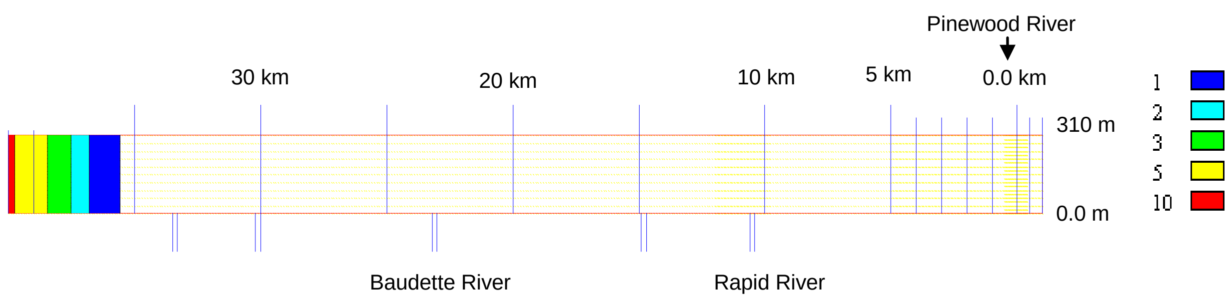
Scale: Horizontal/Transverse = 10/1

Figure 16: Percent Concentrations at the end of 216 hours (9 days)



Scale: Horizontal/Transverse = 10/1

Figure 17: Percent Concentrations at the end of 240 hours (10 days)



Scale: Horizontal/Transverse = 10/1

Figure 18: Concentration Breakthrough Curves at points A (north riverbank) and B (south riverbank) around 5 km downstream of Pinewood (points shown on Figure 1)

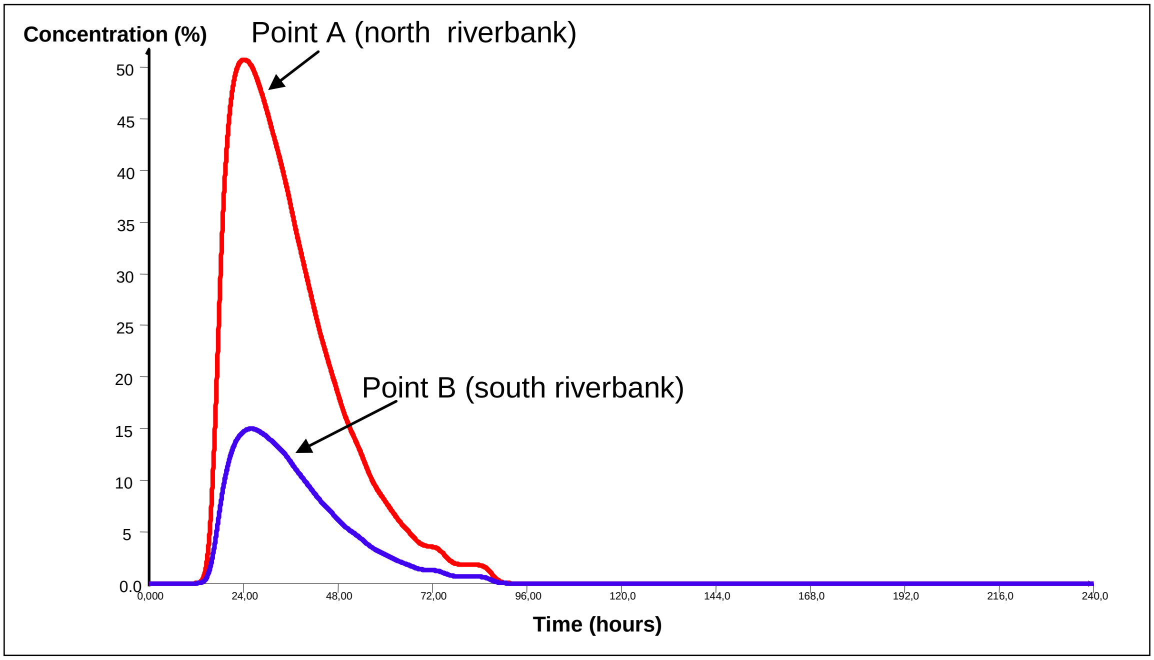


Figure 19: Percent Concentration Breakthrough Curves at Points along North Riverbank

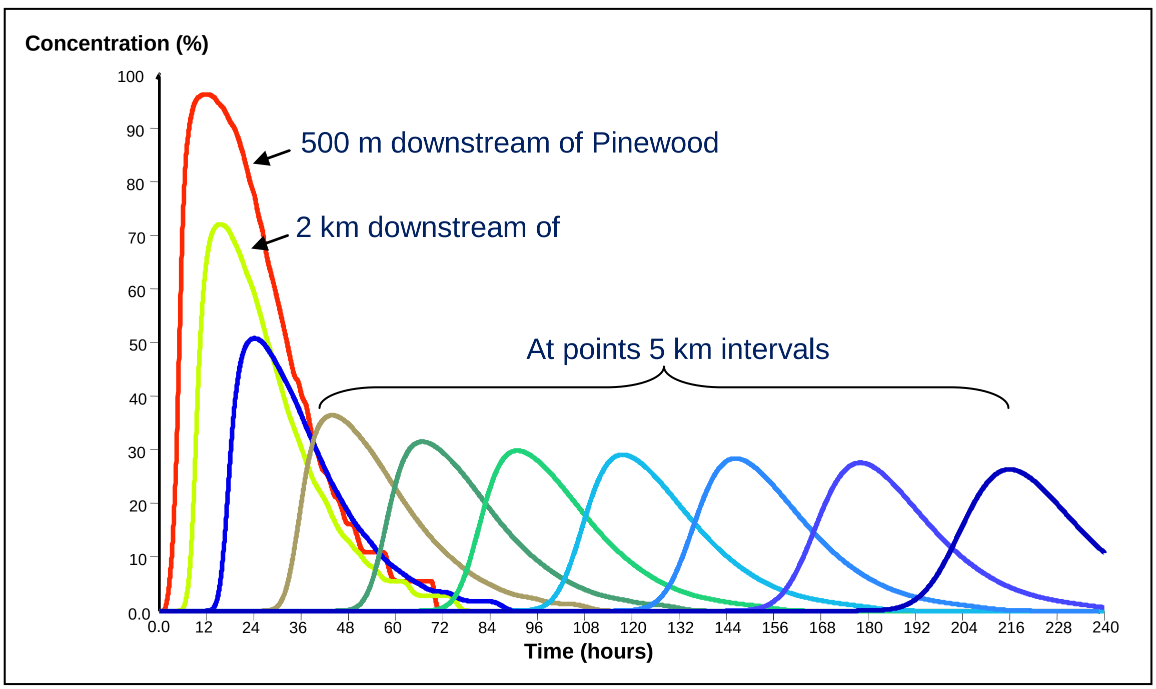
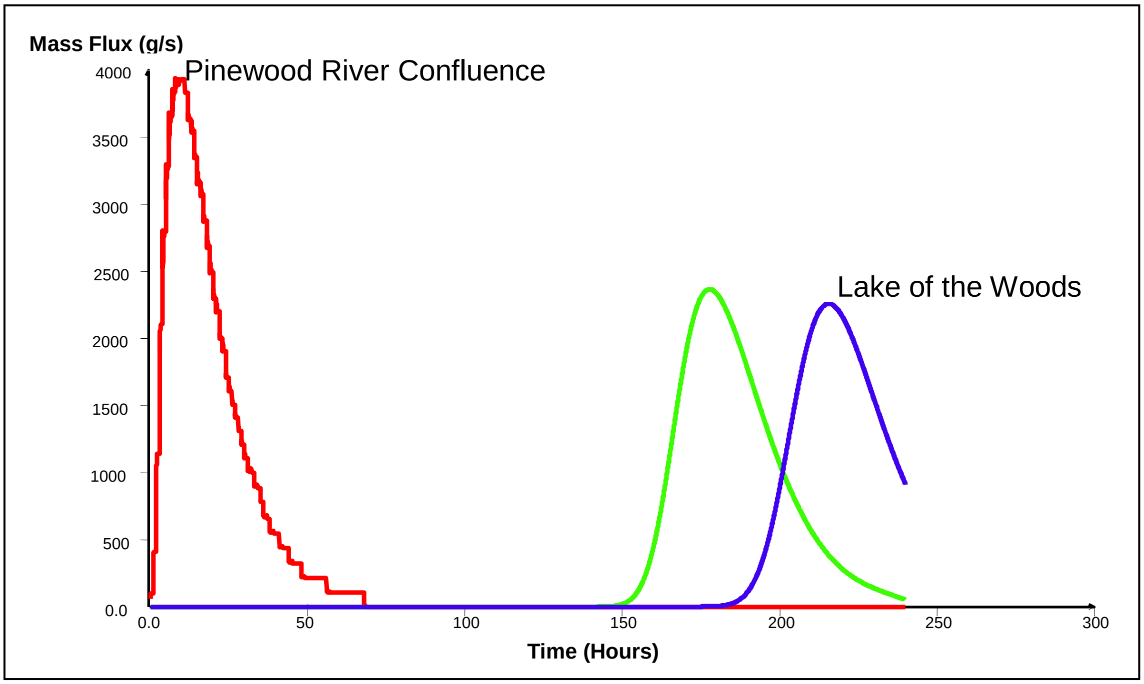


Figure 20: Mass Flux Breakthrough Curves near Pinewood and Lake of the Woods in the Rainy River



APPENDIX A

TMA FAILURE ASSESSMENT RESULTS

Table A1: TMA Failure Hydrograph at Tailings Dam and at Confluence with Rainy River

Simulation Date/Time	Flow at Tailings Dam (m^3/s)	Flow at Rainy River Confluence (m^3/s)
2013-04-06 23:00	0	0
2013-04-07 00:00	0	0
2013-04-07 01:00	94	0
2013-04-07 02:00	513	0
2013-04-07 03:00	213	0
2013-04-07 04:00	26	0
2013-04-07 05:00	8	0
2013-04-07 06:00	3	0
2013-04-07 07:00	1	0
2013-04-07 08:00	0	0
2013-04-07 09:00	0	0
2013-04-07 10:00	0	0
2013-04-07 11:00	0	0
2013-04-07 12:00	0	0
2013-04-07 13:00	0	0
2013-04-07 14:00	0	0
2013-04-07 15:00	0	0
2013-04-07 16:00	0	0
2013-04-07 17:00	0	1
2013-04-07 18:00	0	4
2013-04-07 19:00	0	11
2013-04-07 20:00	0	20
2013-04-07 21:00	0	27
2013-04-07 22:00	0	32
2013-04-07 23:00	0	36
2013-04-08 00:00	0	38
2013-04-08 01:00	0	39
2013-04-08 02:00	0	39
2013-04-08 03:00	0	39
2013-04-08 04:00	0	38
2013-04-08 05:00	0	36
2013-04-08 06:00	0	35
2013-04-08 07:00	0	33
2013-04-08 08:00	0	31
2013-04-08 09:00	0	30
2013-04-08 10:00	0	28
2013-04-08 11:00	0	26
2013-04-08 12:00	0	24
2013-04-08 13:00	0	22
2013-04-08 14:00	0	21
2013-04-08 15:00	0	19
2013-04-08 16:00	0	18
2013-04-08 17:00	0	16
2013-04-08 18:00	0	15

Simulation Date/Time	Flow at Tailings Dam (m^3/s)	Flow at Rainy River Confluence (m^3/s)
2013-04-08 19:00	0	14
2013-04-08 20:00	0	13
2013-04-08 21:00	0	12
2013-04-08 22:00	0	11
2013-04-08 23:00	0	10
2013-04-09 00:00	0	9
2013-04-09 01:00	0	9
2013-04-09 02:00	0	8
2013-04-09 03:00	0	8
2013-04-09 04:00	0	7
2013-04-09 05:00	0	6
2013-04-09 06:00	0	6
2013-04-09 07:00	0	5
2013-04-09 08:00	0	5
2013-04-09 09:00	0	5
2013-04-09 10:00	0	4
2013-04-09 11:00	0	4
2013-04-09 12:00	0	4
2013-04-09 13:00	0	3
2013-04-09 14:00	0	3
2013-04-09 15:00	0	3
2013-04-09 16:00	0	3
2013-04-09 17:00	0	2
2013-04-09 18:00	0	2
2013-04-09 19:00	0	2
2013-04-09 20:00	0	2
2013-04-09 21:00	0	2
2013-04-09 22:00	0	2
2013-04-09 23:00	0	2
2013-04-10 00:00	0	2
2013-04-10 01:00	0	1