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CANADA'S OIL SANDS
INNOVATION ALLIANCE

Oil Sands Mine Water Salt Loading Model

Summary Report

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NOTE:

The purpose of this report is to communicate work completed, findings and next steps without revealing confidential information. Confidential Information used to create this report included in the Appendices has been redacted.

Introduction

Management of salts by oil sands operations is a regional issue that has been evaluated by Canada's Oil Sands Innovation Alliance (COSIA). To assist with the development of a regional salt management strategy, external consultants were hired to develop a set of integrated salt loading models based on hypothetical scenarios that included a process water model and two receiving water models. The integrated model domain comprises the Athabasca River, Lake Athabasca, and the seven companies representing existing and planned Athabasca oil sands mines.

Extraction and oil sands processing activities vary somewhat by company, but salt concentration in process water inventories is expected to increase as a result of:

- Salts from source water inputs:
 - Connate waters (water trapped within the oil sands ore during its formation)
 - River (makeup) water
 - Depressurization groundwater (including water from the Basal Aquifer and other formations)
 - Surface runoff, dewatered fine tailings, and upgraders
- Evaporation further concentrating salts in tailings ponds
- Blowdown release not being practised.

Over the life of mining operations, the resulting increases in salt concentrations may have undesirable consequences, including:

- Increased salinity in pit lakes at closure;
- Increased levels of salt in the Athabasca River when pit lakes release waters;
- Potential future treatment and disposal costs; and
- Challenges associated with terrestrial reclamation.

The process water model entailed mass-balance modelling of process water and tailings pore water chemistry at oil sands mine operations. These waters will accumulate total dissolved solids (TDS) from the contribution of ions, over the life of mining operations. This model accounts for major inflows, outflows, and sinks, for existing and planned oil sands mining operations.

Results from the process water model were carried forward to two receiving water models. The goal of the receiving water models was to determine the most environmentally-appropriate time for discharging treated process water to the Athabasca River. With the exception of groundwater and some treated upgrader wastewaters, which are released to surface watercourses, all oil sands mines operate under a closed-circuit scheme through the operation phase of the mine (under *Alberta Environmental Protection and Enhancement Act* approvals). Most or all accumulated salts will eventually migrate to the Athabasca River over time. The purpose of this project was to determine which of the two following scenarios would lead to lower salt concentrations in the Athabasca River:

- Accumulating salt-laden process waters in the mine during operations and release the treated waters through pit lakes at closure; or
- Releasing treated process water to the river during operations.

While the concentrations predicted by this study were not compared to effects-based criteria, it is generally preferable to maintain concentration of ions and other constituents at levels that are closer to historic levels, which is a key principle of the Lower Athabasca Regional Framework (GoA, 2012). Additionally, lower salt levels are generally more favourable for reclamation of pit lakes (CEMA, 2012), wetlands (Harris, 2007), and terrestrial systems (Alberta Agriculture 2004).

Water release rates, feasibility of release, and treatment methods were evaluated as part of this study. It was assumed that any released process or depressurization waters would first undergo appropriate treatment to reduce concentrations of organic compounds and toxicity, and that assimilative capacity of the Athabasca River would be evaluated through other studies.

Modelling methods

Three separate water models were developed to predict salt loads at oil sands operations and the resulting change in water quality caused by the release of Oil Sands Process Water (OSPW): (i) a process water model, (ii) a GoldSim model, and (iii) a Lake Athabasca hydrodynamic model. The process water model was developed for each operation to predict the mass of each major ion and TDS, as well as the volume of the process water accumulated by each operator. The GoldSim model was developed to predict the water quality in pit lakes for each operator, and the cumulative changes in water quality in the Athabasca River. The Lake Athabasca hydrodynamic model was developed to predict circulation patterns, and spatially and temporally varying salt concentrations. The outputs of the process model were used as inputs for the receiving models. The process water and GoldSim model included major ions and TDS, whereas the Lake Athabasca model included TDS and temperature, which are important hydrodynamic variables.

The study area includes the Athabasca River and its tributaries between Fort McMurray and Embarras, including the oil sands mines located along this reach of the Athabasca River, plus Lake Athabasca. The length of the Athabasca River in the oil sands region was divided into five reaches within the GoldSim Athabasca River model, consistent with other Environmental Impact Assessments (e.g., Teck 2011). Water quality was modelled in each reach, including input from oil sands operations where applicable. Assumed start and end dates for operations, as well as hypothetical dates for active and passive water releases were modelled based on information provided by participating operators.

Two model scenarios were developed to predict Athabasca River water quality under different release conditions:

- **Status quo (passive water release) scenario – Release of treated waters through pit lakes at mine closure:** Salt-laden process water is allowed to accumulate within the mine areas, and the entire volume of free process water, its associated salts, and pore

water release due to tailing consolidation are treated and released through pit lakes at closure

- **Active release scenario – Release of treated waters during mining operations:** Includes blowdown and makeup during operations, from 2015 to end of mine life for each operation, and no net change in free water volume. Free water and pore water concentrations were re-calculated with the lower salt loads, while other inputs are the same as those in the status quo scenario.

Process water model

The process water model was developed using Simulink/Matlab modelling software.

The chemistry component of the site water quality model is based on defining the sources, pathways, and sinks for specific ions in each water flow path and reservoir. It is a mass balance that uses the mass loadings and losses that occur with oil sands extraction, tailings management and placement. Site water chemistry models are used to predict water quality, and to simulate operational and post-operations issues that may arise.

Ion Balance

The process water model allows the operator to determine and predict ionic concentrations under current and future operational conditions (production rates, chemical amendments, process modifications, and tailings management options). The following ions were included in this model:

- **Chloride:** This is a conservative ion (i.e., it follows the water)
- **Calcium, magnesium (divalent cations) and alkalinity (carbonate/ bicarbonate balance):** These are non-conservative ions. The rate of calcite formation is a function of pH and alkalinity
- **Sodium:** This is a relatively conservative ion. Generally, sodium is a major ion in OSPW and occurs with chloride (NaCl)
- **Sulphate:** This is a relatively conservative ion under aerobic conditions, but non-conservative under anaerobic conditions. Changes and mass loadings depend on operational and tailings management options
- **Potassium:** This ion is generally present at low levels so is considered not to play an important role in overall TDS load and concentration.

The model calculates the build-up of salts over the life of oil sands mines. It was necessary to construct a model of each of the sites that represents the water flows resulting in the inventory of free water in the various settling basins. The chemistry associated with the water flows and the major chemicals used at each site were used to calculate the chemistry of the free water, which is defined as the layer of water above the tailings deposits, which include Mature Fine Tails, Composite/Consolidated Tails, and Non-Segregating Tails (MFT, CT, NST).

Model Structure

The dynamic equation that governs the water and ionic balance in the process water model is given by the integral of the difference of the sum of input flow rates and the sum of output flow rates, as seen in Equation 1:

$$(1) \quad \frac{dv}{dt} = \sum Q_{in} - \sum Q_{out}$$

Where $\sum Q_{in}$ is the total flow rate and corresponding chemistry of the incoming streams, and similarly, $\sum Q_{out}$ represents the total outgoing streams, and dV/dt represents the change in water volume and ion mass.

The ion mass accumulated or depleted over time t_1 to t_2 is then given by Equation 2:

$$(2) \quad Mass = \int_{t_1}^{t_2} (\sum Q_{in} - \sum Q_{out}) dt + Mass_0$$

Where $Mass_0$ is the mass of the ion at time t_1 .

The outflows include the mass of ions trapped in the pore water spaces in the various tailings deposits, and this mass is a function of the concentration of the ion in the water leaving the extraction plant for the coarse sand deposits and the concentration of the free water for the fine tails deposits.

GoldSim Model

The GoldSim model was developed to predict a) the water quality in pit lakes for each operator, and b) the cumulative changes in water quality in the Athabasca River. This model included flows from upstream of Fort McMurray, including the Clearwater River, as well as other major tributaries; one pit lake is included per mine. Inflows to the Athabasca River from pit lakes and direct mine water releases were varied according to the results of the process water model under each scenario.

OSPW loadings were included, which are outputs from the process water model. Process water loadings were assumed to enter the Athabasca River only via pit lakes in the Status Quo Scenario, and through pit lakes and directly to the river in the Active Release Scenario. The MS Excel™-based Athabasca River Model (ARM) was used for the Athabasca River portion; the ARM is a standard model that has been employed in a number of other projects.

The GoldSim model begins predictions in 2013 and runs until 2100, beyond the period of peak loading and concentrations in any scenario. This timeframe passes the closure of all operations that were considered, and also allows gradual closure processes (e.g., reduction in process water inflows to pit lakes and release of tailings pore water load).

Model Inputs and Assumptions

Athabasca River Baseline

Baseline conditions in the Athabasca River were represented in the GoldSim model by upstream flows, tributaries, and present-day licensed releases and process-affected seepages.

Two flow conditions were used to provide a range of possible results:

- Daily variable, average flow conditions in the Athabasca River with stochastically generated flow time series for upstream and tributary flows, based on a 50-year hydrological record, and
- Low flow (7Q10) conditions in the Athabasca River and its tributaries. The 7Q10 condition represents the lowest seven-day average flow with a ten-year return period. This flow is applied throughout the simulation period for this evaluation. This simulation does not portray a realistic time-series, but instead indicates a highly conservative prediction of change in Athabasca River concentrations that could be observed at any given time during this period. It is intended to compare the instantaneous results of one scenario with another.

Baseline Athabasca River flows, tributary flows, and licensed discharges are summarized for both flow conditions in Table 1.

Table 1. Summary of Baseline Athabasca River and Tributary Flows

Node Number	Node Name	Stochastic Flow Condition ¹			7Q10 Flow Condition ²
		Minimum	Median	Maximum	
		m ³ /s	m ³ /s	m ³ /s	m ³ /s
-	Upstream Boundary	75	466	4700	97
N1	Sewage	-	0.28	-	0.59
N2	McLean Creek	-	0.06	-	0.051
N3	Mackay River	0.01	3.62	339	0.14
N4	Shipyard Lake	-	0.03	-	0.009
N5a	Millennium seepage	-	0.02	-	0.012
N6a	Suncor Lease 86/17 - South Mine Drainage - seepage	-	0.02	-	0.015
N8	Wastewater Discharge Point	-	0.54	-	0.6
N8a	Wastewater Discharge Point - seepage	-	0.01	-	0.019
N9	Steepbank River	0.019	2.35	81	0.11
N9a	Steepbank River Seepage	-	0.0011	-	0.001
N11	Pond 4 Seepage	-	0.001	-	0.001
N12	Pond 5 Seepage	-	0.0035	-	0.004
N13a	North mine Drainage Discharge Point - seepage	-	0.0035	-	0.046
N35a	Beaver Creek Seepage	-	0.04	-	0.041
N16	Muskeg River	0.012	0.78	64	0.52
N27	Ells River	0.036	3.91	237	0.38
N31	Firebag River	4.2	17.4	238	6.1
N38	Pierre River	0	0.04	13	0.001
N37	Eymundson Creek	0	0.07	35	-
N40	Big Creek	0	0.05	17	0.16
N41	Redclay Creek	0	0.05	17	0.061
N43a	Saline ground water	-	0.2	-	0.2

Baseline, naturally saline, groundwater inflows to the Athabasca River from the calibrated ARM were incorporated into the GoldSim model. As part of the ARM calibration, available groundwater data representative of pre-mining conditions were compiled, including data from 1972-2007. The dataset included data from Hackbarth and Nastasa (1979), the Oil Sands Groundwater Database (OSGD Version 1.6), and groundwater data from baseline studies. Additional details regarding this calibration and its inputs are provided in Shell (2013).

To calibrate the GoldSim model, predicted concentrations of each parameter in the Athabasca River in Reach 5 (upstream of the confluence of the Firebag River to Embarras) were compared to data observed in the Athabasca River near Embarras, under baseline conditions. This calibration method has been used previously to calibrate the ARM in oil sands EIAs, which are reviewed by stakeholders and provincial and federal regulators.

Pit Lakes

One pit lake was modelled for each operation. This pit lake was assumed to have a volume equal to all planned pit lakes for a given operator. The water in each pit lake at closure is assumed to comprise remaining process water inventory, with any remaining lake capacity filled with Athabasca River water. Each pit is assumed to release directly to the Athabasca River at closure.

Each pit lake was assumed to have a 10-year filling time followed by a release period with a 10-year residence time at closure. Water flowing into the pit lakes after closure was assumed to be a mix of process water and background water (represented in the model by Athabasca River chemistry) with a load from tailings pore water released from surrounding backfilled pits. Total mass of each parameter in the tailings pore space, as predicted by the process water model, was assumed to flow passively to the pit lakes. One third of the total pore water load is assumed to migrate to the free water over time, with the balance assumed to remain entrained in the tailings. The loading rate from the pore water to the free water is defined by Equation 3:

$$(3) \quad \frac{M_i}{M_0} = e^{-kt_i}$$

Where:

- M_i = Mass at time i (tonnes)
- M_0 = Mass at time 0 (initial mass, tonnes)
- K = constant, 0.03 (1/ years)
- t_i = Time (years)

Status Quo Scenario – Release of treated waters through pit lakes at mine closure

Under the Status Quo Scenario, OSPW is disposed of through pit lakes following cessation of mining. Additionally, pore water entrained in the tailings is expected to migrate into the overlying free water as the tailings settle, and subsequently migrate to pit lakes. Background runoff, consisting of imported Athabasca River water and local runoff, will be used to fill the pits, and

local sources will continue to flow through the pit lakes after filling. As a result, the accumulated mass of salts in the pit lakes will be released gradually to the Athabasca River.

Active Release Scenario – Release of treated waters during mining operations

In the Active Release Scenario, a portion of the salt load predicted for each operator is released to the Athabasca River during operations.

The release rate varied for each operator and ion, and depended on the magnitude of the Substance Load Allocation allowance and the total accumulated mass of each ion at each operation.

Lake Athabasca (Hydrodynamic) model

The predicted inflows from the GoldSim model (concentration and flow rate), and the flow rates and TDS loadings from other tributary inflows around the lake were inputs for the hydrodynamic Lake Athabasca model to predict spatial and temporal changes in TDS concentration. Only the stochastic simulations were inputs to the Lake Athabasca Model, because those represent a realistic long-term time-series.

The program Delft3D (Roelvink and Banning 1994; Deltares 2011) was used to predict TDS concentration in Lake Athabasca. Delft3D was run as a two-dimensional model using the hydrodynamic and salt transport components of the model (the Delft3D-Flow module).

Model Segmentation

The bathymetry of Lake Athabasca, seen in Figure 1, was derived from the Atlas of Alberta Lakes (Mitchell and Prepas, 1990). Forty-four grid points were placed along the east-west direction and 47 grid points along the north-south direction. The gridded lake had a total surface area of 7,600 km² and a volume of 1.5x10¹¹ m³. The average surface area of each grid cell was 3.7 km².

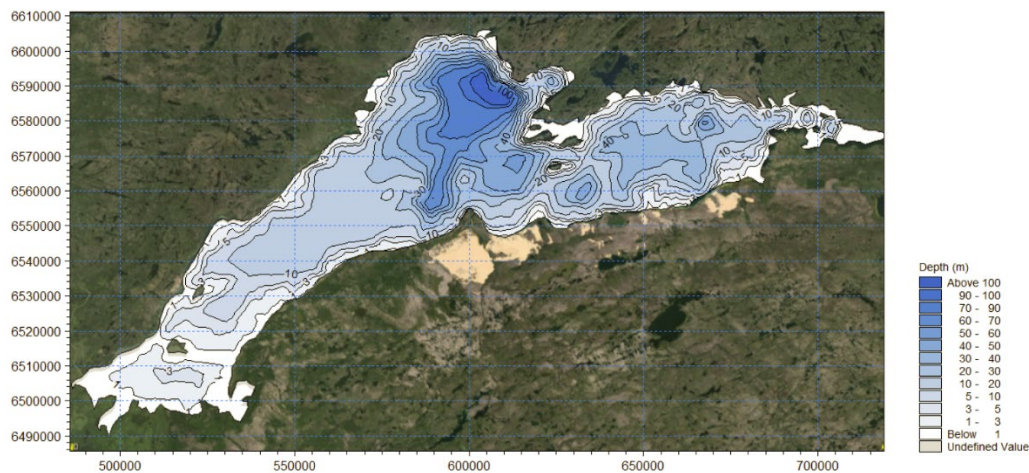


Figure 1. Bathymetry of lake Athabasca. Values on axes are Universal Transverse Mercator coordinates.

Model inputs

Hydrological Inputs

Ten different boundary condition locations (inflow and outflow points) were identified for Lake Athabasca. These boundaries were named and set according to the nearest sampling station, and are shown in Figure 2.

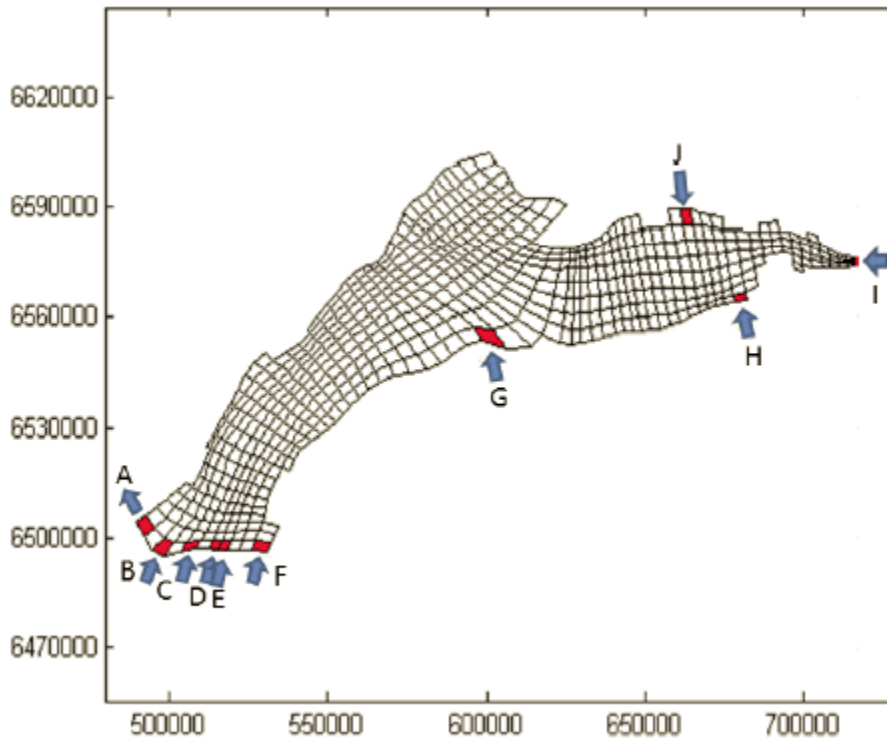


Figure 2. Model boundaries. Blue arrows indicate the normal direction of water flow. Values on axes are Universal Transverse Mercator Coordinates.

A = Outflow to Riviere des Roches; B = Embarras; C = Fletcher; D = Goose; E = Big Point; F = Douglas River; G = William River; H = McFarlane River; I = Fond du Lac; J = Oldman River.

Lake outflow to the Riviere des Roches was calculated by the model. Daily inflow rates between 2006 and 2011 were acquired from Environment Canada (now Environment and Climate Change Canada) monitoring station data. This time period provided the most complete and consistent dataset of flow rates for all stations in the study. Daily inflow rates were estimated from data for the McFarlane River and Embarras River, respectively.

Inflow rates under the Baseline scenario for the Embarras, Fletcher, Goose, and Big Point stations were taken from monitored data at the Embarras gauging station upstream of the split with the Richardson River and were divided in accordance with Neill et al. (1981). Under the Status Quo and Active Release Scenarios, inflow to the Embarras, Fletcher, Goose, and Big Point stations was partitioned as a function of total inflow from the Athabasca River.

Meteorological inputs

Meteorological inputs are drivers of lake circulation. Meteorological data in this study included:

- Sky cloudiness
- Relative humidity
- Air temperature
- Net radiation
- Wind speed
- Wind direction
- Precipitation rate
- Evaporation rate

Cloud cover, relative humidity, wind speed, wind direction, and evaporation rate were taken from the Fort McMurray monitoring station record for 2002 to 2006. Daily air temperature and precipitation rates measured at Fort Chipewyan were available for 2006-2011. Net solar radiation was averaged monthly from measurements taken between 1953 and 2011 at the Stoney and Aurora climate stations.

Ice dynamics

Ice was assumed to cover the entire surface of Lake Athabasca between November 1 and May 31 each year. Ice thickness growth was set to approximately 1.1 m per year. Ice melting occurred during April and May. During this period, precipitation rates were set to balance the volume of water removed from ice formation. Lake depths near the inflows from the Athabasca River were increased from 1 m to 2 m to prevent the lake from freezing to the bottom.

Total dissolved solids

The hydrodynamic module of Delft3D requires temperature and salinity as inputs. Measured water chemistry data were summarized on a monthly basis. Data sources for water chemistry include Alberta Environment and Sustainable Resource Development (now Alberta Environment and Parks) and the 2011-2012 Eastern Athabasca Regional Monitoring Program (EARMP) baseline report (CanNorth 2012).

Model Simulations

The time-series of flow and TDS concentrations from 2013-2100 for the inflows other than the Athabasca River were created by repeating the five-year time-series used for calibration. Those time-series were used in both the Status Quo and Active Release Scenarios.

Assumptions

- Input water chemistries and loads used in the modelling are representative of their respective input sources; the assumption is that data represent input sources, and will continue to do so in the future.

- A single pit lake was assumed for each oil sands operator; in reality, each operation will include a series of smaller pit lakes that will discharge at different rates and times. A single pit lake is assumed to be an adequate representation of the sum of multiple pit lakes.
- Saline groundwater input to the Athabasca River is constant and independent of flow conditions in the river.
- Active release rates were developed for each parameter independently and were not based on an expected process water quality.
- Flow of water in Lake Athabasca can be described using a single depth layer. The hydrodynamic model assumes there is complete vertical mixing.

Results

Process water model

The final mass of each parameter (i.e., element, TDS) accumulated during operations in the free water and tailings pore water, and the final volume of free water, as predicted by the process water model were calculated for each operator. Additionally, a time-series of masses for chlorides and TDS for both the Status Quo and Active Release Scenarios was determined. These data were input into the GoldSim model.

GoldSim model

Predicted Athabasca River chloride and predicted TDS concentrations at Reach 5 (upstream of the confluence of the Firebag River to Embarras) from the GoldSim model are shown in Figure 3 and Figure 4, respectively. Time-series for each of the five simulated conditions noted below are presented in each figure:

- Baseline, stochastic flow condition;
- Status Quo Scenarios, stochastic flow condition;
- Active Release Scenario, stochastic flow condition;
- Status Quo Scenario, low flow (7Q10) condition; and
- Active Release Scenario, low flow (7Q10) condition.

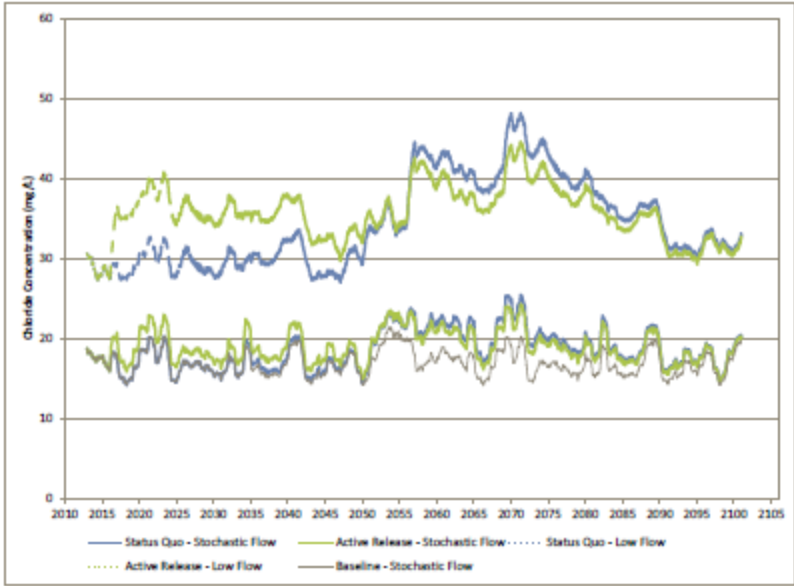


Figure 3. Predicted chloride concentration at Reach 5.

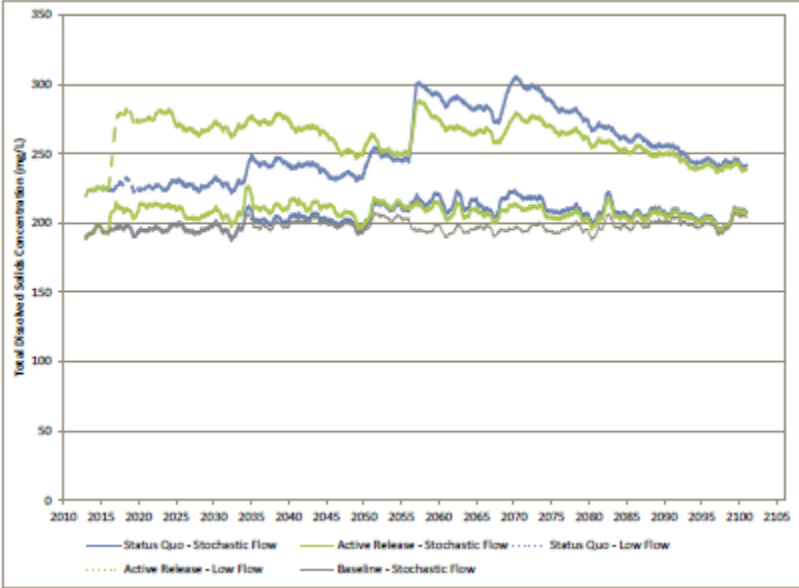


Figure 4. Predicted Total Dissolved Solids (TDS) concentration at Reach 5.

Lake Athabasca (Hydrodynamic) Model

Mean horizontal water velocities in Lake Athabasca were extracted from the five-year calibration found in Shell (2013). The highest average velocities were at the inflow from Fond du Lac, where the lake narrows (Figure 5). A recirculation pattern was established in the middle of the lake, with very small velocities between the middle of the lake and the Fond du Lac and

Athabasca River inflows. Inflow from the Athabasca River did not exhibit a recirculation pattern, and flow within that area exited the lake at the outflow to the Riviere des Roches.

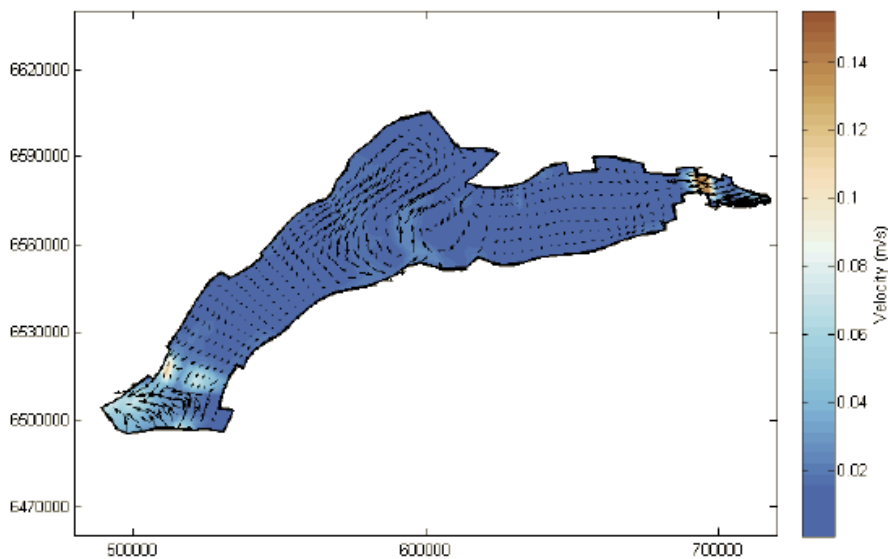


Figure 5. Velocity field of Lake Athabasca. Arrow size indicates velocity magnitude and direction. Velocities >0.05 m/s are represented as 1/10th of actual length. Values on axes are Universal Transverse Mercator coordinates.

The relationship among TDS concentrations under the Baseline, Status Quo, and Active Release Scenarios in Lake Athabasca, as seen in Figure 6, followed the same pattern as that from the GoldSim model prediction, as seen in Figure 4. Concentrations near the outlet are predicted to be similar to those near the mouth, shown in Figure 6. The Baseline scenario had the lowest TDS concentrations of all the scenarios in the simulation. The concentration of TDS was initially higher under the Active Release Scenario compared to the Status Quo Scenario. The difference in TDS concentration between the Active Release and Status Quo scenarios began to decrease around the year 2033. In 2055, the TDS concentrations in Lake Athabasca near the mouth of the Athabasca River were equal under the Active Release and Status Quo Scenarios, and the TDS concentrations under the Active Release scenario remained below Status Quo concentrations for the rest of the simulation. Overall, the maximum difference in TDS concentrations in Lake Athabasca was predicted to be within 10 mg/L near the mouth of the Athabasca and less than 1 mg/L in the middle of the lake.

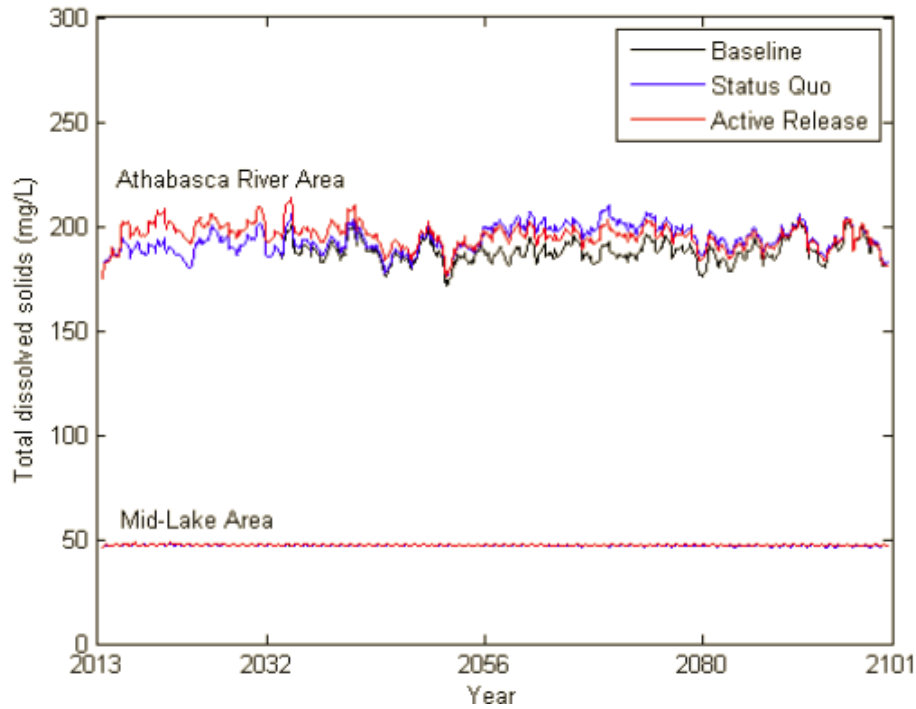


Figure 6. Total dissolved solids (TDS) concentration near the mouth of the Athabasca River and in the middle of Lake Athabasca.

Under all scenarios (including Baseline), the highest concentrations of TDS were located within approximately 20 km of the mouth of the Athabasca River (Figure 7 and Figure 8). Outside of this zone, TDS concentrations remained below 50 mg/L, with slightly lower concentrations near the inflow of the Fond du Lac River.

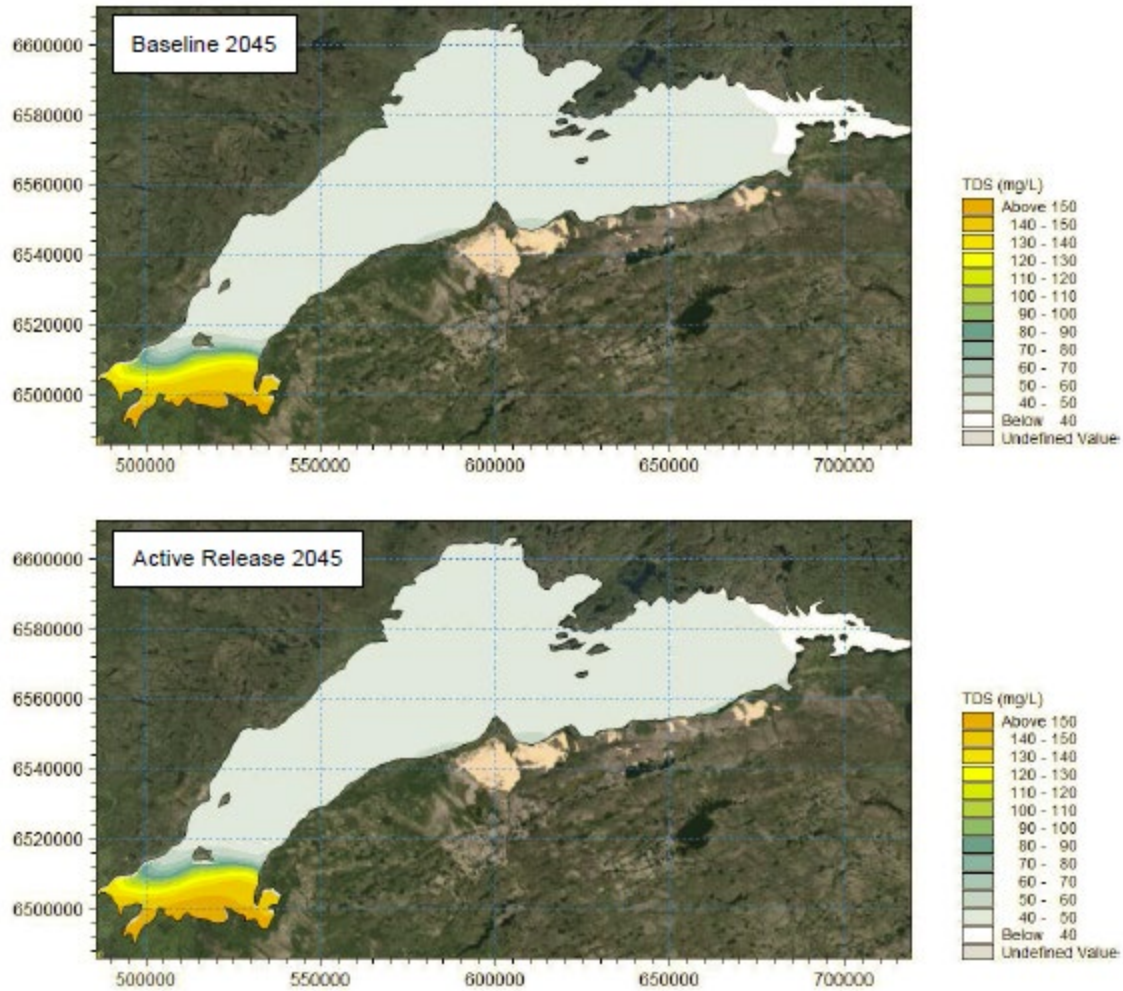


Figure 7. Total dissolved solids (TDS) concentrations for the Baseline and Active Release scenarios at the year 2045 snapshot. Values on axes are Universal Transverse Mercator coordinates.

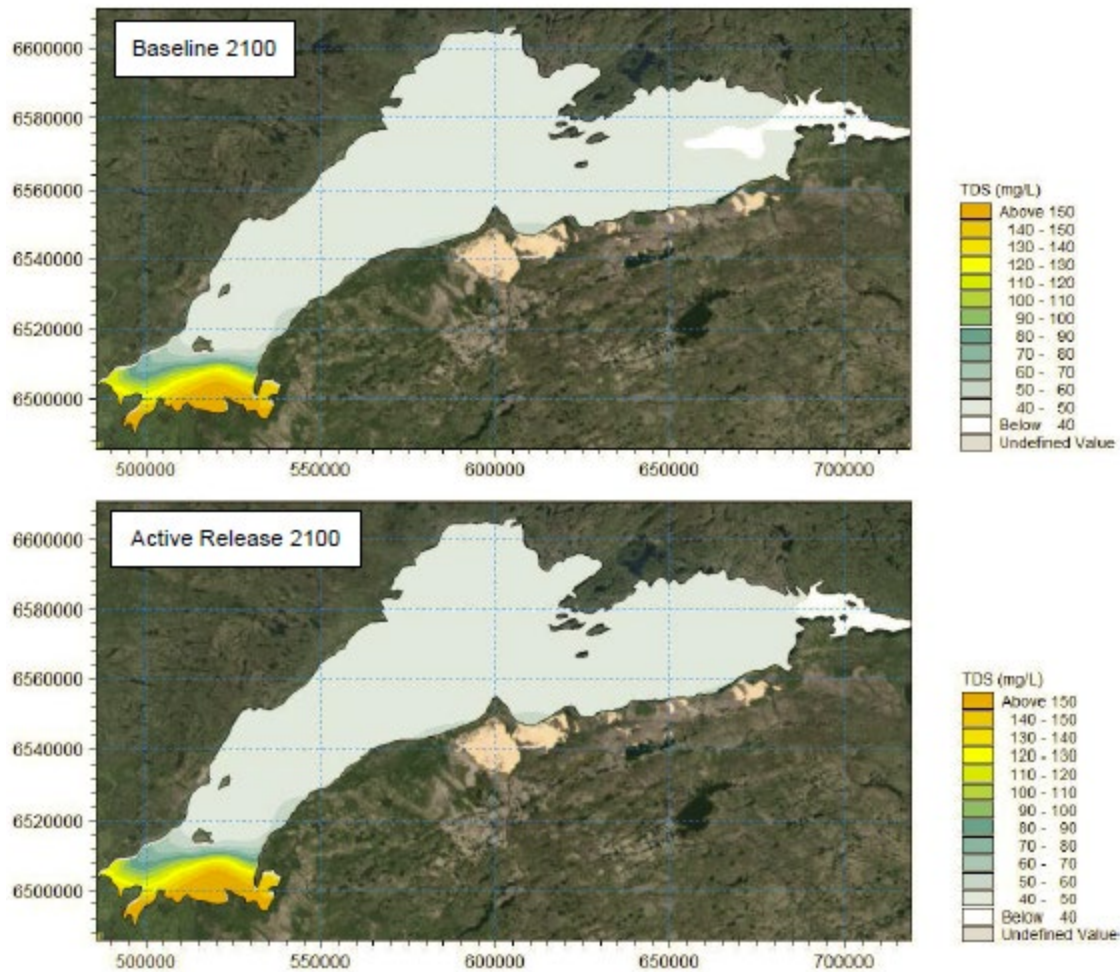


Figure 8. Total dissolved solids concentrations for the Baseline and Active Release scenarios at the year 2100 snapshot.

Discussion

The process water modelling indicated that most of the salts stored in OSPW will be stored in tailings pore water over the long-term. Approximately one-third of these salts were assumed to migrate back to the receiving environment, through pit lakes and ultimately to the Athabasca River. The pit lakes are intended to capture the salts in the pore water, which will eventually be diluted by precipitation and local runoff as it makes its way to the environment.

Athabasca River results indicated that active release of process water during operations would not increase peak concentrations of modelled parameters by more than 15% above baseline conditions in the Athabasca River at Reach 5. In general, active release would raise concentrations in the Athabasca River to concentrations expected for the Status Quo conditions, but elevated concentrations occur sooner. In the long term, the Active Release Scenario would improve water quality in the Athabasca River compared to the Status Quo Scenario by lowering closure concentrations and speeding up the time to return to baseline. Fine-tuning of

assumptions and iterative adjustment of releases, in conjunction with SLA modelling, could be used to optimize release rates to obtain the lowest overall concentrations in the future.

In contrast, peak ion and TDS concentration in pit lakes would be substantially lower (up to 40%) under the Active Release Scenario compared to the Status Quo Scenario. However, the reduction in pit lake concentrations varies by operation, due to variability in free water load, pore water load, and pit lake volume. The release load under the SLA varies by operator, which affects the change in concentrations between the Status Quo and the Active Release Scenarios. In all cases, pit lake water quality would be improved under the Active Release Scenario compared to the Status Quo Scenario, because there would be less mass in the pit lake following operations. Improved water quality in pit lakes would result from a gradual release of mass during operations rather than accumulating mass in tailings ponds that would ultimately become part of the initial pit lake water cap.

The hydrodynamic modelling results predict that changes in the TDS concentration of Lake Athabasca would be limited to an area approximately 20 km from the mouth of the Athabasca River. This corresponds with a general northeast to southwest flow from Fond du Lac to the lake outflow at the Peace River, and strong currents leading from the mouth of the Athabasca River directly to the lake outflow. Concentrations of TDS near the Athabasca River mouth under the Active Release Scenario were expected to decrease to Status Quo concentrations after 40 years, and stay below Status Quo concentration until 2100. The model predicts negligible changes in TDS concentrations in the middle of the lake.

Summary

In summary, the following key conclusions can be drawn from this study:

- The main sources of salts to the tailings are connate water, depressurization, and river water (used as makeup water).
- Most of the salts remaining at oil sands mines at closure will be in tailings pore water.
- The timing of OSPW release has little effect on the concentrations of ions and TDS in the Athabasca River because of the large assimilative capacity of the river.
- Active release of OSPW during operations had the potential to substantially reduce concentrations of ions and TDS in process water and pit lakes at closure.
- Circulation patterns in Lake Athabasca constrain the effects of inflow from the Athabasca River to a zone that extends approximately 20 km from the mouth with an overall movement toward the lake outlet, minimizing the potential for accumulation or an increase in whole lake concentrations.

Data limitations and uncertainty

The predictions presented in this report represent reasonable estimates of the chemistries of process water, pit lakes, the Athabasca River, and Lake Athabasca, based on the available data.

Nevertheless, some limitations resulted from assumptions to this complex system, and those assumptions could affect model results; for example:

- Long term closure conditions will be driven by the release of pore water from the tailings, which was only evaluated prescriptively in this study. Further study of these mechanisms on a regional basis would improve confidence in long-term predictions. Changes in project site conditions will result in changes to water quality predictions.
- Only limited data regarding the chemistry of Lake Athabasca were available, especially on the Saskatchewan side of the lake. Most of the locations with aquatic chemistry data did not have measurements for every month. Flow rates for some of the identified boundaries were not available and had to be estimated from ratios and regression equations from stations that appeared to behave similarly.

It is unlikely that the key findings would be affected by these limitations, or that the key findings would change if these limitations were not present.

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