Technology and Innovation
4700 Daybreak Parkway
South Jordan, Utah
84095
USA
T +1(801) 204 2350
F +1(801) 204 2890

Internal memo

From	Doug Oliver, Principal Advisor – Hydrogeology (T&I) Zak Brown, Senior Advisor – Hydrogeology (T&I) Craig Stevens, Principal Advisor – Hydrogeology (T&I)
To	Rod Williams (IOC), Callie Andrews (IOC)
CC	Mike Muggridge (IOC), Sarah Butt (IOC), Melanie Kennedy (Golder Associates)
Reference	14738
Date	28 July 2014
Subject	**Technical Memorandum** **Groundwater Modeling Predictive Results for** **IOC Wabush 3 Project**

Key Findings

The IOC south area groundwater flow model constructed by Rio Tinto T&I in 2012 has been re-calibrated and refined for the Wabush 3 area based on hydrogeologic investigations performed in 2011-2013. The steady-state calibration was evaluated by comparing simulated water levels with measured water levels from wells and piezometers in the Wabush 3 area. The difference between simulated values and measured values is known as the residual or calibration error. The range of residuals (maximum over prediction and maximum under prediction) was 3.5 to -6.8 meters. The mean calibration error was 1.7 m, the mean absolute error was 3.8 m, and the root mean squared error (RMSE) was 4.3 m. The normalized RMSE was 3.6%, indicating an adequate calibration with respect to observed water levels (a general rule-of-thumb is that the normalized RMSE should be less than 10%).

Following recalibration, the groundwater flow model was used to predict water levels and flows (minimum necessary dewatering rates) to the proposed Wabush 3 and Luce pits for the planned life of mine (LOM) through 2063. Impacts to nearby lakes (Dumbell Lake and Leg Lake) were evaluated by comparing simulated groundwater inflow and outflow rates to the lake during the LOM.

For the base case (calibrated groundwater flow model with the proposed Wabush 3 and Luce pit mine plans simulated through time), groundwater inflow to the Wabush 3 pit increased through time reaching about 450 gallons per minute (gpm) by the year 2033 and then remained between 450-500 gpm through 2063. These flow rates are significantly less than dewatering rates observed at Luce pit because geologic data collected thus far and the structural models developed for the site do not indicate a direct connection from the Wabush

3 pit to the surrounding lakes (Leg Lake, Dumbell Lake, White Lake) with high hydraulic conductivity features (e.g., large fault zones, shear zones, or leached zones).

Changes in groundwater flow to Dumbell Lake (in the form of reductions in groundwater inflow to the lake) for the base case are predicted to be minimal, particularly compared to the overall water balance, which is primarily controlled by surface water flow. The maximum reduction in groundwater flow directly to the Dumbell Lake during the Wabush 3 LOM is predicted to be 2 gpm, which is insignificant compared to the surface water inflow to the lake (average of 1,600 gpm for measured flows). Surface water flows may decrease if pit dewatering reduces groundwater discharge to streams that flow to Dumbell Lake, but this was not modeled. Surface water flows also will decrease as a function of decreases in catchment area as a result of mining.

Changes in groundwater flow from Leg Lake (in the form of increases in outflow from the lake with groundwater flow to the pit) for the base case are predicted to be less than surface water inflows to the lake. The maximum outflow from the lake during the LOM is predicted to be 146 gpm, which is 42% of the surface water inflow of 340 gpm (average of measured flows). Surface water flows are also expected to decrease once the water table is lowered by pit dewatering, thus reducing discharge to streams that flow to Leg Lake, but this was not modeled.

The hydrogeology of the Wabush 3 area and the hydraulic connection between the pit and the surrounding lakes, particularly Dumbell Lake and Leg Lake is still somewhat uncertain. Because of this uncertainty, multiple sensitivity runs were performed to assess the predicted inflows to the pit that might result if the pit is directly connected to Dumbell Lake and/or Leg Lake via higher hydraulic conductivity structures (similar to those present between Luce Lake and Luce pit). Simulations indicate that the magnitude of predicted inflows to the Wabush 3 pit and impacts to the surrounding lakes are highly sensitive to these structures. Inflows to the Wabush 3 pit are most sensitive to the hydraulic connection to Leg Lake, due to its higher elevation (Leg Lake elevation ~715 m amsl) relative to the pit (Wabush 3 pit at end of LOM elevation ~430 m amsl). Impacts to Dumbell Lake are less because it is much lower (Dumbell Lake elevation ~575 m amsl).

Detailed Findings

Introduction and Purpose

Rio Tinto Iron Ore Company of Canada (IOC) plans to develop Wabush 3, a new mine pit planned for the area south of Luce pit. The Wabush 3 pit and associated waste rock dumps and overburden stockpile are located within the catchments of a number of lakes including Dumbell Lake, the nominated back-up water supply for the Town of Labrador City, Leg Lake, and White Lake/Luce pit. Drum Lake and Pumphouse Pond are located within the footprint of the Wabush 3 pit and will be removed. The overburden stockpile is also close to the catchment of Beverley Lake, the current municipal water supply for Labrador City. The Wabush 3 life of mine (LOM) is planned to extend until 2063 when the pit reaches its maximum depth at an elevation of about 430 meters above mean sea level (m amsl).

Significant field data collection and aquifer hydraulic testing have been performed in the Wabush 3 area since Rio Tinto T&I completed the conceptual groundwater model (*IOC Site-wide Conceptual Groundwater Model,* Rio Tinto T&I, 2012a) on which the numerical groundwater flow model (*IOC South Groundwater Flow Model and Updated Luce Pit Dewatering Prediction*, Rio Tinto T&I, 2012b) was based. These conceptual and numerical groundwater models have been updated to incorporate the new Wabush 3 data, as summarized in this memorandum. Following recalibration, the groundwater flow model was used to predict flows (minimum necessary dewatering rates) to Wabush 3 and Luce pits and impacts to nearby lakes (as estimated by changes in groundwater inflow and outflow rates) over the LOM for both pits.

Wabush 3 Hydrogeologic Investigations

Major hydrogeological data collection efforts in the Wabush 3 area were performed and documented as follows:

- 2011 by Golder (*Draft Wabush 3 and Wabush 6 Hydrogeological and Hydrological Technical Report*, Golder Associates, 2011),
- 2012 by AMEC (*Summary of Field Work – Drilling and Packer Testing of Borehole W3-12-143*, AMEC Environmental & Infrastructure, 2012a),
- 2013 by IOC (*Wabush 3 Pump Test Results*, Rio Tinto IOC, 2013; other internal documents and data files).

These investigations included:

- Drilling and geologic logging and packer testing of 11 boreholes
- Packer testing of boreholes to assess hydraulic properties of the rock mass (61 tests; results in Table 1)
- Installation of 20 piezometer/monitoring wells and one large diameter test well (locations are shown on Figure 1; survey and construction data are presented in Table 2)
- Water level monitoring (both manual and continuous) in piezometers/monitoring wells and two open holes
- Water quality sampling and analysis for piezometer/monitoring wells
- Constant pumping rate aquifer test in Test Well TW-13-01.

In addition to hydrogeological investigations, surface water hydrology and environmental baseline studies have been undertaken in the Wabush 3 area and are summarized in:

- 2011 by Golder (*Draft Wabush 3 and Wabush 6 Hydrogeological and Hydrological Technical Report*, Golder Associates, 2011),
- 2012 by AMEC (*Surface Water and Hydrology Baseline Report for Proposed Wabush 3 Mine Site*, AMEC Environmental & Infrastructure, 2012b),

Although not specific to Wabush 3, relevant structural geological interpretation and modeling at IOC have been performed since 2011 and are summarized in:

- *Luce Preliminary Structural Architecture Model*, an internal memo prepared by Alasdaire Pope (Rio Tinto Exploration - PGG), 16 January 2012 (Rio Tinto Exploration, 2012a)
- *IOC Carol Project - 3D Interpretation and Modeling*, an internal memo prepared by Steven Coombes (Rio Tinto Exploration Canada), 18 December 2012 (Rio Tinto Exploration, 2012b).

Hydraulic conductivity data from packer tests

As part of the Wabush 3 hydrogeological investigations, 61 packer tests were performed in the Wabush 3 area by Golder, AMEC, and IOC (Table 1). Tests performed and analyzed by Golder, AMEC, and IOC have approximately the same geometric mean - Golder: 8 x 10^{-5} centimeters per second (cm/sec); AMEC: 4 x 10^{-5} cm/sec; IOC: 7 x 10^{-5} cm/sec. Similarly the geometric mean of packer test results from the Luce pit area performed by IOC in 2013 is 2 x 10^{-4} cm/sec. However, the geometric mean of falling head tests performed in piezometers in the Luce pit area prior to 2012 is 8 x 10^{-7} cm/sec, two orders of magnitude lower than the geometric mean from the Wabush 3 packer tests.

Hydraulic conductivity data from packer tests in the Wabush 3 area were also evaluated with respect to rock type, depth below ground surface, and test type. There were no clear differences in hydraulic conductivity based on depth below ground surface (0-50 meters below ground surface [m bgs], 50-100 m bgs, 100-200 m bgs, and >200 m bgs) or type of test (falling head and constant rate). For intervals tested with both constant rate and falling head tests, the hydraulic conductivity values were nearly the same, but on average slightly greater for the constant rate tests relative to the falling head tests.

There were no clear correlations between rock type and hydraulic conductivity for the packer tests, as all rock types evaluated had fairly similar geometric mean hydraulic conductivity values, indicating hydraulic conductivity is largely controlled by fractures. Orthoquartzite had the lowest geometric mean hydraulic conductivity (4 x 10^{-5} cm/sec; n=7) and quartz-magnetite-specularite had the highest geometric mean hydraulic conductivity (9 x 10^{-5} cm/sec; n=25). The other two rock types evaluated were quartz carbonate gneiss (geometric mean hydraulic conductivity 6 x 10^{-5} cm/sec; n=4) and quartz-specularite schist (geometric mean hydraulic conductivity 6 x 10^{-5} cm/sec; n=7). The general pattern of results was similar to that of Luce pit area – quartzite generally had the lowest hydraulic conductivity. Many of the intervals included more than one rock type; packer tests with several disparate rock types or without a dominant rock type were excluded from the analysis.

Installation of piezometers and wells

As part of the 2011-2013 Wabush 3 hydrogeologic investigations, 20 piezometers/monitoring wells were installed, two holes were left open for water level measurements and one large diameter test well was installed. Locations of piezometers and wells are shown on Figure 1 and survey data and construction details for these wells are provided in Table 2. Pressure transducers were installed in 10 of the piezometers installed in 2011 and water levels have been monitored continuously (4 readings per day) in these since November 2011. The test well TW-13-01 is screened to 231 m bgs.

Aquifer testing of Test Well TW-13-01

An aquifer test was performed in test well TW-13-01 to better understand hydraulic characteristics in the Wabush 3 area. This well is screened in the Middle Iron Formation (MIF) ore body and is located in the eastern area of the proposed Wabush 3 pit. The test well TW-13-01 is constructed of 16-inch (40-cm) diameter casing and screen with a 67 m screened interval extending from 164 to 231 m bgs. The Wishart quartzite is immediately to the east separating TW-13-01 from Dumbell Lake. Testing included background water level monitoring, a variable pumping rate step test, a 5-day constant pumping rate test, and recovery test (water level monitoring data collection). The variable pumping rate step test was performed in to determine a sustainable pumping rate for the constant rate test. The constant rate test was run for 5 days at a nearly constant pumping rate that ranged between 1113-1136 gallons per minute (gpm). The maximum drawdown in the pumping well TW-13-01 was 22.85 m. Spatially, drawdown was quite variable in the piezometers/monitoring wells due to the fractured nature of the aquifer. The maximum drawdown observed in a piezometer in response to pumping TW-13-01 was 12.9 m in W3-13-175, which is19 m from TW-13-01. Other piezometers with drawdown greater than 1 m include:

- W3-13-174 with 1.8m of drawdown (308 m northeast of TW-13-01, toward Dumbell Lake)
- W3-11-76D with 1.2 m of drawdown (766 m north of TW-13-01 and along the inferred NE-SW shear zone in the Middle Iron Formation).

Drawdown response through time showed behaviours indicative of porous media, but the distribution of drawdown was indicative of fracture flow (significant drawdown at distance in W3-13-76D and no measurable drawdown at closer wells).

Drawdown data from TW-13-01 and W3-13-175 were analysed with time-drawdown and distance-drawdown methods resulting in a mean transmissivity value of 4×10^{-3} m^2/sec and a storativity of 0.0009 (Rio Tinto IOC, 2013). Assuming a saturated thickness of 110 m (depth to water was 121 m bgs at start of test and bottom of well is at 231 m bgs), a hydraulic conductivity of 3×10^{-3} cm/sec was calculated. This is greater than the mean from packer tests in the Wabush 3 area, but this well targeted a high hydraulic conductivity zone.

Structural features in the Wabush 3 area that may affect groundwater flow

Wabush #3 is located along the axis of a major shear zone that runs northeast-southwest within the Wabush Iron Formation. Aside from high permeability of faults and fractures, the Iron Formation has leached zones of high permeability limonite and goethite, particularly along fault/fracture zones. Potential flow from Leg Lake to Wabush 3 depends on the presence of these high permeability features. If Leg Lake and Wabush #3 pit are both located on the same high permeability feature, flow to Wabush #3 may be similar to flows from Luce Lake to Luce pit. However, this appears unlikely as the current structural models (Rio Tinto Exploration 2012a and 2012b) do not show such a connection. Test well TW-13-01 is in a highly conductive fracture zone in the Middle Iron Formation, likely along the primary NE-SW shear zone presented in the structural model and appears connected to piezometer W3-11-76D.

Dumbell Lake and White Lake are separated from Wabush #3 pit by low permeability Wishart Quartzite and Attikamagen Formation. Drawdown beneath Dumbell Lake as a resulting of dewatering the Wabush 3 pit is likely to be negligible because the amount of groundwater flow to Dumbell Lake is believed negligible compared to the surface water flow. Furthermore, the lake will act as constant head water source during pit dewatering. Predictive simulations were performed with the numerical groundwater model to predict changes in groundwater flow rates to Dumbell Lake and to compare groundwater flow to surface water flow to Dumbell Lake. Due to the complexity of structural features in the Wabush 3 area, there are possibly some structural/stratigraphic features that could control the hydraulic conductivity distribution and groundwater flow, but that may not be represented in the groundwater flow model. However, there likely are some fracture zones that cross-cut the Wishart Quartzite. To evaluate uncertainty in the fracture network, sensitivity runs were performed to evaluate impacts to Dumbell Lake if high permeability zones connect Wabush 3 to Dumbell Lake

Conceptual groundwater model summary for Wabush 3 area

The groundwater conceptual model for the Wabush 3 area is generally the same as the *IOC Site-wide Conceptual Groundwater Model* (Rio Tinto T&I, 2012a) that was developed primarily with data from the Luce pit area. Groundwater flow is primarily through fractures (faults, shear zones, joints, bedding planes, geologic contacts) and weathered/leached zones (goethite/limonite zones) within the bedrock aquifers. Flow also occurs within unconsolidated lacustrine, alluvial, and glacial deposits, the saturated thickness and areal extent of these deposits are generally limited in the mine area. Recharge to the groundwater system occurs through infiltration of precipitation, as well as leakage from lakes, streams, and bogs in topographically higher areas. As a result, groundwater flow is generally from topographically higher areas toward from topographically lower areas. Overall, regional groundwater flow is likely to be ultimately toward Wabush Lake, as it is the lowest point in the area at ~525 m amsl. However, mining activities, particularly pit excavation and dewatering, has significantly altered local groundwater flow patterns in the mine area. Groundwater flow in the mine area is likely generally toward the pits as these are now the lowest points in the area and they act as hydraulic sinks (final Wabush 3 pit will be ~430 m amsl).

The hydraulic conductivity of the bedrock is highly variable, with the highest values in fractured zones and leached limonitic/goethite zones. Due to the orientation of preferential pathways (faults, shear zones, leached zones, geologic contacts), preferential flow paths are generally north-south (NNE-SSW) along these major structural features, as indicated by the TW-13-01 aquifer test results. Although likely less conductive, some easterly to westerly groundwater flow pathways are also present. Faults and shear zones likely have a greater impact on hydraulic conductivity (and hence flow) than rock type. On average, hydraulic conductivity in the Wabush 3 area appears to be slightly higher than in the Luce pit area.

Seepage from Leg Lake to the Wabush 3 pit could be significant and similar to the flows from Luce Lake to Luce pit, but the structural models do not show any major features connecting them. Seepage from White Lake and Dumbell Lake to Wabush 3 is likely to be minimal because the pit is separated from these areas by Wishart Quartzite and major shear zones are oriented north-south (NNE-SSW) do not connect these lakes to the proposed Wabush 3 pit.

Re-calibration of numerical groundwater model for Wabush 3 area

The numerical groundwater flow model of the southern portion of the IOC mine site (MODFLOW-SURFACT model constructed in Groundwater Vistas and previously described in the report *IOC South Groundwater Flow Model and Updated Luce Pit Dewatering Predictions*, Rio Tinto T&I, 2012) was updated and recalibrated for the Wabush 3 area using recent exploration data (structural geologic models) and the hydrogeologic data (water levels, hydraulic conductivity data, drawdown data from aquifer tests) described above. As the original model was built with the intention of simulating the proposed Wabush 3 pit, the domain already included Leg Lake and Dumbell Lake and did not need to be modified. Minimal hydrogeologic data existed in the Wabush 3 area at the time of the initial model development, and the model was constructed with little hydrogeologic differentiation in the Wabush 3 area. For calibration of the updated model, water level data were imported as calibration targets, and the hydraulic conductivity (previously relatively homogeneous in the area) was modified to match the observed average water levels and measured hydraulic conductivity ranges while also respecting the structural geologic interpretation and the aquifer test data. At this time, the model grid in the area (or increased vertical discretization) was not refined, though it may be necessary to refine the grid during the predictive simulations to more accurately represent the mine plan.

Eleven calibration targets (water levels from piezometers or wells in the Wabush 3 area) were used to calibrate the steady-state model. Average water levels for 2013 were used for calibration. Many of the water levels (particularly the shallow completions) exhibit large transient variation, but have no consistent trend (decline or increase), therefore average water levels were used for the steady-state calibration. Although 21 piezometers/monitoring well completions exist in the area, because all completions of nested wells (i.e., shallow, middle, deep) fell within the first layer of the numerical model, 10 were considered redundant and were not used. Typically the deepest completion was used as a target, because many of the shallower completions seemed to be in perched layers or somewhat isolated from the primary flow system (based on observed water level responses during the TW-13-01 aquifer test). The calibration targets provided coverage across most of the Wabush 3 area. The hydraulic conductivity distribution and magnitude were adjusted in the area until an adequate match to observed average water levels was achieved via manual methods (quantitatively evaluated via the normalized root mean squared error [RMSE], equal to the RMSE divided by the range of observed water levels [118 m]). The steady-state calibration was evaluated by comparing simulated water levels with measured water levels from wells and piezometers in the Wabush 3 area. Simulated water levels are plotted against the observed water levels for each calibration target in Figure 2. The one-to-one line represents a perfect fit; points that fall below this line represent water levels that are underestimated by the model and points above the line are overestimates. The residual for a given calibration target is the difference between the simulated and the observed water level and is also known as the calibration error. The range of residuals (maximum over or under prediction) was 3.5 to -6.8 meters. The mean calibration error was 1.7 m, the mean absolute calibration error was 3.8 m, and the

RMSE was 4.3 m. The normalized RMSE of 3.6% was achieved, indicating an adequate calibration with respect to observed water levels (a general rule-of-thumb is that the normalized RMSE should be less than 10%). The assigned hydraulic conductivities in the area ranged between 2.3 x 10^{-3} cm/sec and 2.0 x 10^{-7} cm/sec (geometric mean of 1.0 x 10^{-5} cm/s), which is within the range of observed measurements, with the areas of highest hydraulic conductivity aligned with major structural features identified during exploration drilling and in the existing structural model.

A simple transient simulation was also performed to simulate the aquifer test at TW-13-01. During the aquifer test, TW-13-01 was pumped at a constant rate of approximately 1125 gpm for 5 days. The storage parameters from the Luce pit area were used in the simulation (storativity of 1 x 10^{-6}, specific yield of 0.05). Due to the heterogeneities of the fractured rock aquifer that are not explicitly represented in the model, it was expected that a perfect match to the observed water levels during the test would not be achieved. This exercise was performed as a qualitative verification on the calibration. Simulated drawdown in W3-13-175, the observation well showing the greatest drawdown during the aquifer test, was 11.6 m, while the actual observed drawdown was 12.9 m. This indicates that the model is capable of simulating transient perturbations of the flow system.

Predictive simulations of Proposed Wabush 3 Pit

The re-calibrated south area model was used to predict groundwater levels and flows for the proposed Wabush 3 pit over the LOM (through 2063). These simulations also incorporated the Luce pit LOM (through 2053). Pits were incorporated into the model as transient seepage face (drain) boundary conditions to determine the induced outflow of groundwater (flow to the pits) as the pits are deepened through time. Pit shell elevations were obtained from IOC mine planners on 5-year intervals. Elevations were then interpolated linearly on one year intervals for input to the model. Detailed mine plans were not simulated in these predictions.

Model-predicted water levels for current conditions (2013) are shown on Figure 3. These are from the calibrated model illustrating baseline conditions (pre-Wabush 3 mining, but with Luce pit dewatered to 540 m amsl). Groundwater in the Wabush 3 area flows toward Leg Lake, Dumbell Lake and Luce pit. Figure 4 shows the predicted water table elevation contours at the end of LOM in 2063 with Wabush 3 dewatered to about 430 m amsl and Luce pit dewatered to 320 m amsl (the end of LOM for Luce pit is planned for 2053, but for simplicity in the model dewatering of Luce pit was assumed to extend through 2063).

For the base case (Run 1, simulating the Wabush 3 and Luce pit mine plans to the calibrated model), groundwater inflow to the Wabush 3 pit increased through time reaching about 450 gpm by the year 2033 and then remained between 450-500 gpm through 2063. Predicted flows to the Wabush 3 pit are relatively low compared to flows to Luce pit (approximately 8,000 gpm). This is primarily because the proposed Wabush 3 pit is not directly hydraulically connected to any lakes in the way that Luce pit is connected to Luce Lake. The Wabush 3 pit is also higher in elevation reaching a minimum elevation of approximately 430 m amsl, while the final depth of Luce pit is 110 meters deeper (pit floor at approximately 320 m amsl). Note that these predicted flow rates are based on simulating the pit shell as a seepage face, and actual dewatering rates necessary to keep water levels below the pit floor and pore pressures in the pit walls low may need to be somewhat higher than these predicted flows.

These predicted flow rates should be considered long-term average minimum dewatering rates. However, in practice the actual necessary instantaneous dewatering rate to maintain water levels some distance below the pit floor and maintain slope stability will be somewhat higher. How much higher will depend on how early dewatering commences relative to mining, seasonal variation in recharge, up-time of the dewatering system, and localized heterogeneity in hydrogeologic parameters. Based on predicted inflows to Luce pit, previous predictive modelling, and observational data, the actual dewatering rates necessary may be up to 50% greater than those predicted here.

Sensitivity Analysis

Because of uncertainty associated with the hydrogeology, particularly the distribution of hydraulic conductivity, multiple scenarios were simulated to determine the influence that uncertainties in hydrogeologic parameters and hypothetical structural features may have on the predicted results. Changes to the calibrated model (e.g., hydraulic conductivity distribution, recharge, etc.) were made and then the model was run for a 50-year period from the present to end of LOM (2013-2063) with both Wabush 3 and Luce pits. While many simulations were performed in this sensitivity analysis, only a select subset is presented here for clarity. These simulations included:

- Run 1 - the base case simulation in which the Wabush 3 and Luce pit mine plans were added to the calibrated model (model-predicted potentiometric contours for the water table in 2013 and 2063 are shown in Figures 3 and 4, respectively)
- Run 2 – Same as Run 1 except the hydraulic conductivities in the Wabush 3 area were increased by a factor of 10
- Run 3 – Same as Run 1 except that potential recharge was increased by a factor of 2
- Run 4 – Same as Run 1 except a narrow zone of higher hydraulic conductivity material was assumed to extend from the center of the Wabush 3 pit to the northeast and intersect with Dumbell Lake to simulate a fracture zone through the Wishart Quartzite; other hydraulic parameters unchanged
- Run 5 – Same as Run 3 plus a second narrow zone of higher hydraulic conductivity connecting the Wabush 3 area with Leg Lake to the southwest to simulate a fracture zone; other hydraulic parameters unchanged

High values for the storage parameters (storativity of 1×10^{-3}, specific yield of 0.1) in the Wabush 3 area were used for all runs, as a conservative assumption. The predicted inflows were found to not be as sensitive to changes in storage parameters as they were to the other parameters that were modified (i.e., hydraulic conductivity and recharge).

The model-predicted flow rates to Wabush 3 for the LOM (present-2063) are presented on Figure 5. Maximum long term average flows to Wabush 3 are predicted to be approximately 500-1,000 gpm for Runs 1-4. Run 5 assumes there is a high hydraulic conductivity zone that connects the pit area to Leg Lake.

Predicted inflows to Wabush 3 are highly sensitive to the area's connection to Leg Lake and to a lesser extent to its connections to Dumbell Lake. Current geologic data and structural models (Rio Tinto Exploration, 2013) do not suggest that the area is directly connected to either Leg or Dumbell Lake via high hydraulic conductivity structural feature, as is the case between Luce Lake and Luce pit. Runs 4 and 5 were performed to assess the unlikely scenario that the Wabush 3 area is connected via a highly conductive structure to one or both of the lakes. For Runs 4 and 5, the connecting features were assigned the highest conductivity assigned to the Wabush 3 area during calibration (2.3×10^{-3} cm/s). Predicted inflows increase in each case, though a much larger increase in flow to Wabush 3 occurs if the area is connected to Leg Lake. This is due to its proximity to the pit and its elevation, which is 140 meters higher than Dumbell Lake (Leg Lake has an elevation of approximately 715 m amsl, while Dumbell Lake is at approximately 575 m amsl). This creates a much steeper gradient between Leg Lake and the Wabush 3 pit as it deepens. Run 5 resulted in a maximum predicted inflow of just over 3,000 gpm.

The model-predicted flow rates to Luce pit during the Wabush 3 LOM (present-2063) are presented on Figure 6. Maximum long term average flows to Luce pit are predicted to be approximately 8,000 gpm for Runs 1-4. Flows to Luce pit are lower in Run 5 because this run assumes there is a high hydraulic conductivity zone that connects the Wabush 3 pit area to Leg Lake, which effectively diverts some of the flow from Leg Lake to Wabush 3 pit that otherwise would report to Luce pit in the other simulations. Note that these predicted flow rates are based on simulating the pit shell as a seepage face, and actual dewatering rates necessary to keep water levels below the pit floor and pore pressures in the pit walls low may need to be somewhat higher than these predicted flows. Previous modelling performed to assess necessary dewatering rates at Luce pit indicates that approximately 10,000 gpm of extraction is necessary to keep water levels at least one bench lower than the pit floor (T&I, 2012b), approximately 2,000 gpm more than the 8,000 gpm predicted with this model.

To assess impacts to Leg Lake and Dumbell Lake as a result of Wabush 3 dewatering, flow budgets for the general head boundary cells representing these lakes were predicted through time from 2013 to 2063 and are presented in Figures 7 and 8. For these figures, negative numbers represent net discharge to the lake from groundwater, while positive numbers represent net recharge to groundwater from the lake. Dumbell Lake remains a zone of groundwater discharge across all scenarios, though the discharge decreases through time due to Wabush 3 dewatering. Changes in groundwater flow to Dumbell Lake (in the form of reductions in groundwater inflow to the lake) for the base case (Run 1) are predicted to be minimal during the Wabush 3 LOM. The maximum reduction in groundwater flow directly to the Dumbell Lake is predicted to be 2 gpm as flow rates decreased from 13 gpm to 11 gpm. Similarly Runs 2 and 3 resulted in declines of about 2 gpm in groundwater discharge to Dumbell Lake during the Wabush 3 LOM. Surface water flow to Dumbell Lake has been measured to be 1,600 gpm (0.103 m^3/s for gauge #2) based on a limited field program (AMEC, 2012b), so this would represent a reduction in flow to Dumbell Lake of 0.1% of the surface water component of inflow to the lake. Connecting the Wabush 3 pit to Dumbell Lake with a more conductive structure (Runs 4 and 5) resulted in higher initial discharge rates to the lake (roughly 10 times higher than Runs 1-3), and larger decreases in discharge due to dewatering (106 gpm for Run 4, and 137 gpm for Run 5, representing 7-9% of the surface water inflow to the lake). Surface water flows may decrease if pit dewatering reduces groundwater discharge to streams that flow to Dumbell Lake, but this was not modeled. Surface water flows also will decrease as a function of decreases in catchment area as a result of mining.

Leg Lake is a source of recharge to the groundwater system for all simulations. Changes in groundwater flow from Leg Lake (in the form of increases in outflow from the lake with groundwater flow to the pit) during the LOM for the base case (Run 1) are predicted to be 146 gpm. For Runs 2-4, the predicted reduction in groundwater inflows to Leg Lake range from 139-188 gpm. Surface water flow to Leg Lake has been measured to be 340 gpm (0.0.021 m^3/s for gauge #7) based on a limited field program (AMEC, 2012b), so this would represent a reduction in flow to Leg Lake of 41-55%. When connected via higher conductivity structures to the Wabush 3 area (Run 5), the predicted changes in flow to Leg Lake inflows through time are much higher (2,557 gpm), many times higher than surface flows to the lake, so it would be completely drained (in the model, it acts as an infinite source of water, thus the unrealistically high value is predicted). Surface water flows are also expected to decrease once the water table is lowered by pit dewatering, thus reducing discharge to streams that flow to Leg Lake, but this was not modeled.

References

AMEC Environmental & Infrastructure, 2012a. *Summary of Field Work – Drilling and Packer Testing of Borehole W3-12-143*, Draft letter report prepared by Jacqueline Brook (AMEC Environmental & Infrastructure) for Stephane Normandin (IOC), 19 November 2012.

AMEC Environmental & Infrastructure, 2012b. *Surface Water and Hydrology Baseline Report for Proposed Wabush 3 Mine Site*, November 2012.

Golder Associates, 2011. *Draft Wabush 3 and Wabush 6 Hydrogeological and Hydrological Technical Report*, 20 December 2011.

Rio Tinto Exploration, 2012a. *Luce Preliminary Structural Architecture Model*. Internal memo from Alasdaire Pope (RTX-PGG) to Mike Muggridge (IOC), 16 January 2012.

Rio Tinto Exploration, 2012b. *IOC Carol Project - 3D Interpretation and Modeling*. Internal memo from Steven Coombes (RTX-Canada) to Mike Muggridge (IOC), Mike Belben (IOC), Alasdaire Pope (RTX), 18 December 2012.

Rio Tinto IOC, 2013. *Wabush 3 Pump Test Results, Aquifer Pump Test and Water Quality Results*. By Sarah Butt (IOC), 9 December 2013.

Rio Tinto Technology & Innovation (T&I), 2012a. *IOC Site-wide Conceptual Groundwater Model,* Internal Memo from Doug Oliver (Rio Tinto T&I) to Mike Muggridge and Sarah Butt (IOC), 20 January 2012.

Rio Tinto Technology & Innovation (T&I), 2012b. *IOC South Groundwater Flow Model and Updated Luce Pit Dewatering Predictions*, Draft report prepared by Zak Brown and Doug Oliver (Rio Tinto T&I) to Mike Muggridge (IOC), 17 December 2012.

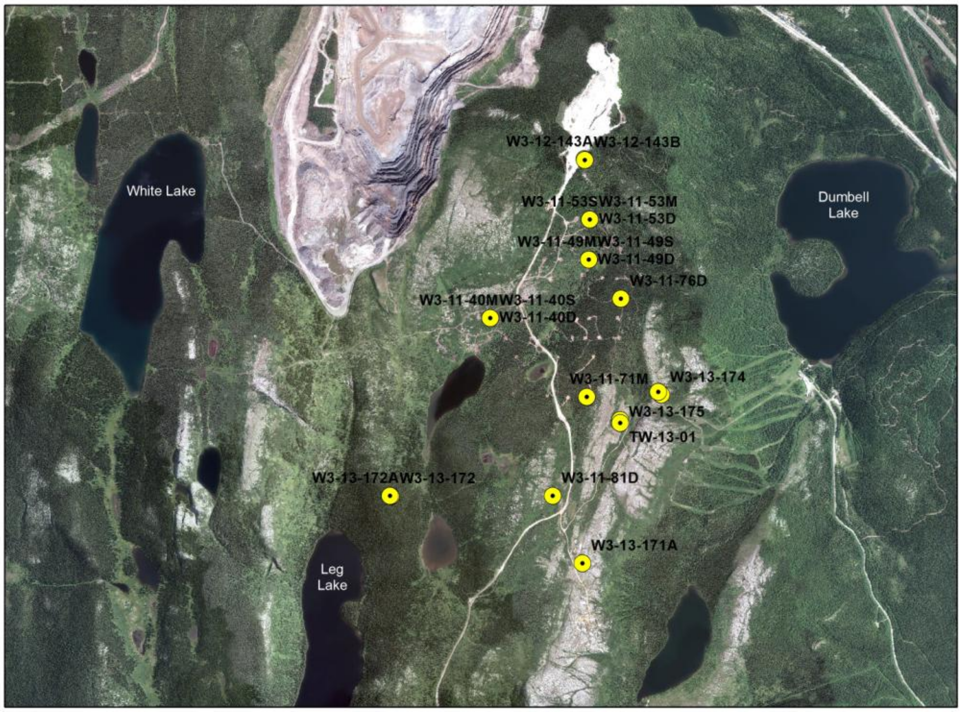

Figure 1. Wabush 3 area site map with piezometer/monitoring wells and test well.

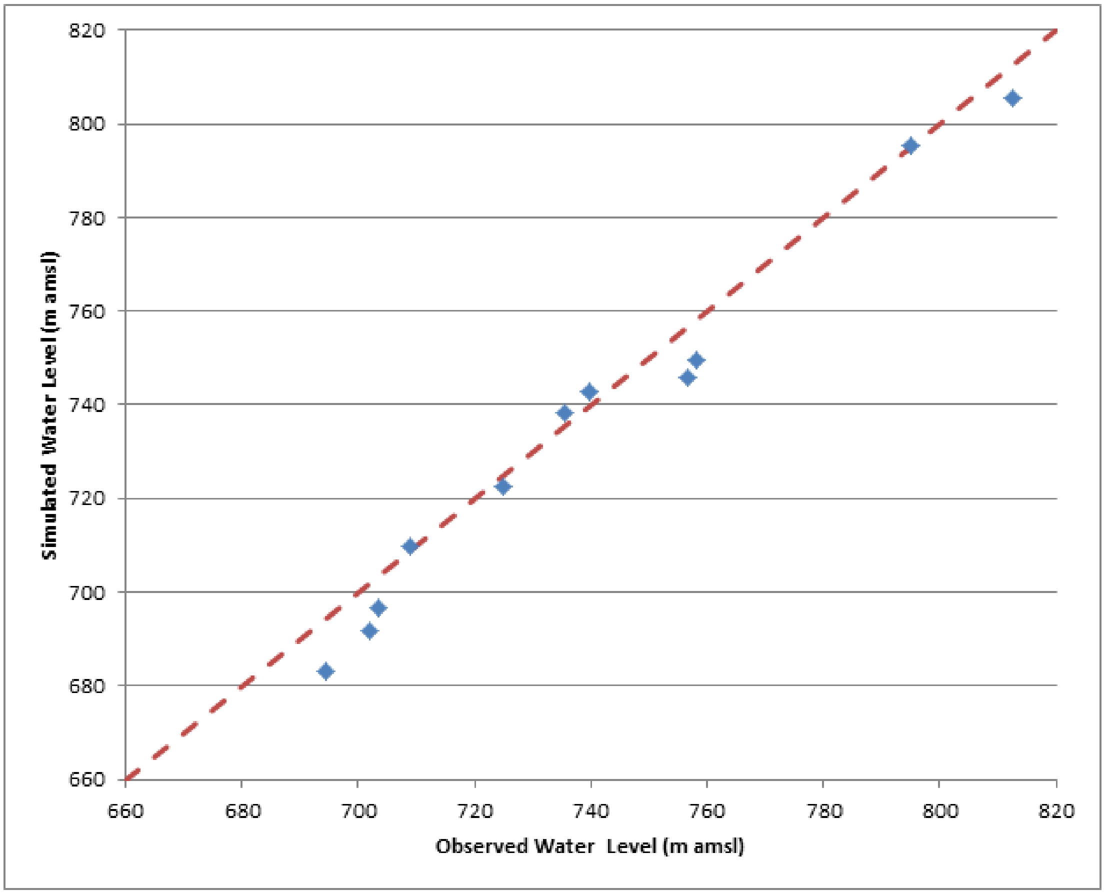

Figure 2. Simulated vs. observed water levels for steady-state calibration (2013).

Figure 3. Model-predicted water table elevation contours for current (2013) baseline conditions prior to Wabush 3 mining (Luce pit dewatered to 540 m amsl).

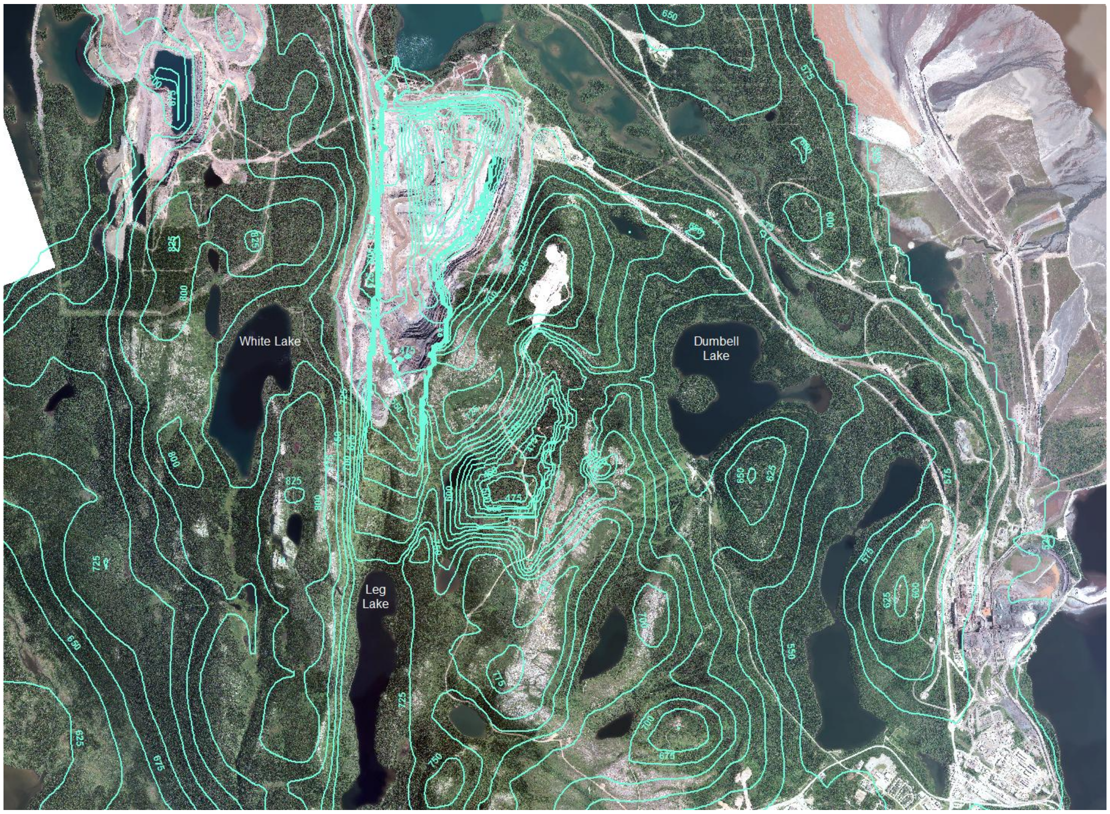

Figure 4. Model-predicted water table elevation contours at the end of Wabush 3 LOM in 2063 (simulation also includes Luce pit dewatering to 2063).

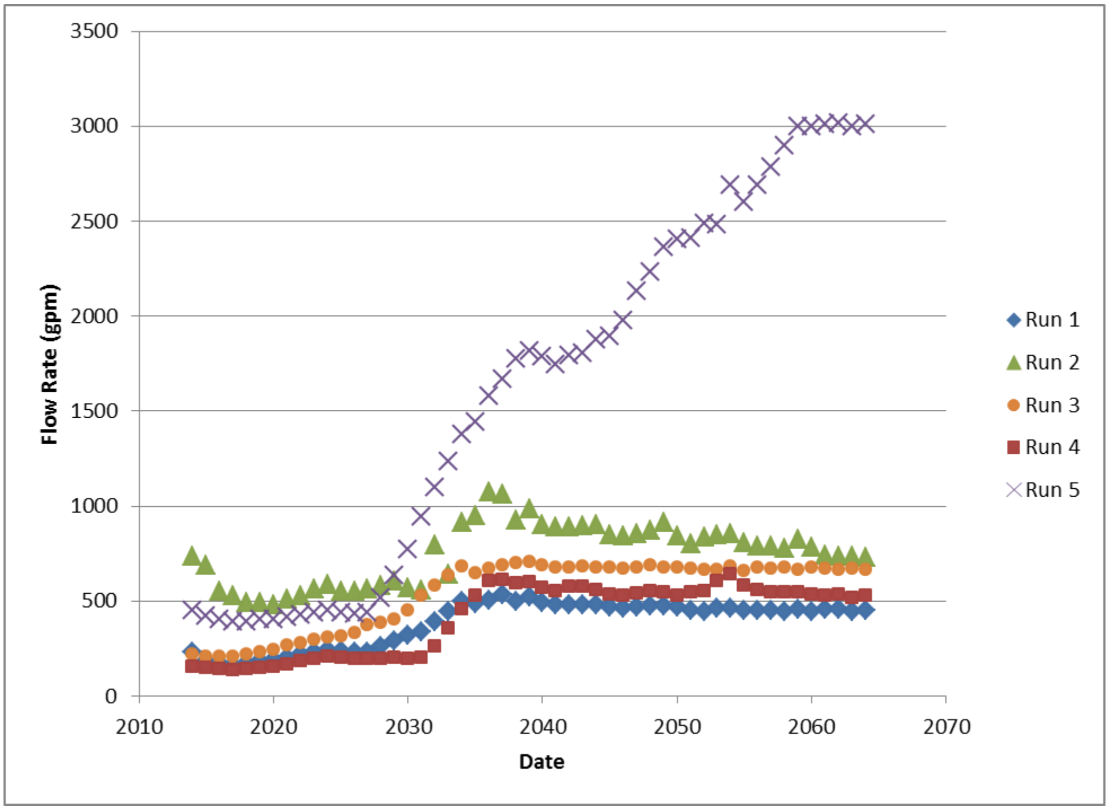

Figure 5. Predicted inflows to Wabush 3 pit through LOM (Runs 1-5; Run 1 is the base case).

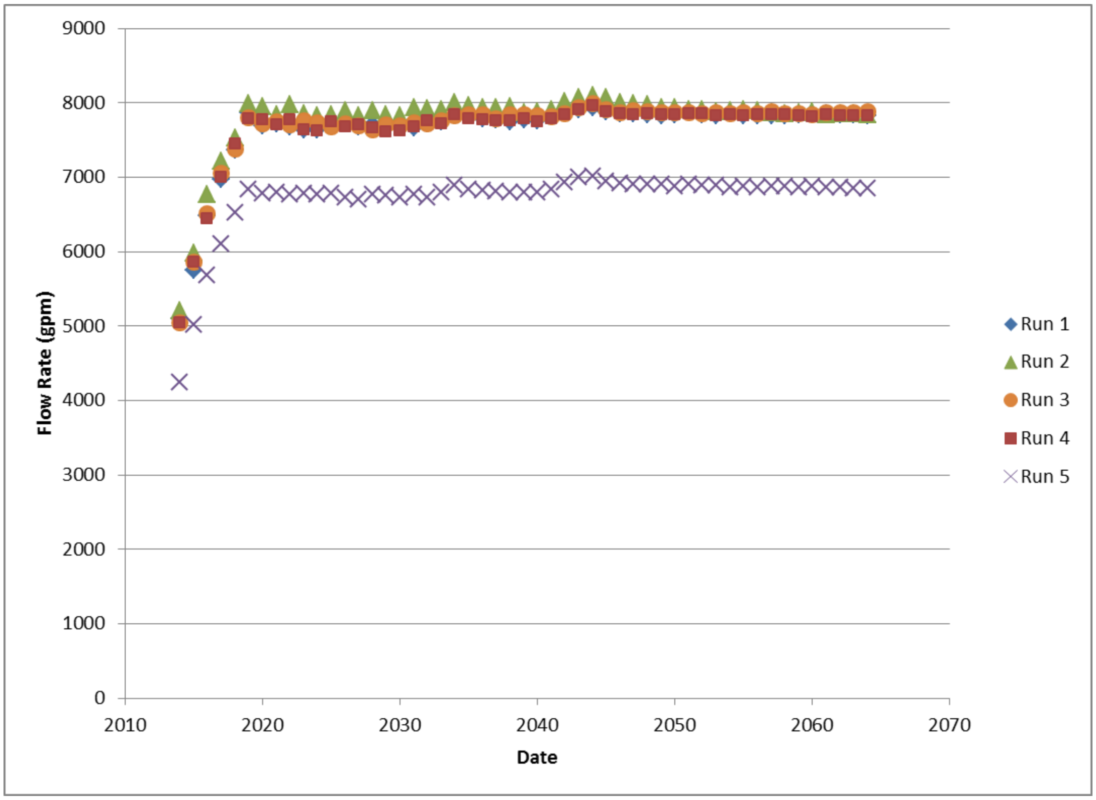

Figure 6. Predicted inflows to Luce pit through LOM.

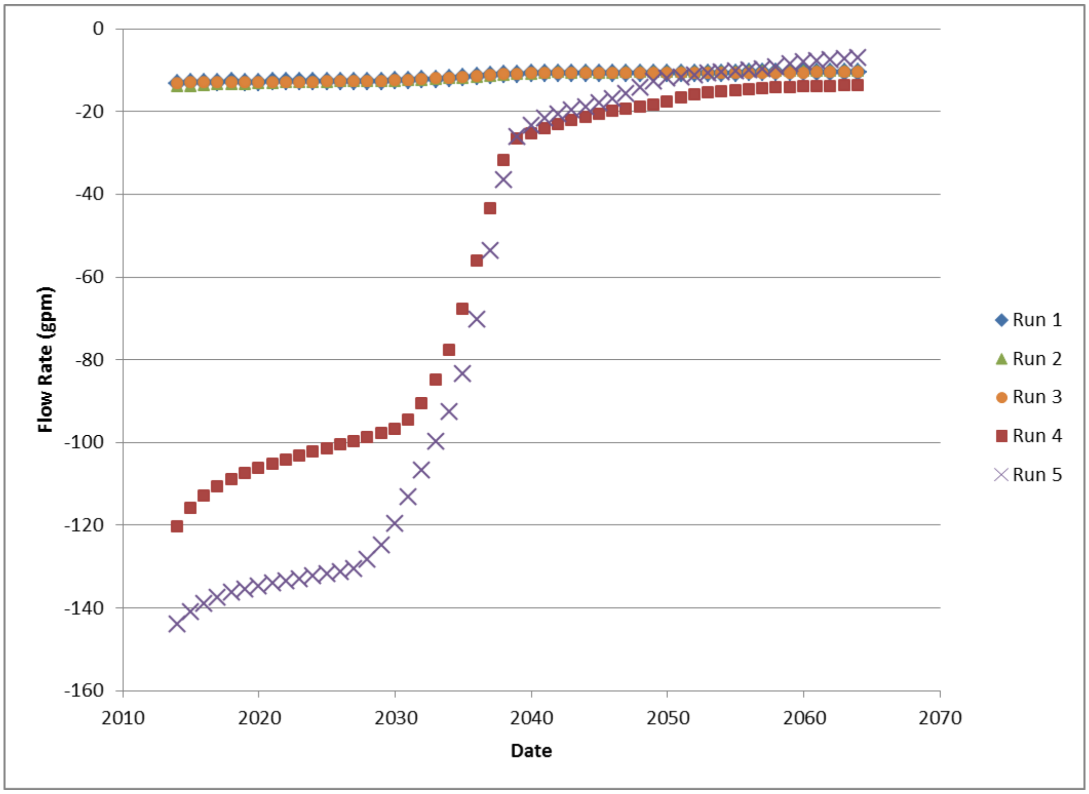

Figure 7. Predicted groundwater inflow to Dumbell Lake during Wabush 3 LOM (negative values represent groundwater flow into the lake).

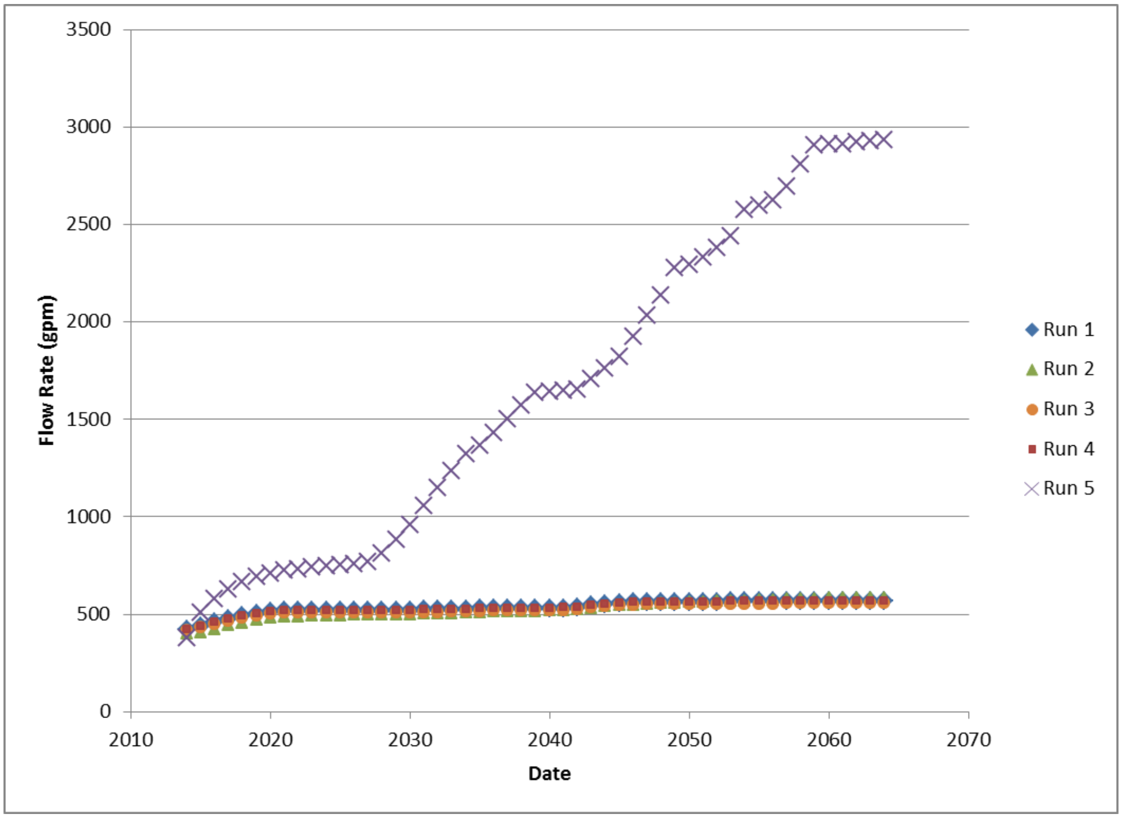

Figure 8. Predicted groundwater outflow from Leg Lake during Wabush 3 LOM.