TECHNICAL MEMORANDUM

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2019 UPDATED PREDICTIONS OF GROUNDWATER INFLOW TO TIRIGANIAQ UNDERGROUND MINE

1.0 INTRODUCTION

The following technical memorandum describes the updated hydrogeological modelling undertaken in 2019 for the Tiriganiaq Underground Mine. The main objective of this work was to calibrate an existing groundwater model to observed groundwater inflow and measured hydraulic heads in piezometers and then to provide updated predictions of groundwater flow to the underground over the life of mine (LOM).

2.0 BACKGROUND AND HISTORICAL HYDROGEOLOGICAL PREDICTIONS

The updated predictions of groundwater inflow to Tiriganiaq underground presented in this memo utilize a previously developed numerical model for Tiriganiaq Underground. This model was originally built using FEFLOW software in support of the FEIS (AEM 2014) and has subsequently underground revision over time as new information is collected. Groundwater inflows predicted to the underground using the FEIS Model and mine plan are summarized in Table 1. These inflows consider the presence of three regional faults (the Lower Fault Zone, Pike Fault and North Fault).

Table 1: Base Case Predicted Groundwater Inflow to Tiriganiaq Underground - FEIS Modelling, FEIS Mine Plan

Mine Year	Average Flow (m^3/day)
Years -2 to 1	420
Years 2 to 4	540
Years 5 to 12	640

In 2016 the numerical and conceptual model for Tiriganiaq was updated following an extensive field campaign by Agnico Eagle Mines Limited (Agnico Eagle) in 2015 to fill in data gaps. This field campaign was conducted utilizing two independent technical advisors, Dr. Shaun Frape and Dr. Walter A. Illman (both of the University of Waterloo), to provide advice and comments throughout the development of the field work plan. Documentation of the field program and results of updated modelling that incorporated this test data is presented in two Golder reports (Golder 2016a; 2016b).

The conceptual model developed for the 2016 Model assumed the following structures were present:

- Lower Fault Zone, North Fault and Pyke Fault
- RM-175
- Northwest Faults

The model also assessed the potential influence of two additional structures (Wesmeg and ENE faults) through sensitivity analysis. At the time of the 2016 Model update, mining was predominantly within permafrost and observations of groundwater inflow associated with potential structures could not be assessed. Predicted groundwater inflows to the underground based on the 2016 Model and mine plan (V5) are presented on Table 2. The V5 mine plan tracks the updates to the mine plan by Agnico Eagle as the development is built and changes are made to the sequencing of mining in consideration of progress to date (for example priority of stope development).

Table 2: Base Case Predicted Groundwater Inflows - 2016 Model, V5 Mine Plan

Mine Year	Period	Predicted Inflow (Base Case) (m^3/day)
-4	2016 Q2	70
-4	2016 Q3	80
-4	2016 Q4	120
-3	2017 Q1/2	180
-3	2017 Q3/4	230
-2	2018	300
-1	2019	280
1	2020	300
2	2021	340
3	2022	340
4-5	2023-2024	420
6-7	2025-2026	380
8-9	2027-2028	390
10-11	2029-2030	380
12-13	2031-2032	360

In 2018, an environmental and socio-economic assessment was completed for the discharge of treated groundwater effluent from the underground mine of the Tiriganiaq deposit into the marine environment near Rankin Inlet, in fulfillment of the Nunavut Impact Review Board (NIRB) Final Environmental Impact Assessment (FEIS) Addendum Guidelines (NIRB 2018). As a requirement of the NIRB Project Certificate No.006, Agnico Eagle had to provide a saline water management plan to address the potential for higher-than-predicted volumes of saline water inflows into the underground mine. Therefore, the Groundwater Management Plan (Agnico Eagle 2018) was updated using the 2016 groundwater inflows presented in Table 2 (Base Case) and was submitted under the 2018 FEIS Addendum for the “Saline Effluent Discharge to Marine Environment” project. This Project was approved in January 2019.

Since the completion of the above predictions and as the underground has been developed below the permafrost, Golder and Agnico Eagle have periodically reviewed the location of groundwater inflows and observed that potentially not all of the faults assumed in the 2016 Conceptual Model are contributing to observed flow underground, and that instead other faults, such as the ENE structures and splays associated with the Lower Fault may be contributing to groundwater inflow.

3.0 REVIEW OF WATER INTERSECTIONS AND ASSESSMENT OF POTENTIAL ZONES OF ENHANCED PERMEABILITY

As the underground is developed, grouting is being used to mitigate the groundwater inflow to the underground development. During mining, significant water intersections are noted in the rock face or drilled boreholes and estimated flow rates are recorded. Following water intersection, grouting typically occurs quickly to minimize the management of saline groundwater and observed inflows are likely biased high; left un-grouted, intersected flows would be expected to diminish as storage in the rock is depleted.

In early 2019, water intersections were reviewed in collaboration with Agnico Eagle to identify structures in their geologic model which could be of hydrogeological significance. The quality of this data improves with time as more of the mine intersects unfrozen bedrock. Review of these intersections has indicated high initial inflows (greater than 100 l/min) in the area of the ENE Fault, Lower Fault and Lower Fault Splay, with few high inflow intersections observed along the Wesmeg and Northwest Faults. The data review indicate that inflows may also be associated with the Upper Oxide and Iron Formation; however, on the scale of the current numerical model this would not be differentiated from the Lower Fault and Lower Fault Splay (essentially the Upper Oxide and Iron Formation are part of the area interpreted to be associated with the structures).

In consultation with Agnico Eagle, the conceptual structure model for the hydrogeological model was therefore modified to include the following structures:

- Lower Fault, Pyke Fault and North Fault
- REM175, which had an observed inflow along the exploration ramp in the 2016 study
- ENE Fault and Lower Fault Splay

Hydraulic properties of the ENE Fault and Lower Fault Splay were assumed to be 1×10^{-7} m/s, which was the maximum value from the pumping test. Initial properties of the other structures and hydrostratigraphic units were left unchanged from the 2016 Model for the start of model calibration. A summary of hydrostratigraphic units in the model, and their initial properties prior to model calibration are summarized on Table 3.

Table 3: Summary of Hydrostratigraphic Units and Initial (Pre-calibration) Hydraulic Properties

Unit	Depth Interval (m)	Hydraulic Conductivity (m/s)[a]	Specific Storage (1/m)[b]	Effective Porosity (-)[c]
Shallow Rock	0 to 60	3×10^{-7}	1×10^{-6}	0.001
	60 to 120	3×10^{-8}	1×10^{-6}	0.001
Hanging Wall Unit[d]	120 to 1500	3×10^{-9}	1×10^{-6}	0.001
Foot Wall Unit[d]	120 to 1500	3×10^{-10}	1×10^{-7}	0.001
Lower Fault Zone	60 to 1000	1×10^{-7}	1×10^{-7}	0.001
Lower Fault Splay	60 to 1000	1×10^{-7}	1×10^{-7}	0.001
RM-175	60 to 1000	5×10^{-8}	1×10^{-7}	0.001
ENE fault[e]	60 to 1000	1×10^{-7}	1×10^{-7}	0.001
North Fault	60 to 1000	1×10^{-7}	1×10^{-7}	0.001
Pyke Fault	60 to 1000	5×10^{-7}	1×10^{-7}	0.001

a) Estimated from in situ testing (FEIS and 2015 Underground Program) and experience from other similar sites.
b) Estimated from in situ testing (2015 Underground Program) and experience from other similar sites.
c) Guimerà J, Carrera J. 2000. A comparison of hydraulic and transport parameters measured in low permeability fractured media. J Contam Hydrol 41 (2000): 261-281.
d) Hydraulic conductivity within the unfrozen permafrost zone (0 ˚C to -3.4 ˚C) is assumed to be lower than in the deeper unfrozen rock. Linearly decreasing hydraulic conductivity with temperature is assumed within this zone with a full order of magnitude decrease assumed at the top of the basal cryopeg, and hydraulic conductivity equivalent to unfrozen rock at the bottom of the basal cryopeg.
e) ENE faults and Lower Fault Spaly assume to similar to maximum pumping test hydraulic conductivity.

4.0 CALIBRATION APPROACH

The updated groundwater inflow assessment for the Tiriganiaq Underground mine was based on the numerical hydrogeological model developed for Version 5 (V5) of the Mine Plan (Golder 2016a; Golder 2016b). To support this model update, the following revisions were made to the 2016 model:

- The model boundary conditions were modified to reflect available as-built development stages provided by Agnico Eagle, including Q4 2015, Q2 2016, May 2017, November 2018 and January 2019.
- The incorporated structures were adjusted to reflect structures interpreted to be potentially enhanced permeability zones (see Section 3)
- A 10-metre grout zone was assumed in the as-built underground present in unfrozen bedrock to reflect the grouting campaign undertaken. The effective hydraulic conductivity of the grout curtain was evaluated as part of model calibration, but a reasonable reduction in hydraulic conductivity of up to 1 x 10^{-8} to 5 x 10^{-8} m/s was assumed.

Following the above modifications, the model was calibrated to observed groundwater inflow to the underground and to the hydraulic head responses observed over time in 3 vibrating wire piezometer ports. Underground estimates of inflow available to support calibration when the work was undertaken in early 2019 are summarized in Table 4. The values presented for Q4 2015 and January 2017 are snapshots from seepage surveys and represent estimates from when the mine was still predominantly within the partially unfrozen portion of the permafrost (cryopeg).

Table 4: Observed Groundwater Inflow

Month and Year	Estimate Flow (m^3/day)
Q4 2015	15
January 2017	35
October 2018	155
November 2018	175
December 2018	200
January 2019	195

During calibration, the model was run repeatedly in transient mode and the model parameters iteratively adjusted until a reasonable agreement between predicted and observed hydraulic heads and underground inflow rates were obtained. During the transient simulation, the underground was instantaneously adjusted according to the five as-built mine plans provided by Agnico Eagle. Because it is not practical to simulate the gradual progression of the underground mining, this can result in large jumps in the predicted heads as opposed to the observed slow decline in hydraulic head. Key to the calibration process, therefore, is a comparison of the magnitude of the long- term response between measured and predicted hydraulic heads.

5.0 CALIBRATION RESULTS

Hydraulic parameters were adjusted from the initial values presented on Table 3 to achieve a suitable match between predicted and observed hydraulic heads and underground inflows. A summary of the final parameters assigned to the model at the end of calibration are included in Table 5. Values in Table 5 that are underlined and italicized were modified as part of the calibration process.

Table 5: Summary of Hydrostratigraphic Units and Final (Post-calibration) Hydraulic Properties

Unit	Depth Interval (m)	Hydraulic Conductivity (m/s)[a]	Specific Storage (1/m)[b]	Effective Porosity (-)[c]
Shallow Rock	0 to 60	3×10^{-7}	1×10^{-6}	0.001
	60 to 120	3×10^{-8}	1×10^{-6}	0.001
Hanging Wall Unit[d]	120 to 1500	3×10^{-9}	<u>*2×10^{-6}*</u>	0.001
Foot Wall Unit[d]	120 to 1500	3×10^{-10}	<u>*2×10^{-7}*</u>	0.001
Lower Fault Zone	60 to 1000	1×10^{-7}	1×10^{-7}	0.001

Unit	Depth Interval (m)	Hydraulic Conductivity (m/s)[(a)]	Specific Storage (1/m)[(b)]	Effective Porosity (-)[(c)]
Lower Fault Splay	60 to 1000	*2×10^{-7}*	*2×10^{-7}*	0.001
RM-175	60 to 1000	5×10^{-8}	*2×10^{-7}*	0.001
ENE fault	60 to 1000	1×10^{-7}	*2×10^{-7}*	0.001
North Fault	60 to 1000	1×10^{-7}	1×10^{-7}	0.001
Pyke Fault	60 to 1000	5×10^{-7}	1×10^{-7}	0.001

In general, the following changes were made to improve the match to mine inflow and hydraulic heads:

- The hydraulic conductivity of the ENE fault was increased from 5×10^{-8} m/s to 1×10^{-7} m/s
- The hydraulic conductivity of the Lower Fault splay was increased from 1×10^{-7} m/s to 2×10^{-7} m/s
- The specific storage of the hanging wall was increased from 1×10^{-6} to 2×10^{-6} and the specific storage of the foot wall was increased from 1×10^{-7} to 2×10^{-7}
- The specific storage of the RM-175 fault, ENE fault and Lower Fault splay was increased from 1×10^{-7} to 2×10^{-7}

Table 6 presents a summary of measured versus predicted groundwater flow to the underground at the end of calibration. Measured flows are within 35 m^3/day and there is a general small tendency to overpredict groundwater inflows which is conservative for the prediction of future groundwater inflows to the underground. For evaluation of the relative effects of grouting on groundwater inflow to date, a simulation was completed where the development was advanced between November 2018 and January 2019 and was assumed to have been un-grouted. In this simulation the predicted inflow increased by about 70% from 230 m^3/day to 410 m^3/day, indicating that inflows are being significantly reduced by grouting efforts.

Table 6: Measured versus Predicted Groundwater Inflow to Tiriganiaq Underground

Simulated Stage of As-Built Mine Plan	Closest Measured Inflow to Simulated As-Built Mine Stage (m^3/day)	Predicted Ground Inflow (m^3/day)
Q4 2015 As-Built	15	15
May 2017 As-Built	35	65
Nov 2018 As-Built	175	160
January 2019 As-Built	195	230

Figure 1 and Figure 2 presents hydraulic head response in the piezometer located in the footwall (PZ-ES225-02_VW2) and the two piezometers ports located in the hanging wall (PZ-ML17-350-161_VW1 and PZ-ML17-350-161_VW2). Overall, a reasonable match was obtained between measured and predicted heads in the footwall; however, heads are underestimated in the hanging wall. The underestimation of hydraulic heads in the hanging wall may indicate variability in the hanging wall properties. Agnico Eagle observations underground are that the hydraulic conductivity in the eastern portion of the hanging wall may be lower than that observed further to the west; in the model, a uniform hydraulic conductivity is assigned to the hanging wall. Further calibration at this stage is not considered warranted and the uncertainty in groundwater inflows as a result of the uncertainty in the bedrock properties will be assessed as part of model sensitivity analysis. Further data collection (piezometer installations and hydraulic conductivity testing) is planned for 2020 to reduce the uncertainty in predicted inflows.

6.0 PREDICTED GROUNDWATER INFLOW

6.1 Base Case Estimates

The calibrated model was used to predict groundwater inflows to the proposed Tiriganiaq Underground Mine over the LOM (herein referred to as Base Case estimates). Although grouting is currently being conducted as a mitigation measure to reduce groundwater inflows to the underground development, the influence of grouting is presently not included in the model predictions. As such, predictions presented in the model represent unmitigated estimates of groundwater inflow to the underground development.

Unmitigated groundwater inflows to the underground were predicted to range from an average flow of 380 m^3/day to a high of 580 m^3/day in 2025 and then down to 450 m^3/day at the end of LOM (Table 7). The decrease in inflow as mining progresses is due to effects of changing rock storage. The mine is planned to reach its ultimate depth midway through the mine life, and the impacts of storage will decrease as mining progresses past this point.

The predicted groundwater inflow rates from this analysis are similar to the groundwater inflow predictions in the FEIS, which ranged from 420 m^3/day to 640 m^3/day and somewhat higher than values predicted using the 2016 model (280 to 420 m^3/day) (Table 7).

6.2 Sensitivity Analysis

Parameter sensitivity analysis is a procedure for quantifying the response of model output to an incremental change in model inputs which allows assessment of model uncertainty. Parameter sensitivity analysis generally consists of multiple model simulations with each simulation conducted by varying one input variable, over its potential range in values, at a time within the calibrated model.

In consideration of observations made during the calibration process and historical modelling for the Tiriganiaq underground, the following sensitivity scenarios were evaluated:

- Inclusion of Open Talik Below Lakes B5 and A8. Thermal analysis completed as part of the FEIS for these two lakes were less certain with regards to open talik and therefore the influence of a potential open talik is evaluated as part of sensitivity analysis.
- The hydraulic conductivity of the Lower Fault Splay was assumed to be up to a factor of three higher than in the calibrated model
- The hydraulic conductivity of the Lower Fault Splay and ENE structure were assumed to up to a factor of three higher than in the calibrated model.
- The hydraulic conductivity of the hanging wall and footwall (bulk bedrock) was assumed to be a factor of three higher than in the calibrated model.

Table 7: Sensitivity Analysis Results

Mine Year	Year		Predicted Groundwater Inflow (m3/day)												
			FEIS Model (2014)			2016 Model					2019 Model				
			Base Case	Lower Fault K Decreased to Match Surrounding Bedrock [(1)]	Lower Fault K Increased by Factor of ten	Base Case	Inclusion of Wesmeg EW and ENE Faults	Inclusion of Open Taliks below Lakes B5 and A8	K of Lower Fault Factor of 3 Lower	K of Lower Fault Factor of 3 Higher	Base Case	Inclusion of Open Talik below Lakes B5 and A8	K of Lower Fault Splay Factor of 3 Higher	K of ENE and Lower Fault Splay Factor of 3 Higher	K of Bulk Bedrock Factor of 3 Higher
		Q2				70	70	70	60	90					
-4	2016	Q3				80	80	80	60	120					
		Q4		-		120	130	120	110	170			-		
-3	2017	Q1/2				180	190	180	150	260					
		Q3/4				230	260	230	180	340					
-2	2018	-				300	350	310	280	390					
		Q1									380	380	620	670	510
-1	2019	Q2				280	330	290	250	360	400	400	630	700	540
		Q3									430	430	670	740	600
		Q4	420	360	750						420	420	650	710	590
		Q1									410	410	630	680	590
1	2020	Q2				300	350	310	270	390	410	410	620	670	590
		Q3									420	420	640	690	610
		Q4									420	430	650	700	630
		Q1									420	430	640	680	630
2	2021	Q2				340	410	350	300	440	430	440	640	680	650
		Q3									440	450	640	690	680
		Q4	540	460	970						460	470	650	700	700
3	2022	Q1&2				340	410	360	300	450	480	500	680	720	750
		Q3&4									510	540	700	750	810
4	2023	-				420	510	460	360	550	530	570	720	760	840
5	2024	-									540	580	750	780	850
6	2025	-				380	480	440	330	500	580	620	770	810	930
7	2026	-									570	620	750	790	950
8	2027	-	640	580	970	390	480	570	340	510	530	590	700	730	900
9	2028	-									510	570	670	700	870
10	2029	-				380	460	570	330	490	490	550	650	680	860
11	2030	-									480	540	630	660	840
12	2031	-				360	450	560	320	470	470	530	610	640	830
13	2032	-		-							460	530	600	630	820
14	2033	-						-			450	520	590	620	810

Note
K = Hydraulic Conductivity
[1] Lower Fault K decreased from 1 x 10-7 m/s to 3 x 10-9 m/s to match surrounding bedrock.

Results of the sensitivity analysis for the 2019 Model are summarized on Table 7, along with results of the sensitivity analysis completed for the 2016 and FEIS Models. The 2019 sensitivity analysis indicates inclusion of the open talik below Lakes B5 and A8 resulted in predicted inflows being approximately 0% to 16 % higher than the base case predictions depending on the simulated time period. This influence is less than the influence of the hydraulic conductivity of the structures and the bulk bedrock. Predicted inflows over the LOM were predicted to be up to 950 m^3/day, which correspond to Year 2026 in the sensitivity simulation for the bulk bedrock hydraulic conductivity. This upper bound estimate of inflow (950 m^3/day) is similar to the upper bound estimate from the FEIS (970 m^3/day) and higher than the scenarios considered in 2016.

The scenarios selected for 2019 considers the knowledge of the groundwater flow system at the time of the 2019 modelling, and the results of past sensitivity analyses, as documented in Table 7. Relative to past analysis, a broader range of sensitivity scenarios was considered (for example, increasing the bulk bedrock by a factor of three was not considered in the 2016 and FEIS). Overall, supplemental hydraulic testing and monitoring during mining have reduced the uncertainty and smaller ranges of uncertainty (three times versus ten times changes) are now considered appropriate in the considered scenarios. Application of a factor of ten change in bedrock hydraulic conductivity, for example, would result in an unrealistically high predicted inflow to the underground under current conditions relative to what is being observed underground.

7.0 SUMMARY

Considering the current mine plan (Version 9) and the results of model calibration, groundwater inflow to the underground in absence of further grouting is forecast to vary from an average of 380 m^3/day to a high of 580 m^3/day in 2025 and then down to 450 m^3/day at the end of LOM (base case estimates). The decrease in inflow as mining progresses is due to effects of changing rock storage. The mine is planned to reach its ultimate depth midway through the mine life, and the impacts of storage will decrease as mining progresses past this point.

Predicted inflows are sensitive to the hydraulic properties of the structures and bulk bedrock. For the simulated range of hydraulic conductivity used in the sensitivity analyses, inflow was predicted to be up to 950 m^3/day. This estimate is considered a reasonable upper bound estimate of groundwater inflows based on the understanding of the Site at this stage.

8.0 CLOSURE

We trust the above meets your needs, please contact the undersigned for any questions or concerns.

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https://golderassociates.sharepoint.com/sites/1897983/proposal project management/08_technical memo/rev0/1897983-001-rpt-tiriganiaq-2019modelupdate_rev0_april2020.docx

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Signature Nathan
Date 13 OCT 2020
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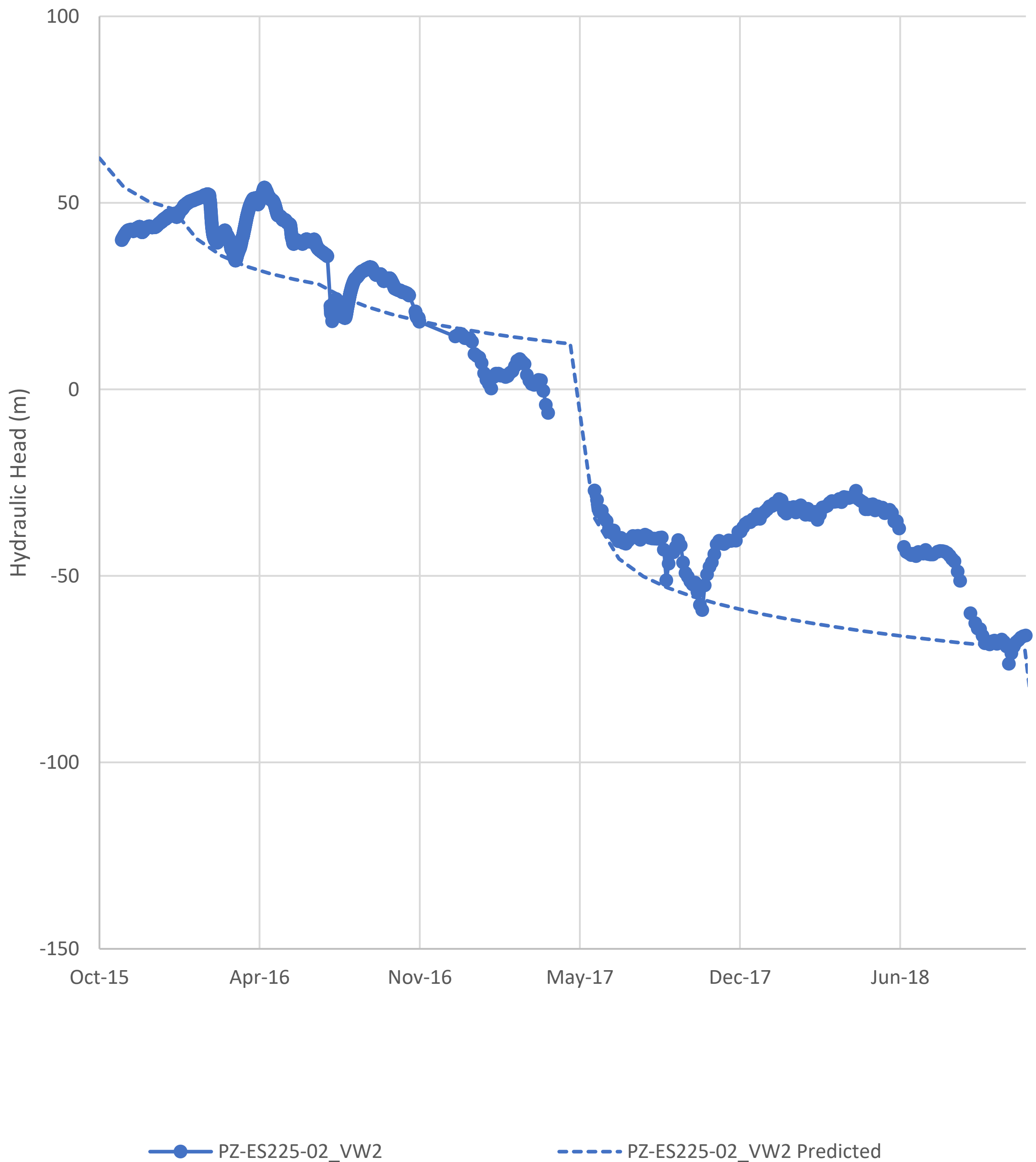
Hydrogeologic/hydrologic investigations and groundwater modelling are dynamic and inexact sciences. They are dynamic in the sense that the state of any hydrological system is changing with time, and in the sense that the science is continually developing new techniques to evaluate these systems. They are inexact in the sense that groundwater systems are complicated beyond human capability to evaluate them comprehensively in detail, and we invariably do not have sufficient data to do so. A groundwater model uses the laws of science and mathematics to draw together the available data into a mathematical or computer-based representation of the essential features of an existing hydrogeologic system. While the model itself obviously lacks the detailed reality of the existing hydrogeologic system, the behaviour of a valid groundwater model reasonably approximates that of the real system. The validity and accuracy of the model depends on the amount of data available relative to the degree of complexity of the geologic formations, the site geochemistry, the fate and transport of the dissolved compounds, and on the quality and degree of accuracy of the data entered. Therefore, every groundwater model is a simplification of a reality and the models described herein are not an exception.

The professional groundwater modelling services performed as described in this document were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practising under similar conditions, subject to the quantity and quality of available data, the time limits and financial and physical constraints applicable to the services. Unless otherwise specified, the results of previous or simultaneous work provided by sources other than Golder and quoted and/or used herein are considered as having been obtained according to recognised and accepted professional rules and practices, and therefore deemed valid. This model provides a predictive scientific tool to evaluate the impacts on a real groundwater system of specified hydrological stresses and/or to compare various scenarios in a decision-making process. However and despite the professional care taken during the construction of the model and in conducting the simulations, its accuracy is bound to the normal uncertainty associated to groundwater modelling and no warranty, expressed or implied, is made.



CLIENT
AGNICO EAGLE MINES LIMITED

PROJECT
TIRIGANIAQ GROUNDWATER MODELLING UPDATE
MELIADINE PROJECT

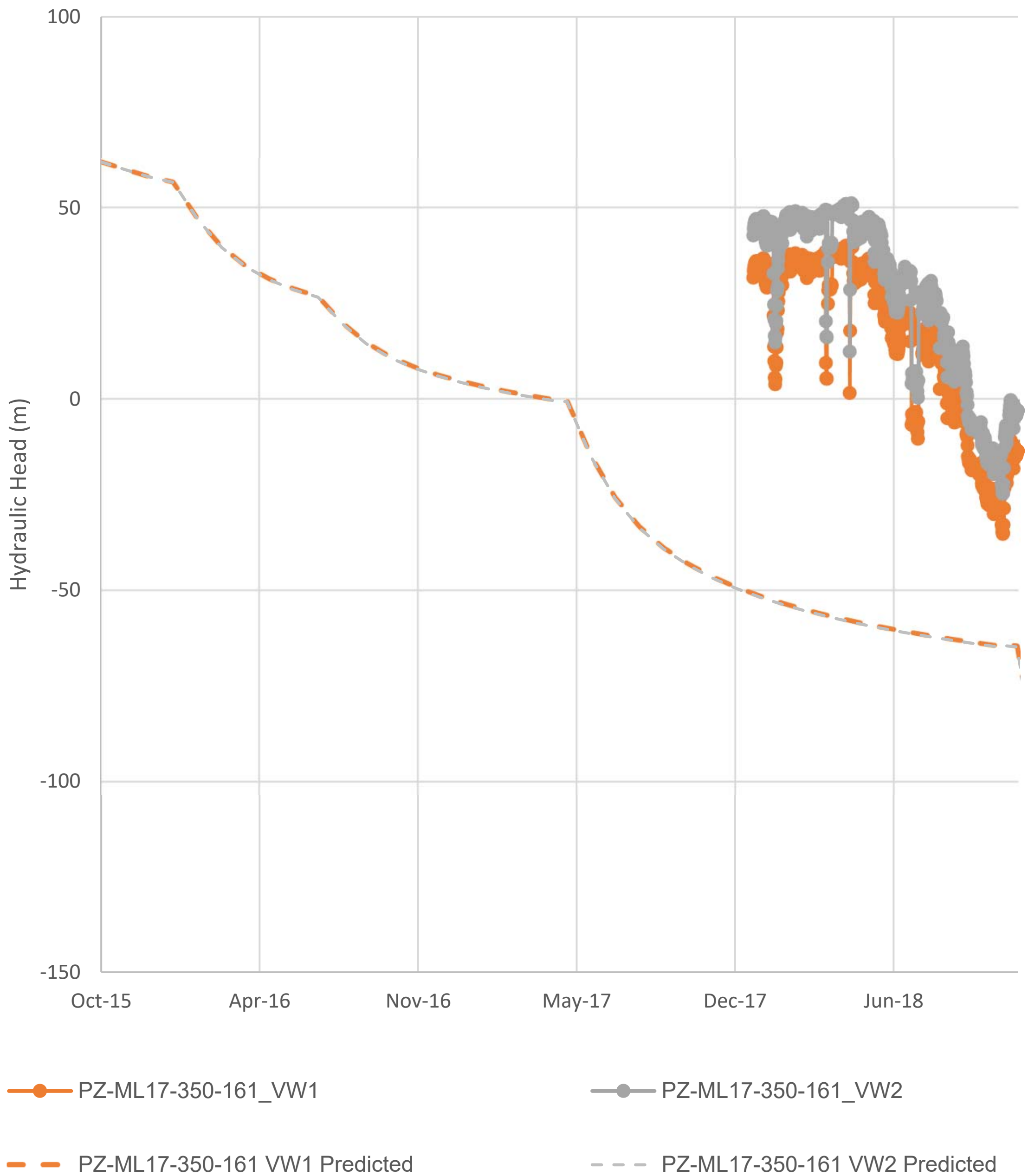
CONSULTANT

GOLDER

YYYY-MM-DD	2020-0224
PREPARED	JL
DESIGN	JL
REVIEW	DC
APPROVED	JL

TITLE
MEASURED VERSUS PREDICTED HYDRAULIC HEAD IN THE FOOTWALL – PZ-ES225-02

PROJECT No.	Rev.	FIGURE
18108905	**A**	**1**



CLIENT AGNICO EAGLE MINES LIMITED			PROJECT TIRIGANIAQ GROUNDWATER MODELLING UPDATE MELIADINE PROJECT
CONSULTANT	YYYY-MM-DD	2020-0224	TITLE **MEASURED VERSUS PREDICTED HYDRAULIC HEAD IN THE HANGING WALL – PZ-ML17-350-161 VW1 AND VW2**
GOLDER	PREPARED	JL	
	DESIGN	JL	
	REVIEW	DC	PROJECT No. **18108905** Rev. **A** FIGURE **2**
	APPROVED	JL	