Flambeau Mining Company
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801-204-2526

November 13, 2018

Mr. Dave Siebert
Bureau Director
Wisconsin Department of Natural Resources
101 S. Webster Street – GEF2
P.O. Box 7921
Madison, WI 53707-7921

Dear Mr. Siebert:

RE: Reclaimed Flambeau Mine Request to Modify the *Updated Monitoring Plan*

Introduction

Since site closure in October 1998, long term monitoring and reporting at the Reclaimed Flambeau Mine (Flambeau) has been ongoing in accordance with the *Mine Permit* (IH-89-14) and the *Updated Monitoring Plan* (FVD, 1991). Both documents include monitoring requirements for a variety of environmental aspects at Flambeau. Evaluations of the monitoring program have been completed, and there are recommended changes to the requirements. The attached memoranda (memo) present recommendations to modify the following elements of the *Updated Monitoring Plan*:

1. Reduction in groundwater monitoring frequency and parameters for wells located within the backfilled pit.
2. Reduction in groundwater monitoring frequency and parameters for intervention boundary wells and other wells outside the backfilled pit.
3. Elimination of future aerial color infrared vegetation photography.
4. Elimination of wetland staff gauge monitoring at WT-5.
5. Elimination of subsidence monitoring at year 40.
6. Simplification of the Annual Report.

Supporting evaluations and recommendations are presented in three attached memos:

Attachment 1: Flambeau Mine Groundwater Monitoring Reduction Evaluation – In Pit Wells

Attachment 2: Flambeau Mine Groundwater Monitoring Reduction Evaluation – Intervention Boundary and Other Wells used for Groundwater Elevation Monitoring

Attachment 3: Reclaimed Flambeau Mine Infrared Vegetation Photography, Subsidence, Wetland Evaluation Reduction, and Annual Reporting Requirements

Attachment 4: Redlined *Updated Monitoring Plan*

The following sections briefly summarize the recommendations made in these three memos regarding changes to long term monitoring. A redlined version of the *Updated Monitoring Plan* is provided in Attachment 4 to document the changes. A new Updated Monitoring Plan and an updated site *Quality Assurance Project Plan* will be provided to the Department upon approval of the monitoring changes.

Evaluations Completed

Three memos, provided as Attachments 1, 2, and 3, summarize the data evaluations performed to support this request to modify the long term monitoring and reporting at Flambeau. The attached memos also summarize the current data collection programs and data previously collected and analyzed.

Attachment 1: Flambeau Mine Groundwater Monitoring Reduction Evaluation – In Pit Wells

- Evaluates data from the in-pit wells to substantiate that conditions have been met to justify a reduction in groundwater monitoring parameters and frequency in the in-pit wells. This analysis includes an evaluation of current conditions in the backfilled pit and potential impacts to the Flambeau River as part of the justification for a reduction in monitoring.

Attachment 2: Flambeau Mine Groundwater Monitoring Reduction Evaluation – Intervention Boundary and Other Wells used for Groundwater Elevation Monitoring

- Evaluates data from the intervention boundary wells and other wells used for groundwater elevation monitoring to substantiate that conditions justify a reduction in groundwater monitoring parameters and frequency in these wells.

Attachment 3: Reclaimed Flambeau Mine Infrared Vegetation Photography, Subsidence, Wetland Evaluation Reduction, and Annual Reporting Requirements

- Evaluates data collected for aerial color infrared vegetation photography, wetland staff gauge monitoring, and subsidence monitoring to substantiate that conditions justify cessation of these monitoring programs.

- Discusses the format of the Annual Report and recommends updates to better suit the current state of the project.

Conclusions

Long term environmental monitoring that has been completed has led to a greater understanding of post-mining environmental conditions at Flambeau. While some aspects of long term monitoring, as laid out in the *Updated Monitoring Plan,* are still appropriate, other aspects could be curtailed while still being protective of the environment. The recommendations made in the attached memos eliminate redundant monitoring efforts where the conditions are well established and stable.

References

Foth Infrastructure & Environment, LLC, 2016. *Quality Assurance Project Plan* for Long-Term Care Monitoring for the Reclaimed Flambeau Mine. October 2016.

Foth & Van Dyke and Associates, Inc., 1991. *Updated Monitoring Plan*. July 1991.

IH-89-14. Decision Findings of Fact Conclusions of Law and Permits; Findings of Fact, Conclusions of Law and Mine Permit, Docket No. IH-89-14, Pages 76-124. January 14, 1991.

If you have any questions, please contact me at (801) 204-2526 or Sharon Kozicki, of Foth Infrastructure & Environment, LLC, at (920) 496-6737.

Sincerely,

Dave Cline
President – Flambeau Mining Company

enclosures
cc: Hank Handzel, DeWitt Ross & Stevens
Timm Speerschneider, DeWitt Ross & Stevens
Leland Roberts, Rio Tinto
Steve Donohue, P.H., Foth Infrastructure & Environment, LLC
Sharon Kozicki, P.G., P.M.P., Foth Infrastructure & Environment, LLC
Zoe McManama - WDNR

Attachment 1

Flambeau Mine Groundwater Monitoring Reduction Evaluation – In Pit Wells

Technical Memorandum

Green Bay Location

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November 9, 2018

TO: Dave Cline, Flambeau Mining Company
Leland Roberts, Rio Tinto

CC: File: 17F777-5000

FR: Allison Haus, Ph.D., Foth Infrastructure & Environment, LLC
Sharon Kozicki, P.G., P.M.P., Foth Infrastructure & Environment, LLC
Steve Donohue, P.H., Foth Infrastructure & Environment, LLC

RE: Flambeau Mine Groundwater Monitoring Reduction Evaluation – In-Pit Wells

1 Introduction

From 1994 through 1998, Flambeau Mining Company (Flambeau) mined an ore body adjacent to the Flambeau River using an open pit method. Upon cessation of mining, the site commenced reclamation, which included backfilling the pit and demolition of most of the site infrastructure.

Long term monitoring, maintenance, and reporting has been ongoing since 1999 in accordance with the *Mine Permit* (IH-89-14) and the *Updated Monitoring Plan* (FVD, 1991). Flambeau petitioned for a Certificate of Completion (COC) in January 2007. The COC signifies that the mine has fulfilled its duties under the reclamation plan. A public hearing was held, and a COC was received in August 2007 for the entire site except for a 32-acre parcel known as the Industrial Outlot.

Groundwater monitoring has continued in two in-pit well nests since they were installed upon completing backfill of the pit. The two well nests, MW-1013/A/B/C and MW-1014/A/B/C are shown on Figure 1. They were installed at approximately the same locations as two well nests present prior to mine excavation, MW-1013G/P and MW-1014G/P. Although reclamation has been achieved, quarterly monitoring (sampling and elevation readings) has continued in these two wells for 18 years. Results from monitoring activities are reported in the annual report for the facility, submitted in January following the reporting year.

2 Purpose

The purpose of this memorandum is to:

1. Describe the regulatory framework and criteria indicating that the groundwater within the pit has reached a stable condition with respect to both elevation and chemistry.

2. Provide a summary of historic trends and current status of the in-pit monitoring well data for elevation and for water chemistry.

3. Evaluate the historic trends and current status with respect to criteria indicating that stability has been reached at the in-pit wells.

4. Propose an approach of reduced monitoring that provides continued adequate confirmation of trends and stability with respect to both elevation and water chemistry at the in-pit monitoring wells.

3 Monitoring Reduction Regulatory Framework

The *Mine Permit,* and subsequent correspondence with the Department, define the conditions required prior to reducing groundwater monitoring at wells in the backfilled pit. Note that the *Mine Permit* was written prior to completion of the in-pit well nests, and the wells referenced in quoted text, MW-1013G, 1013P, 1014G and 1014P, were completed as MW-1013, MW-1013-A, MW-1013-B, MW-1013-C, MW-1014, MW-1014-A, MW-1014-B, and MW-1014-C.

The *Mine Permit*, Part 4(2) and Part 4(3) cite:

Part 4(2)
"Water quality monitoring of wells MW-1013G, 1013P, 1014G and 1014P shall be conducted on a quarterly frequency at all of the wells until at least 8 samples have been obtained from each well. At that time, a reduction in monitoring frequency may be requested by Flambeau and, provided that the monitoring results confirm the predictive modeling of water quality within the backfilled material and verify that no adverse impacts to water quality within the Flambeau River will occur, the Department may approve such request. The parameter list for the sampling round occurring in June of each year shall be expanded as specified in section 10.1.3.2 of the Mining Permit Application. The provisions of NR 140, Wis. Adm. Code, shall be used to determine statistically significant changes in the groundwater quality."

Part 4(3)
"Wells MW-1013G, 1013P, 1014G and 1014P shall be monitored for water level as part of the water level monitoring program described in Section 10.1.3.3 of the Mining Permit Application. The water level monitoring program shall continue on a quarterly frequency until the Department determines that the water levels have stabilized. Water levels shall be deemed as stable when no significant net annual changes occur in water levels over a two year period. An acceptable range of annual fluctuations in groundwater levels shall be based on a statistical analysis of observed pre-mining annual fluctuation ranges of those wells with a pre-mining monitoring record which are to be included in the long term monitoring program. To the extent technically feasible, the entire record of pre-mining water level measurements shall be considered when determining the

normal or acceptable annual fluctuation range. The average annual range will be based on the combined average of the annual fluctuation ranges of all the wells presently on site that are to be included in the long term monitoring program plus or minus one standard deviation. During the post reclamation period as the water table recovers, the net annual fluctuation should be relatively large, showing an upward movement of the water table. As stability is approached, this net upward fluctuation will be reduced through time, eventually falling back into the average annual range that exists today. When the average annual fluctuation falls within this range for two consecutive years, the water table will then be deemed to have stabilized."

The Department explained the above two conditions in a March 20, 2008 letter from Mr. Phil Fauble to Ms. Jana Murphy:

> "As to potential reductions in environmental monitoring frequency, we agree that Part 4(2) of the Mining Permit approval does allow FMC the option of petitioning the Department for a reduction in water quality monitoring frequency at the in-pit wells provided the monitoring results confirm the predictive water quality modeling and FMC can verify no adverse impacts to the water quality of the Flambeau River. However, we feel that any monitoring reduction request should also be tied to the monitoring requirements of Part 4(3) of the Mining Permit as well. In accordance with that condition, the water levels at the in-pit monitoring wells shall be monitored quarterly until FMC can demonstrate that the water levels within the pit have stabilized for at least two years. If the water levels stabilize at levels that cause adverse environmental impacts, the Department may require remedial measures.
>
> Therefore, it is our expectation that the Department will not consider reductions in monitoring frequency until FMC prepares a report demonstrating that the water levels in the pit have stabilized for at least a two-year period and that, at the stabilized level, the site is not and is not expected to cause in the future, an adverse environmental impact to the Flambeau River. The report should also compare the actual monitoring results with the expected results in the predictive modeling and explain any differences. Once the Department has evaluated the report, we may consider appropriate reductions in monitoring within the pit and would adjust the long-term care financial assurance accordingly."

Accordingly, the Department may reduce the monitoring requirements when water levels and concentrations have stabilized at levels that do not have an adverse impact on the Flambeau River. Additionally, the monitoring results should be evaluated in light of the predictive models.

To summarize, the conditions that must be met prior to reducing groundwater monitoring at the in-pit wells include:

1. Achieve water level stability for at least two years.

2. Demonstrate that water quality monitoring results confirm the predictive water quality modeling for pore water within the backfilled material.

3. Verify that there are no adverse impacts to Flambeau River water quality due to groundwater flowing from the backfilled pit.

4 Stable Water Levels

The first condition as listed in Section 3 is stabilization of the water level for at least two years. Evidence that the water table in the backfilled pit has stabilized includes 1) hydrographs of historical data and 2) evaluation of pre-mining versus post-mining fluctuation of groundwater table.

Groundwater elevations at the in pit wells, grouped by period, as well as hydrographs for all historical data, are illustrated in variation plots in Attachment 1, on Figures 1-1a through 1-1c. Post-mining data through June 2018 is subdivided into three groupings: 1997 Q4 through 2002 Q4 (immediate five years following mining); 2003 Q1 through 2016 Q3; and 2016 Q4 through 2018 Q3 (the most recent two years).

Groundwater elevations since 2016 have a smaller range of variation than that observed during the post-mining period prior to 2016. Groundwater elevations steadily increased from 1999 through 2002 at in-pit wells, and stabilized after 2003, as shown in hydrographs (Attachment 1, on Figures 1-2a through 1-2c). Higher groundwater elevations are noted during the latter part of 2010 and 2011. Elevations dropped in 2012 but rebounded again during 2014. A small increasing trend occurring through 2017 reversed with decreased levels observed through the third quarter of 2018.

Per Part 4(3) of the *Mine Permit*, stabilization of the water levels are to be assessed through an evaluation of the net annual changes over a two-year period. The following conditions should be met prior to a reduction in groundwater monitoring:

1. No significant net changes occur in the average annual water level fluctuation over a two-year period when compared to an acceptable annual fluctuation range; and

2. An acceptable annual fluctuation range is based on the combined average of the annual fluctuation ranges of all wells presently on-site included in the long term monitoring program, plus or minus one standard deviation.

Specifically, the average of the annual fluctuation ranges for the in-pit well set (i.e., the MW-1013 and MW-1014 wells nests) is compared for each year to the average of the annual fluctuation ranges observed in the pre-construction (January 1989 through April 1991) and pre-ore removal (July 1991 through January 1993) datasets for the on-site wells plus or minus one standard deviation. A summary of the calculated average annual groundwater fluctuations is provided in Table 1. The average annual fluctuation for the pre-construction and pre-ore removal on-site well dataset is 1.96 feet with a one-standard deviation range of 0.53 to 3.39 feet.

The in-pit well average annual fluctuations are also provided in Table 1 for each year since 2003. The most recent two years illustrate average annual fluctuations for the in-pit well set to be less than the upper standard deviation limit of 3.39 feet. In addition, the in-pit average annual fluctuations have been below the upper standard deviation limit for all but one year since 2003. Therefore, it has been demonstrated that the water table has stabilized.

Table 1

Average Annual Elevation Range Comparison to In-Pit Wells

Period	Count	Average (ft.)	St. Dev. (ft.)	Avg + St. Dev. (ft.)	Avg – St. Dev. (ft.)
All Long Term Monitoring Wells					
Jan. 1989 through Dec. 1992	78	1.96	1.43	3.39	0.53
In-Pit Monitoring Wells					
2003	8	1.15			
2004	8	1.38			
2005	8	0.95			
2006	8	1.00			
2007	8	1.10			
2008	8	1.71			
2009	8	1.32			
2010	8	2.24			
2011	8	1.63			
2012	8	1.14			
2013	8	1.64			
2014	8	3.60			
2015	8	1.50			
2016	8	1.16			
2017	8	1.89			
2018 (thru Q3)	8	1.13			

Prepared by: SGL
Checked by: ASH1

5 Water Quality

The second condition as listed in Section 3 is confirmation of the predictive water quality modeling for pore water within the backfilled material. Evidence of the stability of backfilled pit pore water chemistry has been observed at the eight in-pit wells that have been monitored since 1999: the MW-1013 nest (MW-1013, MW-1013A, MW-1013B, and MW-1013C) and the MW-1014 nest (MW-1014, MW-1014A, MW-1014B, and MW-1014C). The two well nests are shown in plan-view on Figure 1 and in a cross section of the backfilled pit on Figure 2. Type I backfill is waste rock that contained less than 1% sulfide, and Type II backfill is waste rock that contained greater than 1% sulfide. During backfilling, both waste rock types were amended with adequate limestone to neutralize any acidity derived from oxidation reactions.

The MW-1013 well nest is located within the former mine pit on the southwest side. The wells are screened as follows:

- MW-1013 samples shallow pore water in till;
- MW-1013A samples pore water in contact with limestone-amended Type I material; and
- MW-1013B and MW-1013C sample deeper zones in the limestone-amended Type II material.

The MW-1014 nest is within the former mine pit on the northeast side. The wells are screened as follows:

- MW-1014 is screened in shallow sandstone;
- MW-1014A samples pore water in contact with limestone-amended Type I material; and
- MW-1014B and MW-1014C sample deeper zones in the limestone-amended Type II material.

Pore water chemistry at each well has been evaluated with respect to alkalinity, arsenic, barium, cadmium, calcium, chloride, chromium, copper, hardness, iron, lead, magnesium, manganese, mercury, potassium, selenium, silver, sodium, sulfate, total dissolved solids and zinc, in addition to field measured pH, specific conductivity, temperature, and redox. Trend graphs have been presented for each monitoring year in corresponding Annual Reports. These Annual Reports are incorporated by reference. Chemistry trends have been stable for several years, as described in the statistical evaluations within each Annual Report.

5.1 Geochemical Modeling

Predictive modeling of pore water chemistry was performed in 1989 and in 1997. Both predictive models are described below to provide context for the conclusion that monitoring results confirm the predictive models through the data and geochemical mechanisms. The current geochemical conceptual site model is described below to 1) provide context for explanation of differences from observed and predicted pore water chemistry and 2) describe geochemical mechanisms that confirm prediction of stable water chemistry.

The conceptual model upon which both model versions are based is the same. Oxidation occurred during mine operations as sulfide-bearing waste rock was stockpiled at the surface. After mining was complete, the waste rock was mixed with limestone amendment and placed back into the pit. As the backfilled pit pore space re-saturated with water, exposure to oxygen was effectively limited and continued sulfide-oxidation reactions were arrested. The resaturation of the pit, or “first flush,” dissolved soluble salts on the surfaces of the weathered waste rock backfill, liberating sulfate, cationic metals, hydroxide, and other ions. Some of the dissolved sulfate then precipitated out with calcium ions sourced from limestone dissolution, forming the mineral gypsum. Some of the dissolved metals were removed through precipitation with the limestone-derived carbonate ions, i.e., iron-carbonate (siderite). Because ample limestone is available and oxygen ingress is very limited, there has been little to no input of oxidation products to the system over almost 20 years of saturation and the system is at a steady state. No additional oxidation product is anticipated in the future, meaning solute concentrations will continue to remain the same or slowly decrease due to continued dilution over the long term.

At some monitoring locations, concentrations of a few constituents are elevated relative to predicted equilibrium concentrations. Thermodynamics favors precipitation of these constituents into mineral phases, thereby limiting, or “capping” concentrations in solution. However, there can be a lag time for precipitation onset of potentially kinetically-inhibited minerals, the length of which is difficult to predict. Water chemistry trends suggest that rhodochrosite, a kinetically-inhibited manganese carbonate mineral, whose precipitation limits manganese concentrations, has begun to form in at least one well since 1999 (see MW-1014A, on Figure B-7b, of the Annual Report). The stable chemistry trends and results of geochemical modeling suggest that the system is currently at a steady-state with respect to many mineral phases.

5.1.1 1989 Geochemical Model

Table 2 compares 2018 in-pit pore water quality to 1989 predicted values. Samples that exceeded the 1989 prediction are highlighted in yellow.

Table 2

Comparison of Model Predictions to Measured Groundwater Quality in 2018

			Groundwater Samples from 6/20/18									*1989*	*1997*
	Parameter	**Units**	**MW-1005P**	**MW-1013**	**MW-1013A**	**MW-1013B**	**MW-1013C**	**MW-1014**	**MW-1014A**	**MW-1014B**	**MW-1014C**	***Prediction***	***Prediction*** [1]
1	Ca	mg/L	54.3	150	115	572	530	81.9	330	512	155		455
2	Mg	mg/L	21.9	48.3	39.8	136	125	26.5	113	109	35.5		
3	Na	mg/L	9.09	12.8	30.6	23.8	25.9	18.5	40	18.2	9.98		
4	K	mg/L	8.63	2.57	7.04	5.04	21.2	3.3	9.45	14.4	4.36		
5	Alkalinity	mg/L	245	563	340	589	516	170	483	517	272		
6	Sulfate	mg/L	< 1.0	16.6	0.149	1730	1880	134	925	1490	252	1100	1043
7	Cl	mg/L	6.5	8.8	7.5	39.3	50.4	52	12.8	46.9	50.6		
8	pH	SU	7.1	6.18	6.56	6.02	6.14	5.85	6.4	6.1	6.03	neutral	6.6
9	pe	V	22.1000	56.7000	103.5000	118.7000	100.3000	157.2000	152.2000	164.4000	103.2000		
10	Temp	^{o} C	9.81	11.26	10.4	9.86	10.28	8.75	9.12	9.04	8.49		
11	As	mg/L	<0.00028	0.00081	<0.00028	0.00066	0.0192	<0.00028	0.00059	0.00099	0.0254		
12	Ba	mg/L	0.0738	0.158	0.084	0.0166	0.0179	0.0423	0.0142	0.0216	0.0325		
13	Cu	mg/L	< 0.0011	0.0163	< 0.0011	0.437	0.0296	0.0038	0.0026	0.392	< 0.0011	0.014	0.56
14	Fe	mg/L	1.25	13.8	< 0.111	0.21	12.8	< 0.111	< 0.111	< 0.111	4.85	0.32	1.9
15	Pb	mg/L	< 0.00020	0.0004	< 0.00020	< 0.00020	0.00073	< 0.00020	< 0.00020	< 0.00020	< 0.00020		
16	Mn	mg/L	0.0747	26.4	3.48	24.8	9.79	0.809	0.0967	10.1	1.65	0.55	2.3
17	Se	mg/L	< 0.00032	0.00085	< 0.00032	0.00057	< 0.00032	< 0.00032	< 0.00032	0.0016	< 0.00032		
18	Ag	mg/L	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.0001	< 0.00010	< 0.00010	< 0.00010	< 0.00010		
19	Zn	mg/L	< 0.0046	< 0.0046	< 0.0046	0.12	0.38	0.006	0.0072	1	0.272		

Notes

1. Using assumption of CO_2 10%

(yellow) Indicates measured value exceeded 1989 prediction.

(orange) Indicates measured value exceeded 1989 and 1997 predictions.

CO_2 = carbon dioxide

^{o} C = degrees Celsius

mg/L = milligrams per liter

v = volts

SU = standard units

Prepared by: SVF

Checked by: ASH1

The initial predictive modeling of in-pit pore water focused only on copper, iron, manganese, sulfate, and pH. Measured porewater chemistry and predicted values agreement is highlighted for the following parameters:

- Sulfate is below predicted values in five of the eight samples in backfill. In the remaining three, sulfate concentrations are higher than predicted values, but only by approximately 50%, well within the acceptance tolerance.

- Copper is below predicted values in four of the eight samples in backfill. Copper concentration is very close to predicted values in two of the remaining four in-pit samples. In the last two samples (MW-1013B and MW-1014B), copper concentrations are an order of magnitude above predicted values, but have been stable for more than three and five years, respectively; because 1) dissolved oxygen and pH concentrations are stable [with some seasonal fluctuations] and 2) there is no continued influx of oxidized product.

- Iron is below predicted values in five of the eight samples in backfill. In three remaining wells and also in the background monitoring well, iron concentrations are order of magnitude above predicted values, but have been stable for more than five years and are not expected to increase because 1) dissolved oxygen and pH concentrations are stable [with some seasonal fluctuations] and 2) there is no continued influx of oxidized product.

- Manganese concentrations are higher than predicted values in seven of the eight in-pit samples but concentrations are expected to remain stable or fluctuate within the historically observed range because 1) dissolved oxygen and pH concentrations are stable [with some seasonal fluctuations] and 2) there is no continued influx of oxidized product.

- pH is neutral in all wells, as predicted.

In general, some potential differences between predicted and observed concentrations for the parameters described above include:

- Kinetic humidity cell testing results carried forward into the model included only the values derived from testing of rock chips. Rates derived from testing of smaller size fraction rock powder were not included. Surface area is known to be an important factor in loading, and thus not including results from waste rock powder may have underestimated mass loading rates.

- The 1989 water quality predictions were founded upon a model that utilized only five ions and, evaluated solubility with respect to only those oxide and hydroxide minerals comprised of the five ions. As a result, the model did not account for important ion interactions with carbonate, magnesium, and calcium. When correct solubility controls (which are driven primarily by carbonate minerals here) are not accounted for, models can over-predict or under-predict ion concentrations. In this case, by not taking into account the full suite of constituents, the 1989 model under-predicted some concentrations.

- Kinetic inhibition of mineral precipitation, such as rhodochrosite (manganese carbonate), was not accounted for.

pH and redox exert major controls on metals solubility; as pore water pH and oxidation increase, iron and manganese are increasingly removed from solution in precipitates. While precipitation of manganese carbonate (rhodochrosite) and both iron hydroxide and iron carbonate (siderite) minerals is thermodynamically favored, the stability field boundaries between soluble divalent metal in solution and retention in precipitate is very close to the pH measured in the backfill, meaning the driving force for mineral precipitation is limited. This is shown on Pourbaix diagrams for copper, iron and manganese on Figures 3, 4, and 5.

5.1.2 1997 Model

Table 2 also compares 2018 in-pit pore water quality to the 1997 predicted values assuming carbon dioxide (CO_2) = 10%. Samples that exceeded the 1997 prediction are highlighted orange. The 1997 prediction included a more comprehensive suite of parameters. Notably, 1997 prediction improved on 1989 prediction by accounting for load contribution from smaller size fraction waste rock. The 1997 prediction also factored in additional ions with a more complex model completed in MINTEQA2, an equilibrium speciation model (Allison, 1991). In particular, the effect of carbonate was accounted for in the 1997 prediction and is a major driver of solubility phases for metals. The pH was also tied to in-pit carbon dioxide concentrations and recognized as an important driver of mineral solubility. By accounting for carbonate and recognizing malachite (copper carbonate) precipitation, the model correctly predicted copper concentrations.

However, the model again under-predicted sulfate, iron, and manganese concentrations. Some of the same reasoning that limited the 1989 model also limited the 1997 model.

- The backfilled pit system sits very close to the phase transitions between soluble metals in solution and metals precipitated in mineral phases, including iron hydroxide, siderite, and rhodochrosite, which results in a low driving force for mineral precipitation. This low driving force, coupled with likely kinetic inhibition of rhodochrosite precipitation, allows manganese and iron concentrations to be higher than model predictions.

- Total concentration of sulfate is elevated relative to what was predicted in the 1997 model, likely because gypsum solubility is higher than what was assumed in the model. Gypsum solubility can vary with composition of background solution (Stumm and Morgan, 1981). Some species that influence the solubility equilibrium (i.e., species formed by complex formation), may be overlooked in the equilibrium calculation used in the model. For example, magnesium has been shown to inhibit the formation of gypsum (Ahmed, 2014). Some of these factors may have contributed to making the gypsum solubility product (Ksp) modeled in the 1997 model inaccurate.

5.1.3 Current Conditions

Reevaluating current data using a geochemical thermodynamic equilibrium modeling software platform (Geochemist's Workbench [GWB]) illustrates speciation and complexation of all measured ions in solution, and points to processes driving current water chemistry trends.

Sulfate

Both the 1989 and 1997 models correctly predicted that concentrations of sulfate in the backfill pit pore water would predominantly be a function of the solubility of gypsum. Solubility plots (Foth, 2016, 2017, and 2018) confirm that water is in equilibrium with gypsum at the three wells where sulfate concentrations are higher than what was predicted (MW-1013B, MW-1013C, and MW-1014B). This suggests that the K_{sp} initially utilized was lower than the K_{sp} observed in the field, and may not have accounted for the influence of a multicomponent system, the background electrolyte, and/or other polyvalent ions on gypsum solubility (Hem, 1970; Cravotta, 2006).

Copper

Copper concentration was elevated relative to 1989 predicted concentrations at MW-1013B and MW-1014B. The 1989 predictions did not take into account carbonate phases in predicting solubility limits. The model based predictions on copper hydroxide solubility and under-predicted copper concentrations at wells shown in Table 2. The 1997 model improved on the previous model by including carbonate phases. The 1997 model accurately identified additional solubility limiting phases and all copper concentrations are within limits predicted by the 1997 model. Figure 3 illustrates copper-limiting phases in pore water at MW-1013 C.

Manganese and Iron

Geochemical modeling of measured 2017 pore water concentrations are in agreement that secondary mineral precipitates are acting to limit ion concentrations and show that carbonate phases are important in determining concentrations for manganese and for iron. Dominant controls for both these ions are pH and oxidation state.

Pourbaix diagrams, shown on Figures 4 and 5 (using MW-1013C - 2018 water quality data as input), illustrate how pH is an important driver for metal solubility: the predicted stability field for rhodochrosite at MW-1013C begins above pH 6.5. Other studies have noted that while rhodochrosite is the main mineral phases in neutral to alkaline anoxic environments, equilibrium assumptions may not be satisfactory and kinetic processes may be dominant (Lebron and Suarez, 1998). Saturation plots (included within the Annual Reports) show that some wells are supersaturated with respect to rhodochrosite, meaning they are out of equilibrium and suggesting that kinetic controls are important. If there is kinetic inhibition to rhodochrosite precipitation, then mineral formation will not limit manganese concentrations.

Similarly, the Pourbaix diagram for iron speciation illustrates that iron concentrations can be limited in solution by precipitation of iron hydroxide or siderite, but the stability fields for these minerals end within the range of pHs and Ehs observed at wells in the backfilled pit. The Pourbaix diagram depicted on Figure 5 illustrates that iron may be bound in mineral form or free in solution given measured pH and pE conditions and likely explains observed fluctuations in iron concentrations.

Though measured pore water concentrations in the backfilled pit are different from what was predicted in 1989 and 1997 models, pore water quality at the site is stable and has been consistent for many years.

Pore water quality has been modeled annually and evaluated with respect to geochemistry. Details of these assessments have been presented in the Annual Reports. General processes that are responsible for observed water chemistry are highlighted here:

- Iron is limited by precipitation in iron hydroxide and siderite, but prone to fluctuation in response to variations in redox and pH.

- Manganese is thermodynamically predicted to be limited by rhodochrosite, but precipitation may be kinetically inhibited, and/or prone to fluctuation in response to variations in redox and pH.

- Pore water samples are in equilibrium with gypsum, but the 1997 prediction differs from current conditions because the model used a gypsum solubility product that was less than what we observe in field.

5.1.4 Predictive Modeling Summary

Concentrations of measured constituents are forecast to remain stable or to decrease in the future because there is no additional oxidation of waste rock occurring. More specifically:

- Concentrations of sulfate are anticipated to remain stable and/or decrease.

- Manganese concentrations are likely to continue to vary within the historically observed range.

- Iron concentrations are likely to continue to vary within the historically observed range.

- Stable conditions that have been observed for many years are expected to continue in future.

- As the “first flush” continues to migrate through the pit over time, concentrations are expected to decrease.

5.2 Protection of the Flambeau River

The third condition listed in Section 3 is no adverse impacts to Flambeau River water quality due to groundwater flowing from the backfilled pit. Potential impact to the Flambeau River was estimated by performing a concentration reduction factor (CRF) calculation. This procedure calculates the mass loading of a constituent delivered by water entering the Flambeau River from the backfilled pit and assesses the increase in concentration to the river.

This calculation was initially presented in Appendix L of the *Mine Permit Application for the Flambeau Project* (FVD, 1989), then in a memorandum submitted by the Flambeau Mining Company (FMC), to the Department, on October 17, 2000, entitled *Backfilled Pit Water Quality Assessment* (FMC, 2000). The calculation has been updated with current parameter values. The current version can be found in Attachment 2.

As seen in Attachment 2, the calculation involves using Darcy's Law to estimate groundwater flow contribution from the backfilled pit to the Flambeau River. This is done using the difference in head between the pit and river, the hydraulic conductivity of the native material, and the area of flow (product of aquifer thickness and pit width). The resulting flow rate is then compared to both the average and low flow conditions of the Flambeau River to determine the CRFs under those conditions. Three different Darcy's Law calculations were performed in order to determine the sensitivity of the input parameters. The calculation producing the highest CRF (and therefore the highest parameter concentrations) was used in the subsequent pore water parameter concentrations as a conservative measure.

The incremental constituent increase to the Flambeau River under average and low flow conditions was calculated using the CRF and parameter concentrations in groundwater and/or pore water within or immediately adjacent to the backfilled pit. Consistent with an October 2000 memorandum (FMC, 2000), the four parameters evaluated were copper, iron, manganese, and sulfate. Concentrations of these four parameters were evaluated using 2018 data in the MW-1013, MW-1014, and MW-1000PR well nests; and the highest 2018 concentrations were used.

Flambeau River incremental increases were then compared to the background concentrations in the Flambeau River. The background concentrations were presented as a range of lowest to highest values obtained from the up-gradient sampling point (SW-1) over the period between 2000 and 2018.

5.2.1 Results

All calculations are shown in Attachment 2. A summary of the pore water concentrations, the negligible incremental impact on the Flambeau River, and the background river concentrations can be found in Table 3. The incremental increases shown in Table 3 are expressed as concentrations (in milligrams per liter [mg/L]) under both average and low Flambeau River flow conditions.

The results show that the CRFs are on the order of 0.00000010 and 0.0000010 mg/L for the average and low flow conditions, respectively. This results in negligible, unmeasurable, incremental impacts to the Flambeau River that are 3 to 5 orders of magnitude lower than background concentrations in the Flambeau River (Table 3).

Table 3

Pit Pore Water Influence on Flambeau River

		Avg. Flow	Avg. Flow	Low Flow	Avg. Flow	Low Flow	
		1989[a]	**2000[b]**		**2018**		
Parameter	**Pore Water (mg/L)[1]**	**Incremental Concentration Increase[2] (mg/L)**					**Flambeau River Background (mg/L)[3]**
Copper	0.503	0.000000034	0.00000029	0.0000012	0.000000664	0.00000271	<0.00029 - 0.0087
Iron	16.3	0.00000078	0.0000054	0.000022	0.0000215	0.0000877	0.18 - 1.9
Manganese	31.3	0.0000013	0.000012	0.000048	0.000041	0.000167	0.037 - 0.19
Sulfate	1880	0.0033	0.00072	0.003	0.0020	0.010	<2.5 – 10.0

1. Highest 2018 concentration of MW-1013, MW-1014, or MW-1000PR well nests.
2. Using highest calculated concentration reduction factor (i.e., gives the highest concentration).
3. SW-1 (up-gradient) range between 2000 and 2018.

a. FVD, 1989
b. FMC, 2000

Prepared by: MAN
Checked by: MCC2

These results are consistent with the results of the 2000 memorandum (FMC, 2000) and show that the potential for backfill pore water to impact water quality in the Flambeau River is negligible, because the potential incremental changes are estimated to be orders of magnitude below background conditions. Additionally, this analysis is considered conservative, since attenuating reactions such as adsorption are not considered. Based on this evaluation, the conditions of permit have been met to support a reduction in the in-pit monitoring program.

6 Reduced Monitoring Plan Recommendations

Groundwater chemistry at each intervention boundary in pit well has been evaluated quarterly with respect to select parameters during quarterly and annual monitoring.

Quarterly monitoring parameters has included:

- Field parameters: color, odor, oxidation-reduction potential (ORP), pH, specific conductivity, turbidity

- Laboratory parameters: alkalinity, arsenic, copper, iron, manganese, sulfate, total alkalinity, total dissolved solids (TDS), total hardness, and pH.

Annual monitoring parameters has included:

- Field parameters: color, odor, ORP, pH, specific conductivity, turbidity

- Laboratory parameters: alkalinity, arsenic, barium, cadmium, calcium, chloride, copper, iron, lead, magnesium, manganese, potassium, selenium, silver, sodium, sulfate, and zinc.

The proposed annual sampling program will include:

- Field parameters: color, odor, ORP, pH, specific conductivity, turbidity

- Laboratory parameters: alkalinity, arsenic, calcium, chloride, copper, iron, lead, magnesium, manganese, potassium, sodium, sulfate, and zinc.

An annual sampling program will adequately confirm that conditions remain stable. The current and proposed monitoring plans are provided in Table 4 and discussed in more detail in Sections 6.1 through 6.7.

Table 4

Current and Proposed Monitoring Plan

Current Monitoring Plan Quarterly	Current Monitoring Plan Annual	Proposed Monitoring Plan Annual
Field Parameters		
Color	Color	Color
Odor	Odor	Odor
ORP	ORP	ORP
pH	pH	pH
Specific Conductivity	Specific Conductivity	Specific Conductivity
Turbidity	Turbidity	Turbidity
Laboratory Parameters		
Alkalinity	Alkalinity	Alkalinity
Arsenic	Arsenic	Arsenic
Copper	Barium	Calcium
Iron	Cadmium	Chloride
Manganese	Calcium	Copper
Sulfate	Chloride	Iron
TDS	Chromium	Lead
Total Hardness	Copper	Magnesium
pH	Iron	Manganese
	Lead	Potassium
	Magnesium	Sodium
	Manganese	Sulfate
	Mercury	Zinc
	Potassium	TDS
	Selenium	Total Hardness
	Silver	
	Sodium	
	Sulfate	
	Zinc	

Prepared by: ASH
Checked by: SVF

The parameters recommended for removal from the monitoring program include those parameters that have shown very little variation in concentration and/or those constituents whose concentrations are consistently below detection limits.

The parameters recommended for removal include barium, cadmium, chromium, mercury, selenium, silver, and laboratory pH; and each is discussed in more detail in following subsections.

6.1 Barium

Barium concentrations have been stable and/decreasing at in-pit wells. Barium concentrations are expected to be stable or decrease in the future. The in-pit well nest MW-1013 shows barium concentrations have been stable or decreasing since 2007. The in pit well nest MW-1014 has barium concentrations that are similar to those measured at intervention boundary wells at or less than 50 micrograms per liter (µg/L).

6.2 Cadmium

Cadmium concentrations have been stable and/decreasing at in-pit wells. Cadmium concentrations are expected to be stable or decrease in the future. The in-pit well nest MW-1013 shows cadmium concentrations that have been stable or decreasing since 2000. Concentrations since 2004 have been less than 2 µg/L. At MW-1014 cadmium concentrations have been generally decreasing since first measurements and have been less than 3 µg/L since 2009.

6.3 Chromium

Chromium concentrations show very little variation. Chromium concentrations are expected to remain stable or decrease in the future. The in-pit well nest MW-1013 shows chromium concentrations that are at times elevated relative to the intervention boundary wells. Most sampling events at MW-1013 have indicated chromium concentrations below detection, but there have been isolated cases of detects, including 2005 (30 µg/L) and 2014 (10 µg/L). At MW-1014, chromium concentrations have been generally decreasing since first measurements and have been less than 3 µg/L since 2010.

6.4 Mercury

Mercury concentrations show very little variation. Mercury concentrations are expected to remain stable or decrease in the future. Mercury concentrations at the in-pit wells are similar to concentrations at the intervention boundary wells, and below detection for most samples. Mercury was detected above the detection limit once since 1999 in the MW-1013 well nest, at a concentration just above 0.1 µg/L. Mercury was detected above the detection limit once since 1999 in the MW-1014 well nest, at a concentration near 0.05 µg/L.

6.5 Selenium

Selenium concentrations show very little variation. Selenium concentrations are expected to remain stable or decrease in the future. Selenium concentrations at the in-pit wells are similar to the intervention boundary wells, and range from below detection to less than 5 µg/L in both the MW-1013 and MW-1014 well nest.

6.6 Silver

Silver concentrations show little variation and are expected to remain stable or decrease in the future. Silver concentrations at the in-pit wells have occasionally been elevated relative to the intervention boundary wells. The highest observed concentration in the

MW-1013 well nest was almost 15 µg/L, bet generally, concentrations since 2009 have ranged from below detection to less than 3 µg/L. The highest observed concentration in the MW-1014 well nest was more than 20 µg/L, but concentrations since 2010 have ranged from below detection to less than 5 µg/L.

6.7 Laboratory pH

Because measurement of pH in the laboratory occurs outside the hold time for this analyte (15 minutes), all laboratory pH results are qualified during validation process as biased. Taking pH of the groundwater during field event is technically robust and more reflective of conditions at site.

7 Conclusions

The 2017 annual trend analysis indicates few statistically significant trends in water chemistry (Foth, 2017). Geochemical modeling indicates that conditions of equilibrium or near equilibrium are prevalent in the backfilled pit. Calculations of potential effects to the Flambeau River using current data from backfilled pit pore water chemistry demonstrate that there is no risk to the Flambeau River.

The Department has defined regulatory conditions that must be met in order for Flambeau to obtain approval for a reduced groundwater monitoring plan. These requirements were defined in Section 3 as:

- Water levels in the pit are stable;
- Pore water chemistry in the pit is well characterized, stable, and verified through predictive modeling; and
- No adverse impact to Flambeau River.

The results presented in Sections 4, 5 and 6 indicate that these conditions have been met and a reduction in groundwater monitoring at the Reclaimed Flambeau Mine Site is appropriate. A reduction in groundwater monitoring to annually and a reduction in parameters as summarized in Table 4 in the in-pit wells based on the results presented herein is recommended.

8 References

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Ahmed S.B., M.M. Tlili, M. Amami, and M.B. Amor. Gypsum Precipitation Kinetics and Solubility in the NaCl–MgCl2–CaSO4–H2O System.

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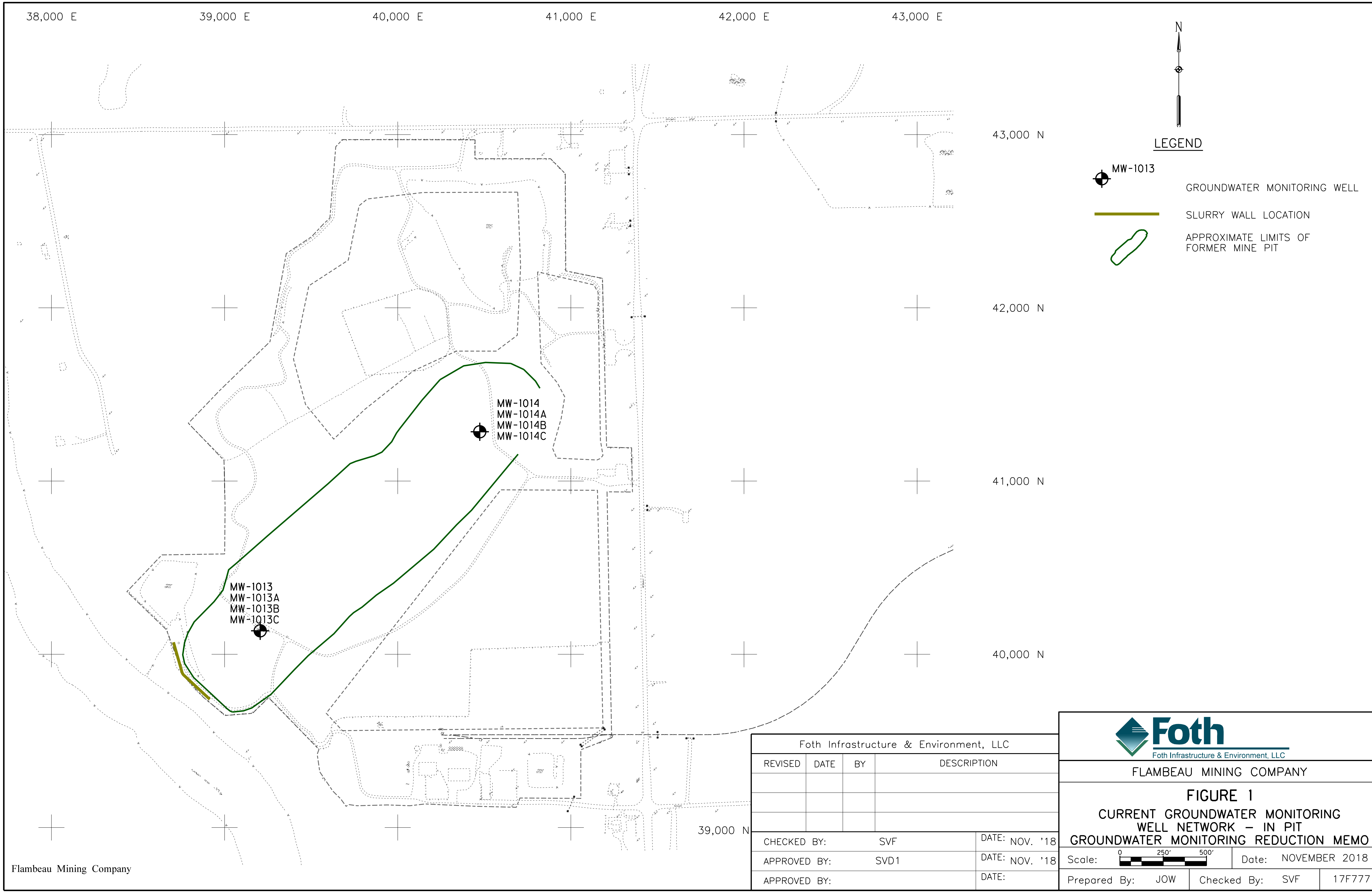
Figures



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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	SVF	DATE: NOV. '18
APPROVED BY:	SVD1	DATE: NOV. '18
APPROVED BY:		DATE:

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FIGURE 1

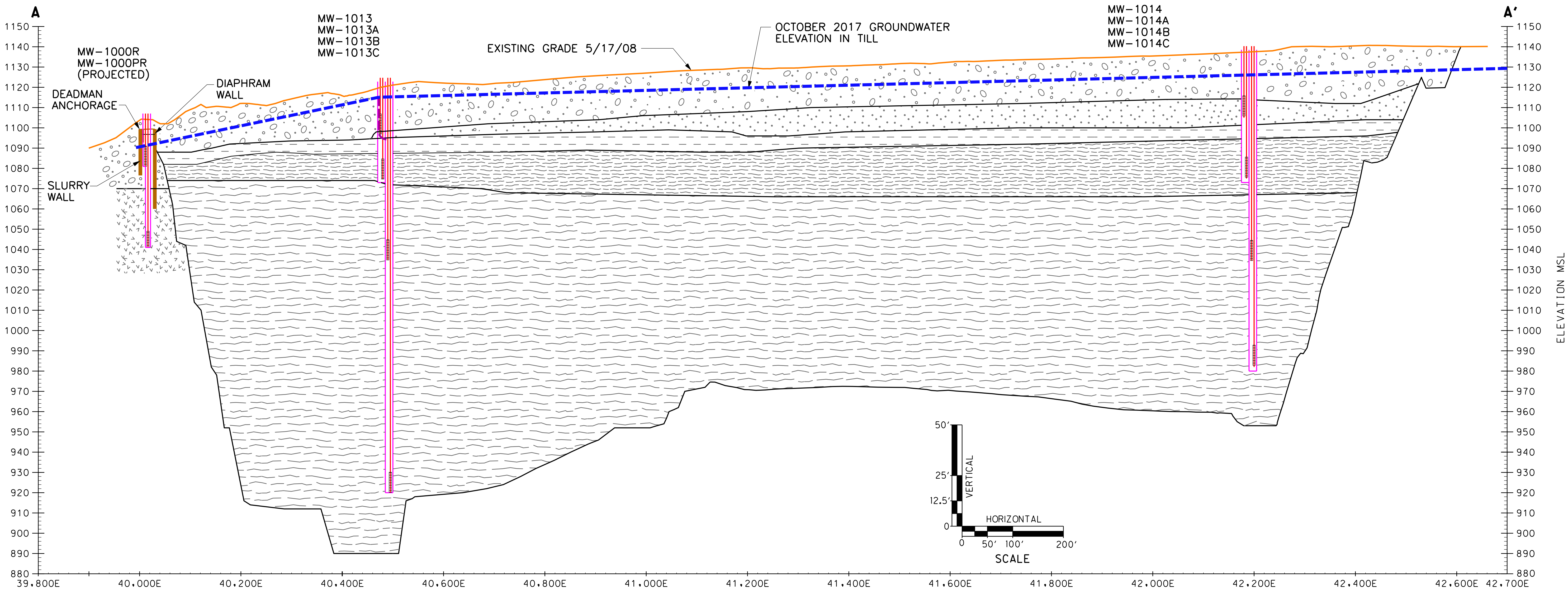
CURRENT GROUNDWATER MONITORING WELL NETWORK – IN PIT GROUNDWATER MONITORING REDUCTION MEMO

Scale: 0 250' 500'

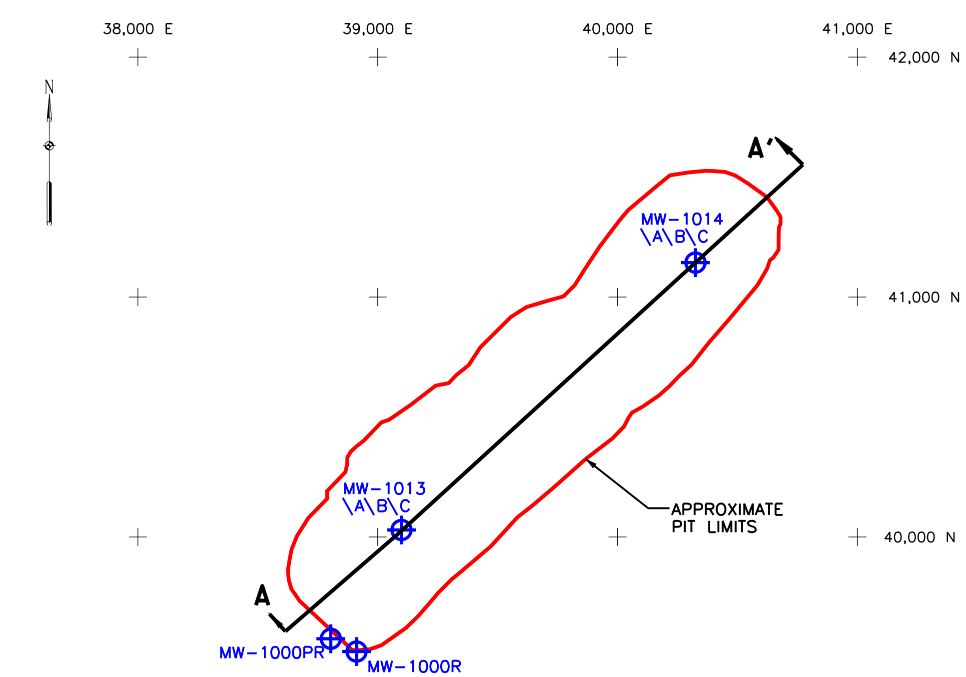
Date: NOVEMBER 2018

Prepared By: JOW | Checked By: SVF | 17F777

pw:\\PW-APS1.foth.com:PW_IE\Documents\Clients\Flambeau Mining\0017F777.00\CAD\Figures\Groundwater Monitoring Reduction Memo\Figure 1 - Current GW MW Network - In Pit.dgn
11/5/2018 dat



MINE PIT COORDINATES
SECTION A – A'



CROSS SECTION LOCATION MAP

SCALE: 1" = 600'

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LEGEND

- TILL
- SANDSTONE
- SAPROLITE
- TYPE I MATERIAL
- TYPE II MATERIAL
- PRECAMBRIAN
- WATER TABLE

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REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	SVF	DATE:	NOV. '18
APPROVED BY:	SVD1	DATE:	NOV. '18
APPROVED BY:		DATE:	

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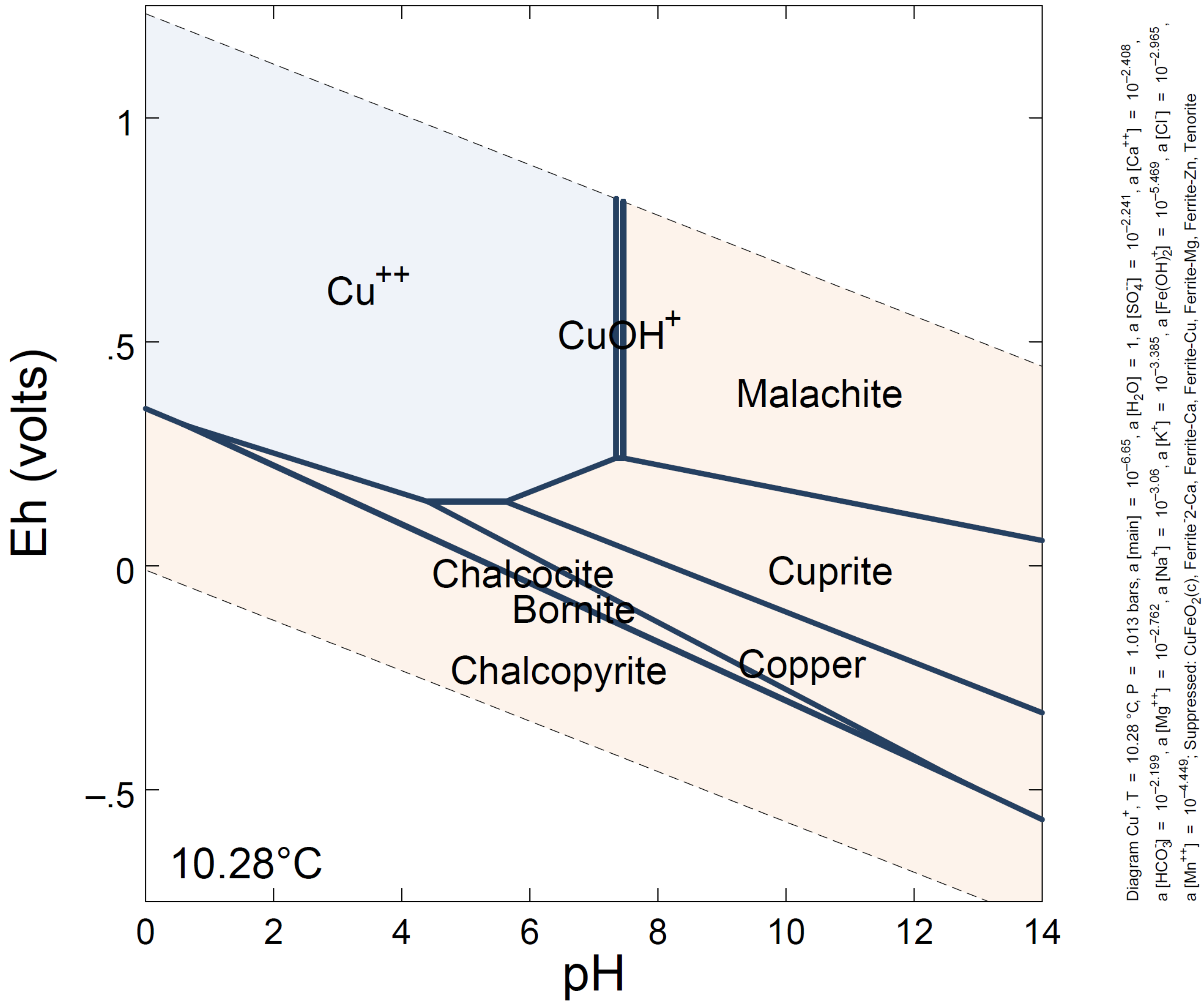
FIGURE 2
MINE PIT CROSS SECTION A – A'
WITH IN-PIT GROUNDWATER
MONITORING WELLS

Scale: SEE BAR SCALE		Date: NOVEMBER 2018	
Prepared By: JOW	Checked By: SVF		17F777

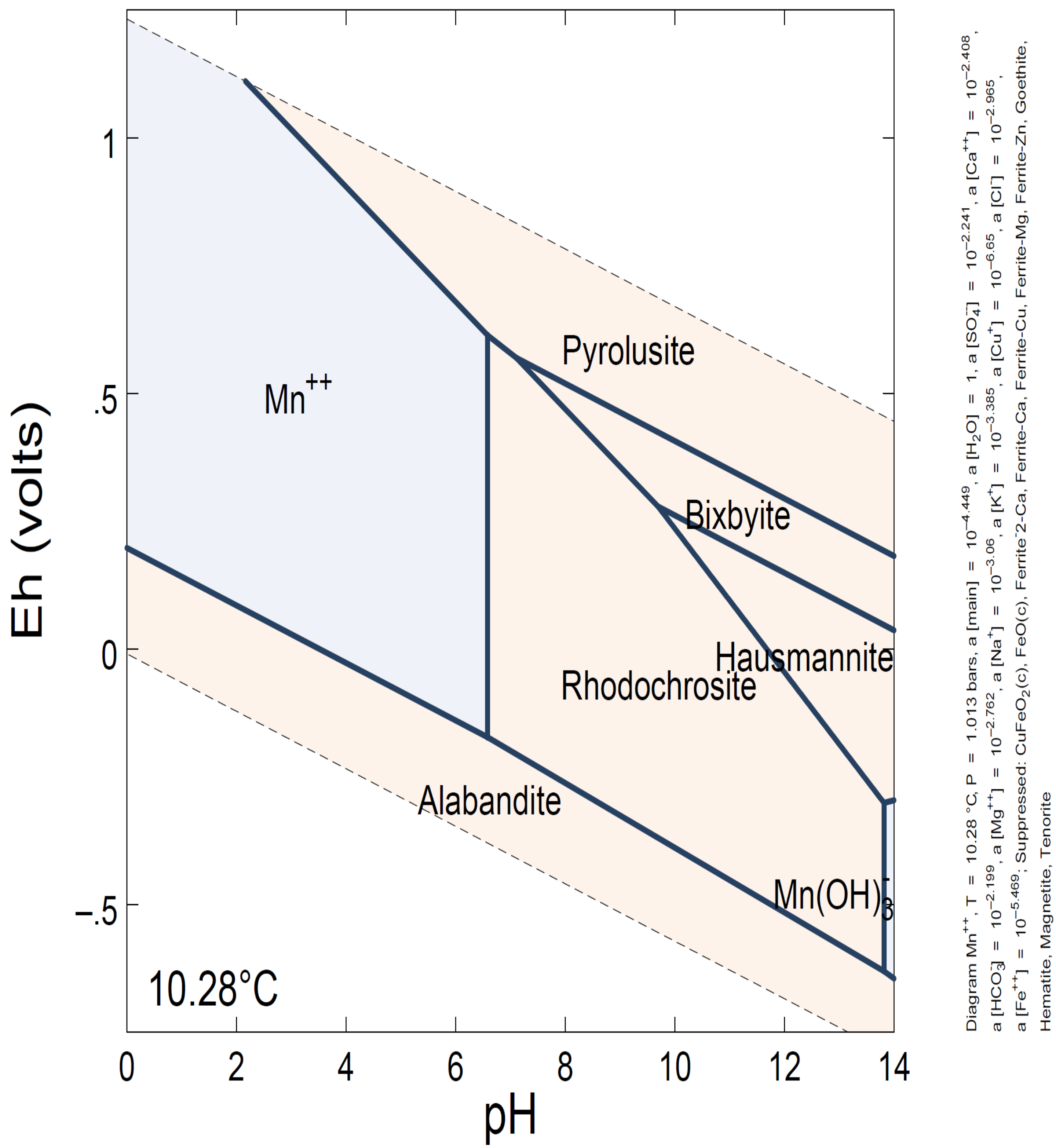
pw:\\PW-APS1.foth.com:PW_IE\Documents\Clients\Flambeau Mining\0017F777.00\CAD\Figures\Groundwater Monitoring Reduction Memo\Figure 2 - Cross Section.dgn
11/5/2018 dat



Foth Infrastructure & Environment, LLC				FLAMBEAU MINING COMPANY	
REVISED	DATE	BY	DESCRIPTION	**FIGURE 3** Pourbaix diagram illustrates predicted stable copper phases as a function of Eh and pH in MW-1013 B GROUNDWATER REDUCTION TECHNICAL MEMO	
PREPARED BY: ASH1			DATE: NOV. '18		
REVIEWED BY: SVF			DATE: NOV. '18	Scale: NOT TO SCALE	Date: NOVEMBER 2018
APPROVED BY:			DATE:	Drafted by: DAT	Project: 17F777

Foth

Path: Q:\Flambeau Mining Company\17F777\GIS\mxd\GW Reduction Tech Memo 1\Figure 3.mxd Date: 11/9/2018



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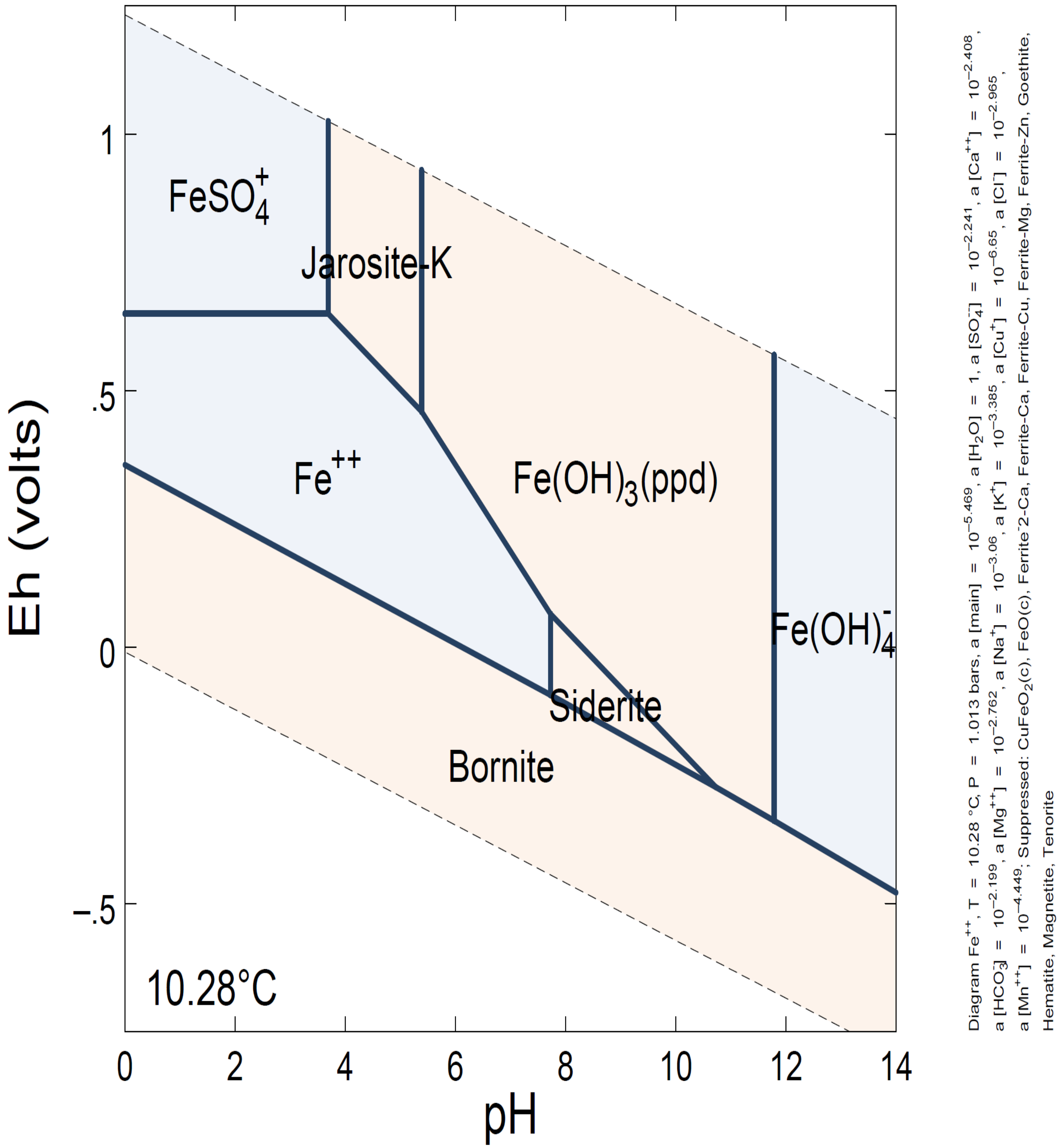
REVISED	DATE	BY	DESCRIPTION
PREPARED BY: ASH1			DATE: NOV. '18
REVIEWED BY: SVF			DATE: NOV. '18
APPROVED BY:			DATE:

FLAMBEAU MINING COMPANY

FIGURE 4
Pourbaix diagram illustrates predicted stable manganese phases as a function of Eh and pH in MW-1013 C
GROUNDWATER REDUCTION TECHNICAL MEMO

Scale:	NOT TO SCALE	Date:	NOVEMBER 2018
Drafted by:	DAT	Project:	17F777

Foth



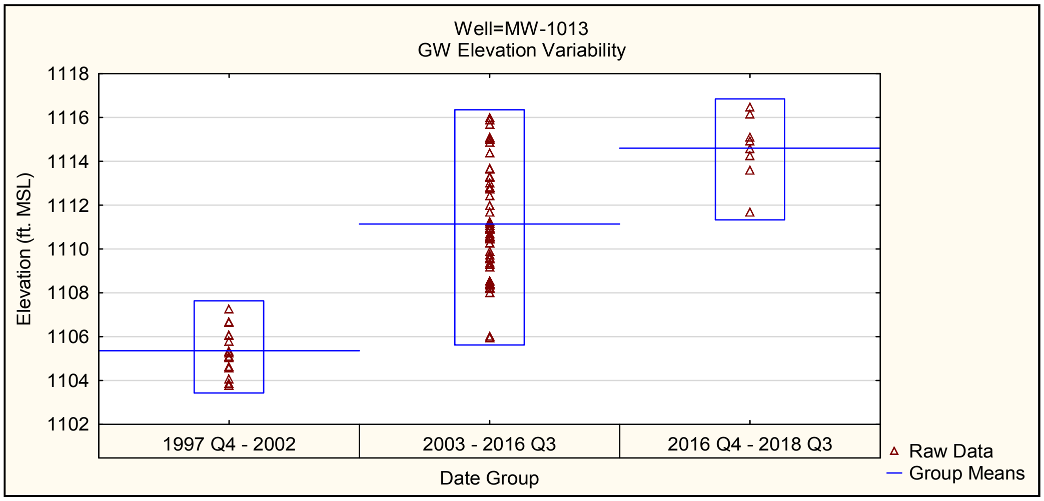
Foth Infrastructure & Environment, LLC				FLAMBEAU MINING COMPANY	
REVISED	DATE	BY	DESCRIPTION	**FIGURE 5** Pourbaix diagram illustrates predicted stable iron phases as a function of Eh and pH in MW-1013 C GROUNDWATER REDUCTION TECHNICAL MEMO	
PREPARED BY: ASH1			DATE: NOV. '18		
REVIEWED BY: SVF			DATE: NOV. '18	Scale: NOT TO SCALE	Date: NOVEMBER 2018
APPROVED BY:			DATE:	Drafted by: DAT	Project: 17F777

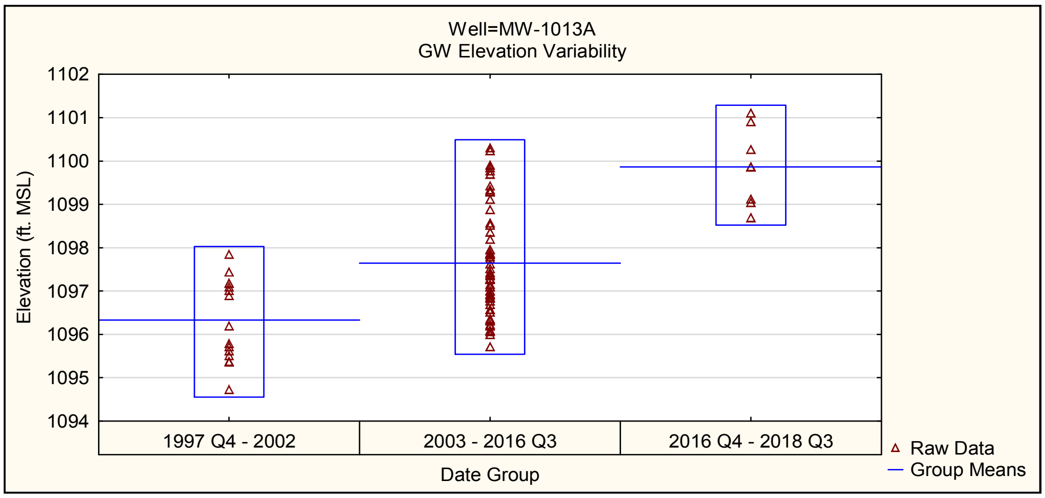
Foth

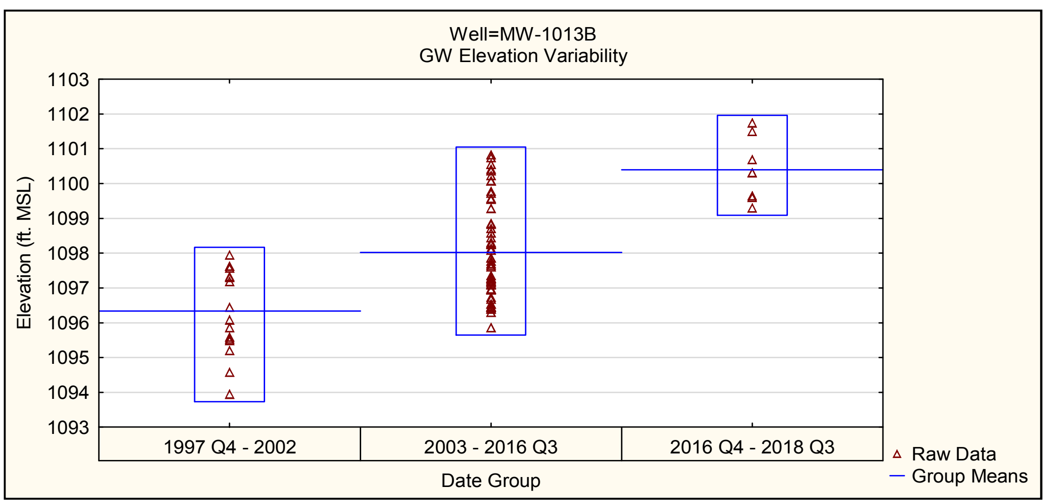
Path: Q:\Flambeau Mining Company\17F777\GIS\mxd\GW Reduction Tech Memo 1\Figure 5.mxd Date: 11/9/2018

Attachment 1

Groundwater Elevation Variation Graphs and Hydrographs
In-Pit Wells







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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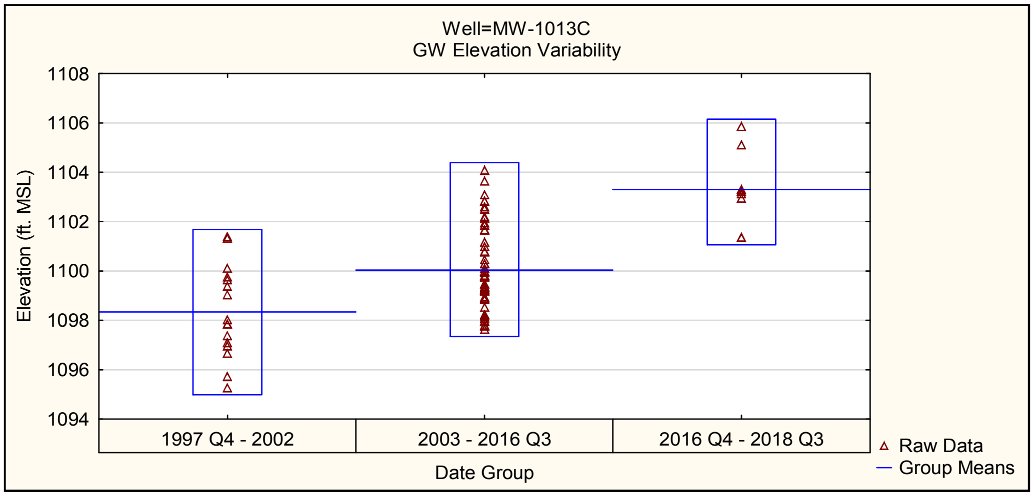
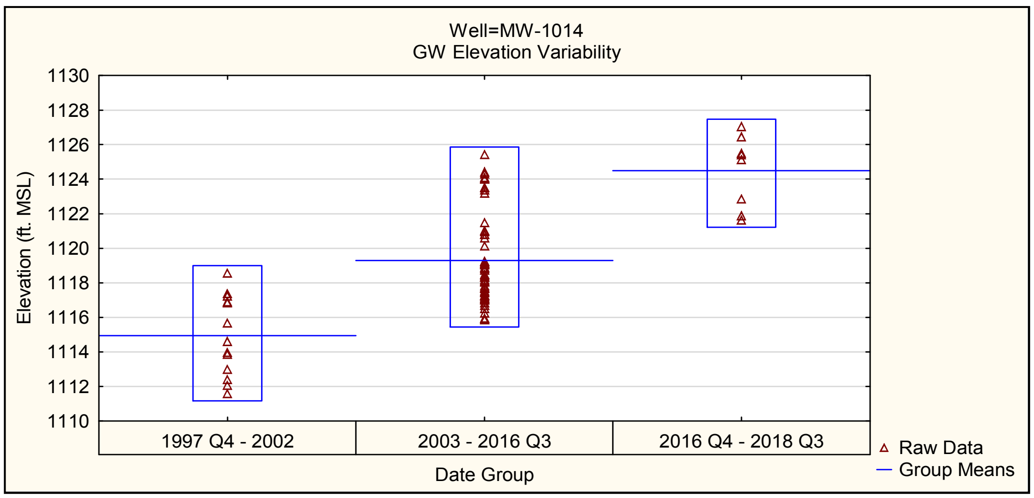
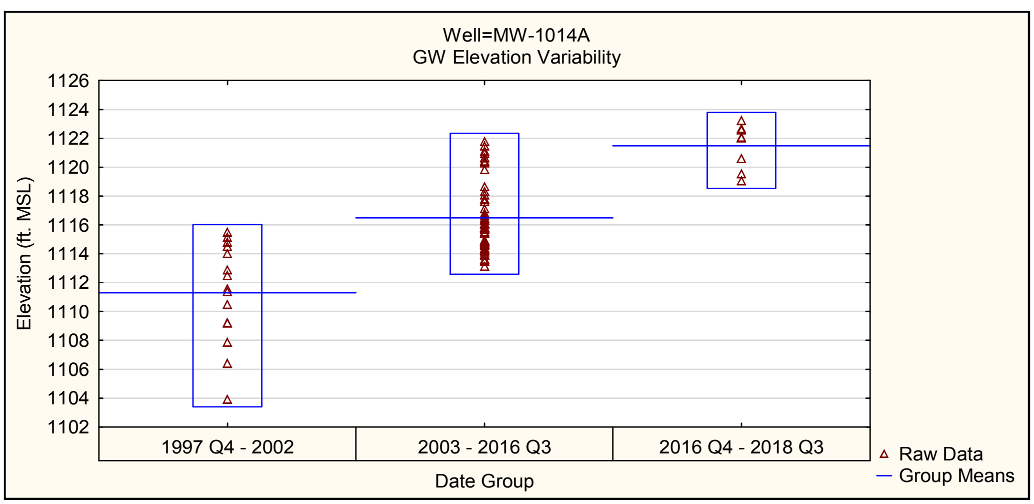
FIGURE 1-1a
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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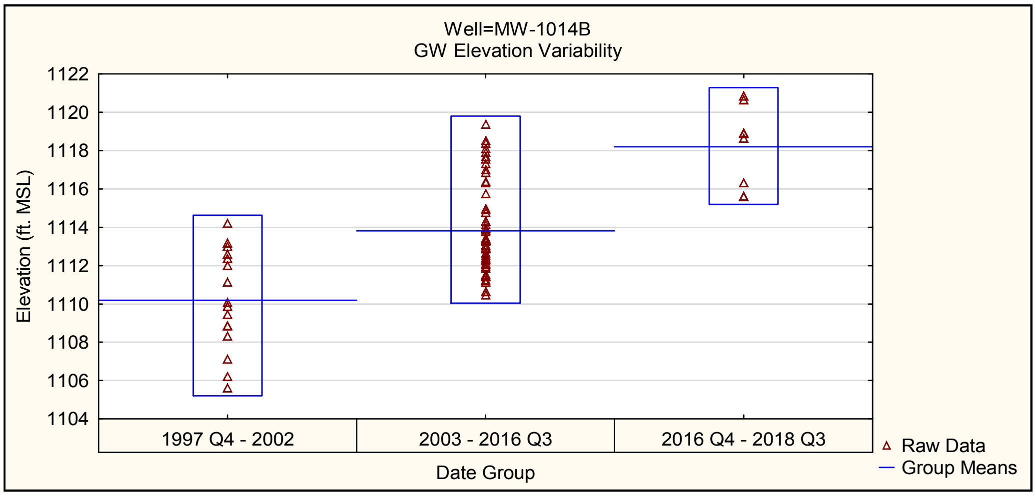
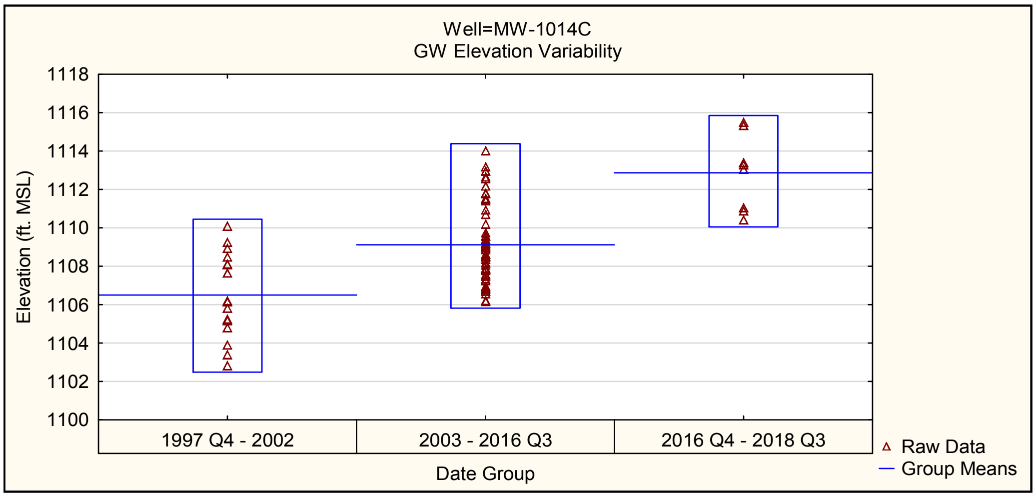
FIGURE 1-1b
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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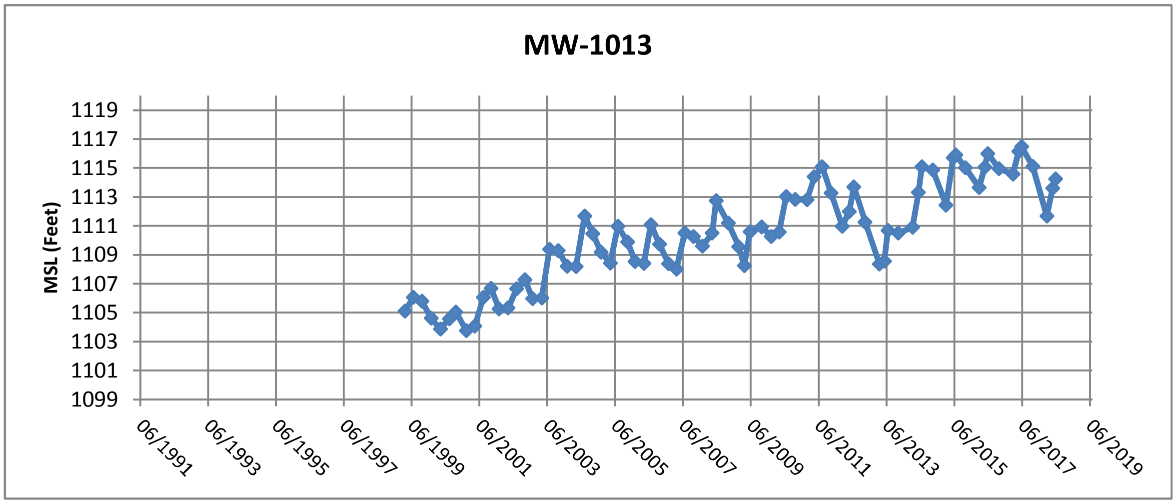
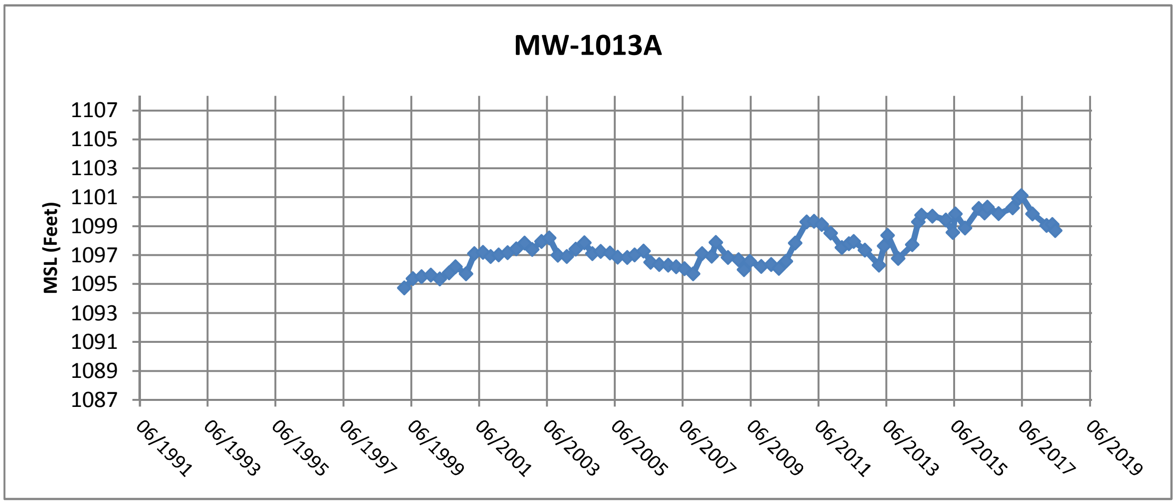
FIGURE 1-1c
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





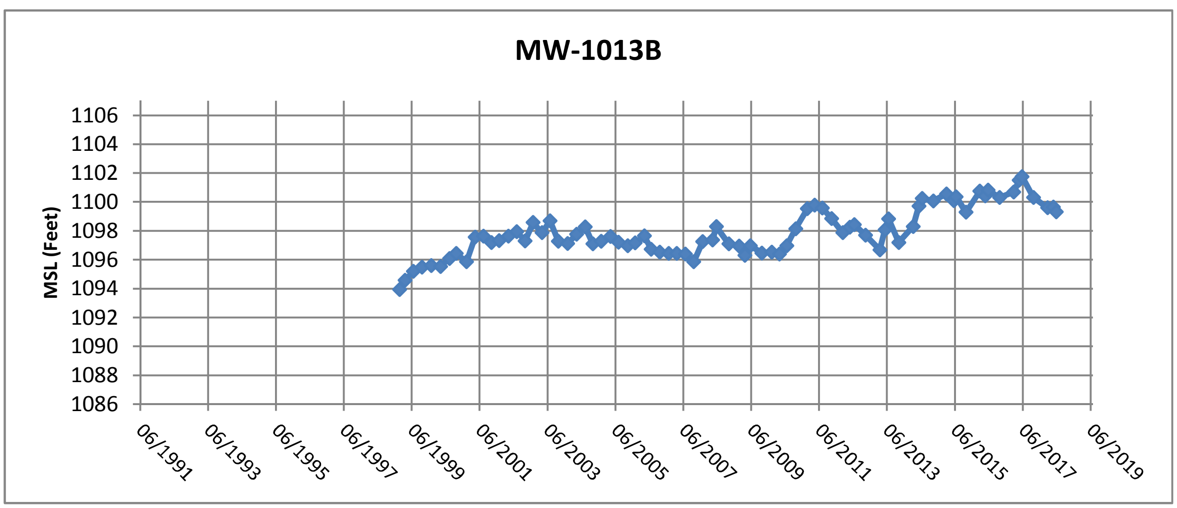


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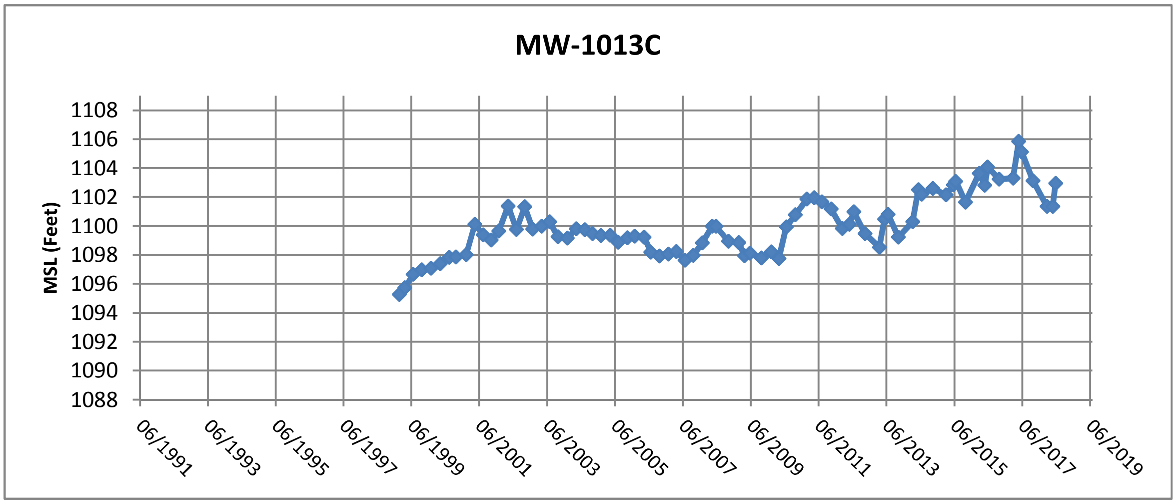
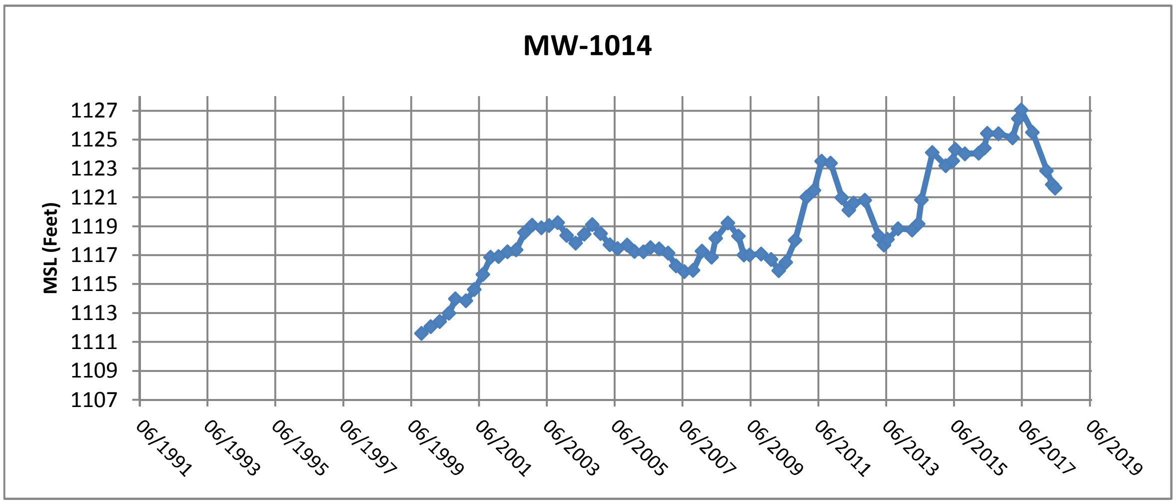
FIGURE 1-2a
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





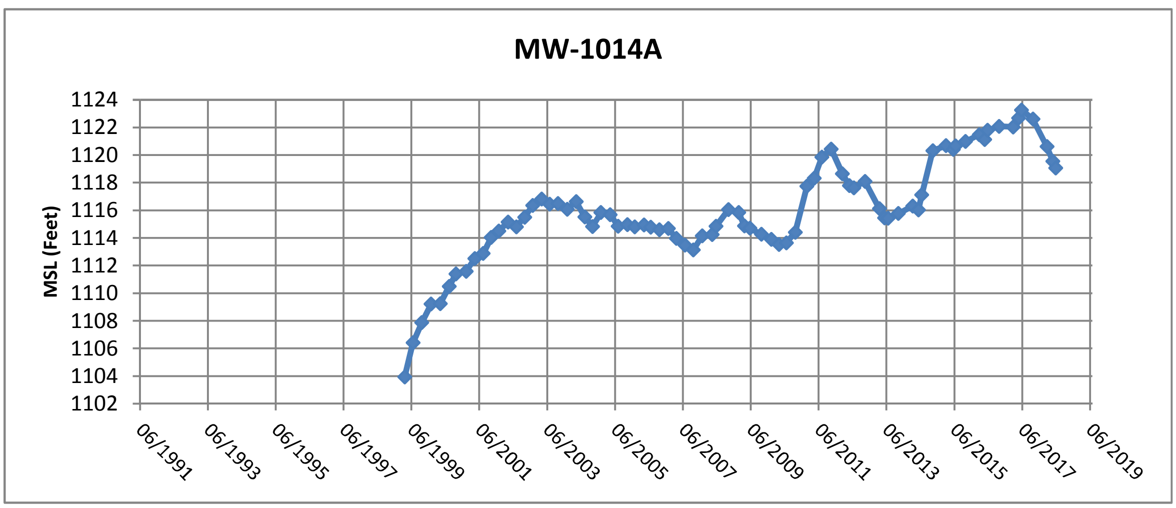


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FIGURE 1-2b
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

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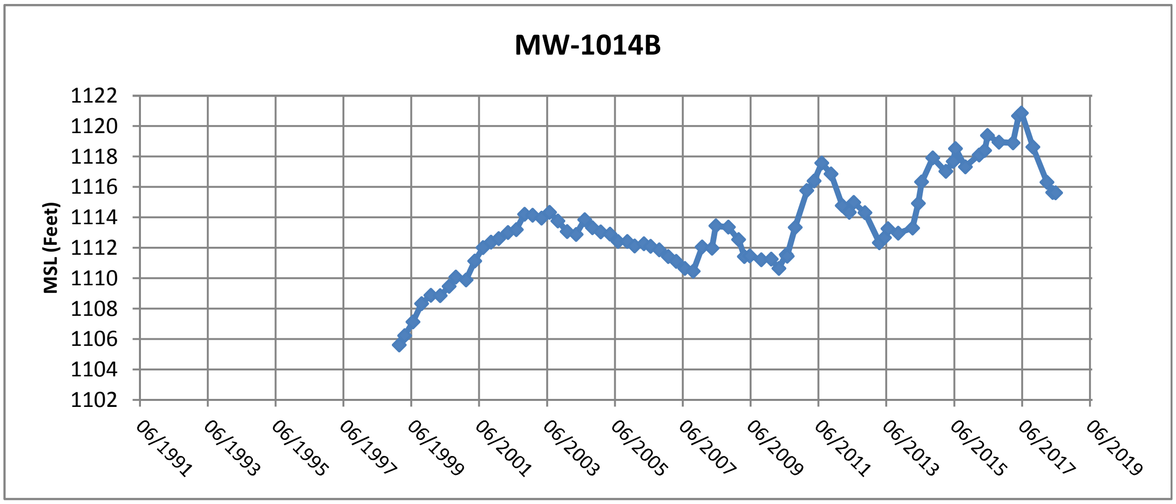

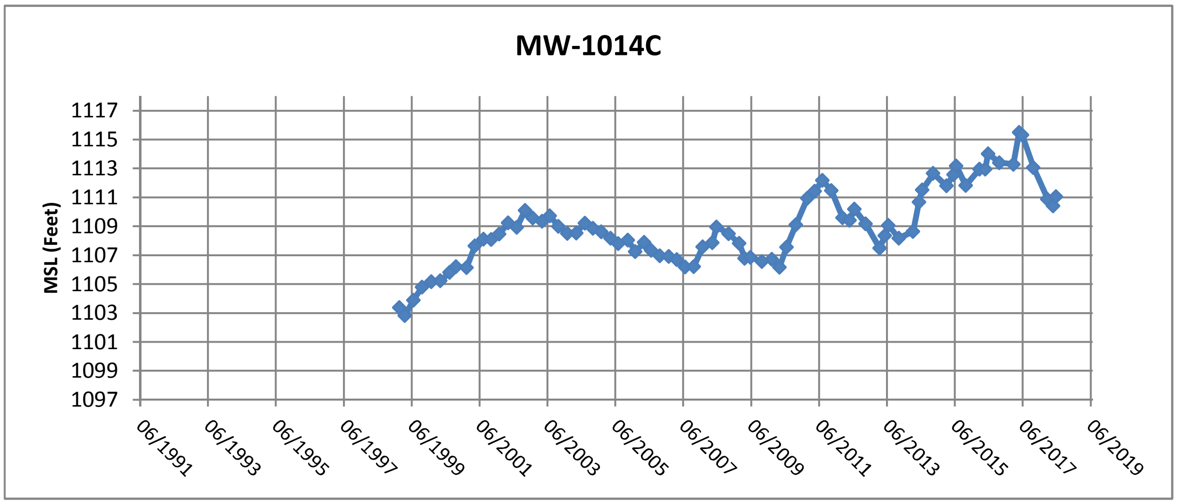

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FIGURE 1-2c
HYDROGRAPHS

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

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Attachment 2

Concentration Reduction Factor Calculations

Flambeau River - Groundwater Pit Flux Calculation

BACKGROUND

This calculation uses Darcy's Law to determine groundwater flow rate (pore water flux) from the backfilled pit to the Flambeau River. The ratio of this flow to the background Flambeau River flow then provides a concentration reduction factor used to estimate effects of pit pore water concentrations on the river.

GOVERNING EQUATIONS

Darcy's Law: Qpit = K * I * A * unit conversions

where:

Qpit = Groundwater Flowrate (ft3/s)
K = Hydraulic Conductivity (ft/d)
I = Groundwater Gradient (ft/ft)
A = Cross-Sectional Flow Area (ft2)

Concentration Reduction Factor (CRF): CRF = Qpit / (Qpit + Qriver)

where:

Qpit = groundwater flowrate from pit (from Darcy's Law above)
Qriver = background flowrate of Flambeau River

Incremental Concentration Increase (ICI) to Flambeau River: ICI = CRF * C

where:

CRF = concentration reduction factor
C = groundwater concentration of given parameter (mg/L)

INPUT DEFINITIONS

Three different Darcy's Law calculations for groundwater flow rate were performed: 1) between pit (MW-1013) and Flambeau River, 2) immediately adajcent to pit (MW-1000PR) and Flambeau River, and 3) inside the pit (MW-1013 and MW-1014). Considering three different perspectives provides options to select the worst case, resulting in a conservative estimate.

Hydrualic Conductivity (K): Hydraulic conductivity of the Precambrian bedrock (Kbr) between the pit and the Flambeau River was taken to be 0.061 ft/d (Engineering Technologies Associates, 1998). Hydraulic conductivity of the Type II pit backfill material (Kpit) was taken to be 0.028 ft/d (Engineering Technologies Associates, 1998).

Groundwater Gradient (I): In Scenario #1, I is taken as difference between water elevations at monitoring points divided by the separation distance. In-pit shallow groundwater elevation in was assumed to be represented by monitoring well MW-1013, and elevations were averaged over the four measurements taken in 2017 (FMC, 2018) and the three taken to date in 2018. This average elevation (MW1013el) was found to be 1114.56 ft above mean sea level (amsl). The Flambeau River elevation (FRel) was taken to be 1085.57 ft amsl from cross-section A-A' in the Environmental Impact Report in the Mine Permit Application (Foth & Van Dyke, 1989). The distance from monitoring well MW-1013 to the Flambeau River

Van Dyke, 1989). The distance from monitoring well MW-1013 to the Flambeau River (Distance1013) is approximately 600 ft.

Scenario #2 used groundwater elevations outside the pit to compare to the Flambeau River. Groundwater elevations outside the pit were represented by monitoring well MW-1000PR, located approximately 125 ft from the Flambeau River (Distance1000PR). The 2017 - 2018Q3 average elevation (MW1000PRel) was 1090.22 ft msl.

Scenario #3 used the in-pit difference between monitoring wells MW-1013 and MW-1014. MW-1014 is located in the northeast corner of the pit, approximately 1700 ft from MW-1013 (Distance1013_1014). The average groundwater elevation (MW1014el) in MW-1014 during 2017 - 2018Q3 was 1124.36 ft amsl.

Cross-Sectional Flow Area (A): The cross-sectional area of flow leaving the pit is defined as the width of the pit multiplied by the thickness of the aquifer. The pit width (Pwidth) is taken to be 650 ft (FMC, 2000). The bottom of the Precambrian bedrock is approximately at elevation 980 ft amsl and is considered to be the aquifer bottom (Engineering Technologies Associates, 1998). The aquifer thickness for the two scenarios involving flow through the Precambrian bedrock (Scenarios #1 & #2) is the difference of the top of the bedrock (BRtop) elevation (approximatley 1080 ft msl) and the bedrock/aquifer bottom (BRbot) of 980 ft amsl, giving an aquifer thickness of 100 ft. The aquifer thickness for flow within the pit (Scenario #3) is the average water table elevation between MW1013 - MW1014 and the pit bottom (Pitbot), estimated at 940 ft amsl.

Flambeau River Flowrate (Qriver): Two different background flowrates for the Flambeau River were used in this calculation. The average flowrate (Qriver-avg) was obtained by averaging flowrates obtained from the USGS gauging station 05360500 near Bruce, WI. Flowrates were averaged using daily values for the 15-year period between 2003 - 2018. The low-flow (Qriver-low) was obtained by using the established 7-day period of lowest flow with a 10-yr recurrence interval. This value was obtained from Engineering Technologies Associates, 1998, and verified by a current search of United States Geological Survey (USGS) data, and equals 412 cubic feet per second (cfs).

Groundwater Concentration (C): Highest 2017 through 2018Q3 groundwater concentration (mg/L) of the MW-1000PR, MW-1013, or MW-1014 well nests. Parameters evaluated were copper (Ccu), iron (Cfe), manganese (Cmn), and sulfate (Cso4).

VARIABLE DEFINITIONS

$Kbr := 0.061 \frac{ft}{day}$ $Kpit := 0.028 \frac{ft}{day}$

$MW1013el := 1114.56\ ft$ $Distance1013 := 600\ ft$

$MW1000PRel := 1090.22\ ft$ $Distance1000PR := 125\ ft$

$MW1014el := 1124.36\ ft$ $Distance1013\_1014 := 1700\ ft$

$Pwidth := 650\ ft$ $BRtop := 1080\ ft$ $BRbot := 980\ ft$ $Pitbot := 940\ ft$

$FRel := 1085.57\ ft$ $Qriveravg := 1681\ \frac{ft^3}{sec}$ $Qriverlow := 412\ \frac{ft^3}{sec}$

$Ccu := 0.503\ \frac{mg}{L}$ $Cfe := 16.3\ \frac{mg}{L}$ $Cmn := 31.1\ \frac{mg}{L}$ $Cso4 := 1880\ \frac{mg}{L}$

<u>CALCULATIONS</u>

Scenario #1 - Flow Between Pit (MW-1013) and Flambeau River:

$I1013 := \frac{(MW1013el - FRel)}{Distance1013}$ $I1013 = 0.0483\ \frac{ft}{ft}$

$A1013 := Pwidth \cdot (BRtop - BRbot)$ $A1013 = 65000\ ft^2$

$Qpit1013 := Kbr \cdot I1013 \cdot A1013$ $Qpit1013 = 0.00222\ \frac{ft^3}{sec}$

$CRFavg1013 := \frac{Qpit1013}{(Qpit1013 + Qriveravg)}$ $CRFavg1013 = 1.32 \cdot 10^{-6}$

$CRFlow1013 := \frac{Qpit1013}{(Qpit1013 + Qriverlow)}$ $CRFlow1013 = 5.38 \cdot 10^{-6}$

Scenario #2 - Flow Immediately Adjacent to Pit (MW-1000PR) and Flambeau River:

$I1000PR := \frac{(MW1000PRel - FRel)}{Distance1000PR}$ $I1000PR = 0.0372\ \frac{ft}{ft}$

$A1000PR := Pwidth \cdot (BRtop - BRbot)$ $A1000PR = 65000\ ft^2$

$Qpit1000PR := Kbr \cdot I1000PR \cdot A1000PR$ $Qpit1000PR = 0.00171\ \frac{ft^3}{sec}$

$$CRFavg1000PR := \frac{Qpit1000PR}{(Qpit1000PR + Qriveravg)} \qquad CRFavg1000PR = 1.02 \cdot 10^{-6}$$

$$CRFlow1000PR := \frac{Qpit1000PR}{(Qpit1000PR + Qriverlow)} \qquad CRFlow1000PR = 4.14 \cdot 10^{-6}$$

Scenario #3 - Flow In Pit Between MW-1013 - MW-1014 :

$$I1013\_1014 := \frac{(MW1014el - MW1013el)}{Distance1013\_1014} \qquad I1013\_1014 = 0.0058\ \frac{ft}{ft}$$

$$A1013\_1014 := Pwidth \cdot \left(\left(\frac{MW1014el + MW1013el}{2}\right) - Pitbot\right) \qquad A1013\_1014 = 116649\ ft^2$$

$$Qpit1013\_1014 := Kpit \cdot I1013\_1014 \cdot A1013\_1014 \qquad Qpit1013\_1014 = 0.00022\ \frac{ft^3}{sec}$$

$$CRFavg1013\_1014 := \frac{Qpit1013\_1014}{(Qpit1013\_1014 + Qriveravg)} \qquad CRFavg1013\_1014 = 1.3 \cdot 10^{-7}$$

$$CRFlow1013\_1014 := \frac{Qpit1013\_1014}{(Qpit1013\_1014 + Qriverlow)} \qquad CRFlow1013\_1014 = 5.29 \cdot 10^{-7}$$

Incremental Concentration Increase (ICI) to Flambeau River:

Note: The MW-1013 - Flambeau River CRF was used in the calculations since of the three options evaluated, it provides for the highest CRF (and concentrations) and is therefore conservative.

$$ICIavg\_cu := CRFavg1013 \cdot Ccu \qquad ICIavg\_cu = \left(6.635 \cdot 10^{-7}\right)\ \frac{mg}{L}$$

$$ICIlow\_cu := CRFlow1013 \cdot Ccu \qquad ICIlow\_cu = \left(2.707 \cdot 10^{-6}\right)\ \frac{mg}{L}$$

$$ICIavg\_fe := CRFavg1013 \cdot Cfe \qquad ICIavg\_fe = \left(2.15 \cdot 10^{-5}\right)\ \frac{mg}{L}$$

$$ICIlow\_fe := CRFlow1013 \cdot Cfe \qquad ICIlow\_fe = \left(8.772 \cdot 10^{-5}\right)\ \frac{mg}{L}$$

$$ICIavg\_mn := CRFavg1013 \cdot Cmn \qquad ICIavg\_mn = \left(4.102 \cdot 10^{-5}\right)\ \frac{mg}{L}$$

$$ICIlow\_mn := CRFlow1013 \cdot Cmn \qquad ICIlow\_mn = \left(1.674 \cdot 10^{-4}\right)\ \frac{mg}{L}$$

$CIavg\_so4 := CRFavg1013 \cdot Cso4$

$ICIavg\_so4 = 0.002 \frac{mg}{L}$

$ICIlow\_so4 := CRFlow1013 \cdot Cso4$ $\quad ICIlow\_so4 = 0.01 \frac{mg}{L}$

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Attachment 2

Flambeau Mine Groundwater Monitoring Reduction Evaluation – Intervention Boundary and Other Wells used for Groundwater Elevation Monitoring

Foth

Technical Memorandum

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November 9, 2018

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Leland Roberts, Rio Tinto

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RE: Flambeau Mine Groundwater Monitoring Reduction Evaluation – Intervention Boundary and Other Wells used for Groundwater Elevation Monitoring

1 Introduction

Quarterly groundwater monitoring at the Reclaimed Flambeau Mine (Flambeau) has been ongoing in accordance with the *Mine Permit* (IH-89-14) since site closure in October 1998 – 20 years ago. Groundwater quality and water elevation are monitored at several intervention boundary wells located outside the boundary of the backfilled pit, including MW-1000R, MW-1000PR, MW-1002, MW-1002G, MW-1004, MW-1004P, MW-1004S, MW-1005, MW-1005P, MW-1005S, and MW-1010P. Wells MW-1015A and MW-1015B, also monitored for groundwater quality and water elevation, are located approximately 1,000 feet northwest of the backfilled pit and adjacent to the compliance boundary. In addition, groundwater elevations have been monitored at several other wells and piezometers located outside the boundary of the backfilled pit, including MW-1001, MW-1001G, MW-1001P, MW-1003, MW-1003P, PZ-1006, PZ-1006G, PZ-1006S, PZ-1007S, PZ-1008, PZ-1008G, PZ-1009, PZ-1009G, PZ-1011, PZ-1012, PZ-R1, PZ-S1, PZ-S3, OW-7, OW-10, OW-39, OW-42, OW-43, ST-9-23, ST-9-23A, ST-9-26 and Sandpoint. Well locations are shown on Figure 1.

The *Mine Permit* (IH-89-14) allows for a reduction in groundwater monitoring once certain conditions are met for in-pit wells. However, the *Mine Permit* does not define the specific requirements that need to be met prior to reducing monitoring frequency at intervention boundary wells and other wells used for groundwater elevation monitoring.

This memorandum evaluates data from the intervention boundary wells and other wells used for groundwater elevation monitoring to substantiate that conditions justify a reduction in groundwater monitoring in these wells. Section 2 summarizes the purpose of this memo and the proposed reduction in the scope of sample frequency, number of analytes measured and number of locations monitored. Section 3 presents the framework used to assess the monitoring reduction request. Section 4 presents the evaluation results, which are used as the basis for the conclusions in Section 5 and recommendations for the reduced groundwater monitoring program in Section 6.

2 Purpose

The purpose of this memorandum is to:

1. Outline the regulatory framework for requesting a reduction in groundwater monitoring and define the approach for meeting the regulatory requirements.
2. Summarize the data evaluation performed to support groundwater monitoring reduction.
3. Demonstrate how the data supports a reduction in groundwater monitoring.
4. Present a proposal for a reduced groundwater monitoring program, to include:
    a. reducing groundwater quality monitoring frequency from quarterly to annually at the intervention boundary wells and the MW-1015 well nest;
    b. reducing the number of analytes measured in the intervention boundary wells and the and the MW-1015 well nest which are currently sampled annually; and
    c. reducing the number of wells in the network where groundwater elevation is monitored.

3 Monitoring Reduction Regulatory Framework

This section describes the regulatory framework pertinent to the long term monitoring program for the intervention boundary wells, the MW-1015 well nest and other wells used for groundwater elevation monitoring. No specific guidance regarding monitoring reduction at these wells is defined in the *Mine Permit*, guidance from the *Updated Monitoring Plan* (Foth & Van Dyke and Associates, Inc., 1991) as it is defined for In-Pit wells has been used as a rubric. The *Updated Monitoring Plan*, prepared in accordance with the *Mine Permit*, recognizes that a reduction in monitoring is appropriate once water levels in wells have stabilized. Specifically, Section 3.1.3.3 of the *Updated Monitoring Plan* cites:

> "*Quarterly water level measurements at wells MW 1013G, 1013P, 1014G, and 1014P,* ***as well as all wells used for this purpose during construction and operations monitoring*** *(Figure 2-1) shall be continued into the long-term care and maintenance period,* ***until water levels are stabilized****. Water levels shall be deemed as stable when no significant net annual changes occur in water levels over a two-year period. An acceptable range of annual fluctuations in groundwater levels shall be based on a statistical analysis of observed pre-mining annual fluctuation ranges of those wells with a pre-mining monitoring record which are to be included in the long-term monitoring*

program. To the extent technically feasible, the entire record of pre-mining water level measurements from the applicable wells shall be considered when determining the normal or acceptable annual fluctuation range.

The average annual range will be based on the combined average of the annual fluctuation ranges of all the wells presently on-site that are to be included in the long-term monitoring program, plus or minus one standard deviation. During the post-reclamation period as the water table recovers, the net annual fluctuation should be relatively large, showing an upward movement of the water table. As stability is approached, this net upward fluctuation will be reduced through time, eventually falling back into the average annual range that exists today. When the average annual fluctuation falls within this range for two consecutive years, the water table will then be deemed to have stabilized. At this point, water level measurements will only be taken at wells for which water quality sampling is performed."

Note that MW-1013G, MW-1013P, MW-1014G, and MW-1014P were the original monitoring wells located within the boundary of the pit prior to its excavation. Once mining and backfill was complete, two well nests were installed in similar locations: the MW-1013 well nest being comprised of wells MW-1013, MW-1013A, MW-1013B, and MW-1013C; and the MW-1014 well nest being comprised of wells MW-1014, MW-1014A, MW-1014B, and MW-1014C. As quoted above, the guidance indicates that the following conditions should be met prior to a reduction in groundwater monitoring:

1. No significant net changes occur in the average annual water level fluctuation over a two-year period when compared to an acceptable annual fluctuation range.

2. An acceptable annual fluctuation range is based on the combined average of the annual fluctuation ranges of all wells presently on-site included in the long-term monitoring program, plus or minus one standard deviation.

4 Evaluation of Results

4.1 Water Levels

Variation plots and hydrographs of the historical groundwater elevations were constructed for the intervention boundary wells, the MW-1015 well nest and other wells used for groundwater elevation monitoring. The variation plots and hydrographs are illustrated in Attachment 1.

4.1.1 Variation Plots

The variation plots (Attachment 1, Figures 1-1a through 1-1n) illustrate the range of groundwater elevations observed between various time periods, as well as the average groundwater elevation for each period. The data are grouped into the periods of pre-construction (January 1989 through April 1991), pre-ore removal (July 1991 through January 1993), mining period (April 1993 through July 1997), and post-mining (October 1997 through June 2018). The post-mining period is further divided into three groupings: October 1997 through 2002 (immediate five years following mining); 2003 through 2016 Q3, and the most recent two years of 2016 Q4 through 2018 Q3.

The variation plots illustrate the lower average groundwater elevations during the mining period, followed by subsequent recovery. While the post-mining 1997 through 2002 datasets show recovering groundwater elevations, average elevations in many wells for the post-mining 2003 through 2016 Q3 period approach the pre-construction and pre-ore removal elevations. During the most recent two years (2016 Q4 through 2018 Q3), almost all well nests had higher averages than the pre-construction and pre-ore removal periods excepting well nests MW-1003 and MW-1004. While average elevations in these two well nests are below pre-ore removal levels, groundwater elevations over the most recent two years have been stable or decreasing.

In addition to the average elevation results, the variation plots illustrate the generally tighter range of groundwater fluctuations observed during the pre-construction and pre-ore removal time periods, followed by the larger fluctuations observed during the mining period (April 1993 through July 1997) and immediate five years following mining (October 1997 through 2002). While groundwater fluctuation subsequently reduced following 2002, more recent data indicates an increase in the fluctuation range, affected in large by variation observed in precipitation. A comparison of groundwater fluctuation to precipitation totals is provided on Figure 2.

Figure 2 illustrates the average annual groundwater fluctuation ranges between 2003 and 2018 Q3, calculated by averaging the individual annual fluctuation range by year for each well across the on-site well set currently in the long-term monitoring program. The pre-construction and pre-ore removal average fluctuation range plus or minus one standard deviation is also presented on Figure 2 for reference. Finally, the precipitation data since 2007 (including estimated snowfall melt) is further presented based on NOAA station number USC00474391 (LADYSMITH 3 W, WI US). It can be seen on Figure 2 that the more recent larger annual fluctuations observed in 2010, 2013, 2014 and 2017 correlate with higher precipitation years.

4.1.2 Hydrographs

To further support the observations made above from the variation plots, hydrographs (presented in Attachment 1, Figures 1-2a through 1-2n) illustrate water levels in all wells with significant drawdown during the production period of 1993 to 1997 generally appear to have stabilized by 2003. Again somewhat correlating with the precipitation data illustrated on Figure 2, higher groundwater elevations are noted during 2010 and 2011, but reduced in 2012. Elevations again rebounded in 2014 corresponding to increased precipitation, and remained elevated through 2017. Fluctuating elevations were again observed in the 2018 data.

4.1.3 Monitoring Plan Criteria

As stated in Section 3, while no specific guidance is defined in the *Mine Permit* regarding monitoring reduction at the intervention boundary wells, the MW-1015 well nest and other wells used for groundwater elevation monitoring, the guidance from the *Updated Monitoring Plan* as it is defined for In-Pit wells is here used as a rubric. Specifically, the average of the annual fluctuation ranges for each well across the on-site well set is compared for each year to the average of the annual fluctuation ranges observed in the pre-construction and pre-ore removal datasets plus or minus one standard deviation. Note that the plus or minus one standard deviation range is illustrated on Figure 2.

A summary of the calculated average annual groundwater fluctuations is provided in Table 1. The average annual fluctuation, calculated as the average of the annual elevation range found within each well, is 1.96 feet for the pre-construction and pre-ore removal time periods, with a one-standard deviation range of 0.53 to 3.39 feet.

Table 1

Average Annual Elevation Range Comparison to Intervention Boundary Wells and Other Wells

Period	Count	Average (ft.)	St. Dev. (ft.)	Avg + St. Dev. (ft.)	Avg – St. Dev. (ft.)
All Long Term Monitoring Wells					
Jan. 1989 through Dec. 1992	78	1.96	1.43	3.39	0.53
Intervention boundary wells and other wells used for groundwater elevation monitoring wells					
2003	39	2.04			
2004	38	2.67			
2005	38	1.27			
2006	38	2.17			
2007	37	1.71			
2008	39	3.26			
2009	38	1.22			
2010	38	4.27			
2011	40	2.37			
2012	39	2.66			
2013	39	3.94			
2014	40	5.36			
2015	40	2.77			
2016	40	1.60			
2017	40	3.79			
2018 thru Q3	40	2.61			

Avg = average
St. Dev. = standard deviation
ft = feet

Prepared by: SGL
Checked by: ASH1

Per the *Updated Monitoring Plan* criteria, the average annual fluctuation falls within this range for two consecutive years a total of eight times since 2003 (Table 1). The only years since 2003 which have observed annual fluctuations greater than 3.39 feet (i.e., the mean plus one standard deviation) are 2010, 2013, 2014 and 2017. These are associated with years of increased precipitation illustrated on Figure 2. Therefore, the water table is deemed to have stabilized and recent fluctuations are the result of environmental conditions.

4.2 Water Chemistry

4.2.1 Trend Evaluation and Monitoring Optimization

Unlike the In-Pit wells, no specific guidance regarding monitoring reduction based on chemistry is defined in the *Mine Permit* or *Updated Monitoring Plan* for the intervention boundary wells and MW-1015 well nest. Therefore, the proposed reduction in monitoring frequency, as well as elimination of certain analytes currently sampled only annually, is based upon other published optimization algorithms.

With water chemistry, analyses of concentration trends are performed on the analytical data to determine if quarterly sampling is necessary, or if redundant information is being gathered which could be optimized. Guidance for monitoring optimization is presented in various sources, such as Reducing or Terminating Groundwater Monitoring at Solid Waste Landfills (WDNR, 2014), Roadmap to Long-Term Monitoring Optimization (USEPA, 2005), Long-Term Groundwater Monitoring – The State of the Art (ASCE, 2003), Cost Effective Sampling algorithm (CES, Ridley, and MacQueen, 1995), and the Monitoring and Remediation Optimization System (MAROS, AFCEE, 2012). The CES method provides an optimal well sampling frequency based on statistics describing the trend, variability and magnitude of concentrations. The MAROS temporal optimization algorithm is similar to the CES method and is referred to as the Modified CES method.

The Modified CES algorithm evaluates temporal trend data relative to a given concentration threshold such as a groundwater standard or other value. The observed trend relative to the concentration threshold is referred to as the "rate of change," or ROC. For example, a trend of 5 µg/L/year relative to a standard of 5 µg/L would have an ROC of 1.0. A very low ROC can imply that sample data is being collected on a monitoring schedule that is more frequent than necessary to informatively evaluate site conditions. In other words, redundant data is being collected. At times, a statistically significant trend may even be present, but only with a very low ROC, implying only a minimal change in actual concentration levels relative to the given concentration threshold.

The concentration threshold for calculating the ROC in this analysis was taken as the well-specific concentration average prior to ore-removal (prior to April 1993) if available. Where no well-specific data prior to ore-removal exists (i.e., MW-1000R, MW-1004, MW-1015A and MW-1015B for all quarterly parameters, arsenic in all wells and annual parameters in all wells), no ROC is calculated.

The Modified CES algorithm optimizes sampling frequencies based on statistics describing the statistical significance of an observed trend, the corresponding ROC and the magnitude of concentrations. The ROC is considered to be low if the concentration trend during a one-year period is less than half of a given threshold value, while a high ROC indicates a trend that is twice the threshold value. Using the ROC and statistical trend results, general sampling frequency recommendations of quarterly, semiannual or annual are provided in the MAROS algorithm (AFCEE, 2012). A general overview of the algorithm providing further details on determination of recommended sampling frequencies is provided in Attachment 2.

4.2.2 Temporal Trend Analyses and Optimization Results

Summaries of the trend test results and results of the ROC analyses are provided in Table 2 for the quarterly parameters and in Table 3 for the annual parameters. Detailed results of the analysis are provided in Attachment 3 for the quarterly parameters and Attachment 4 for the annual parameters. Historical trend graphs of the quarterly and annual parameters are also provided in Attachments 3 and 4, respectively.

Both the statistical trend tests and ROC analyses of the quarterly parameters (Attachment 3) and annual parameters (Attachment 4) were performed on the most recent five years of data (i.e., 2013 Q4 through 2018 Q3). In addition, the statistical trend tests and ROC analyses of quarterly parameters (Attachment 3) were also performed on the most recent two years of data (i.e., 2016 Q4 through 2018 Q3). For the quarterly data, this provides an assessment of not only longer term trends over the past five years, but also recent short term trends.

The trend tests were performed by the nonparametric Mann-Kendall statistical test for trend. Based on the statistical significance level of the trend test result, the trend conclusion in Attachments 3 and 4 is given as follows: D = decreasing; PD = probably decreasing; I = increasing; PI = probably increasing; S = stable; NT = no trend. The ROC analysis, performed through linear regression, is summarized as: L = low; LM = low to medium; M = medium; MH = medium to high; H = high.

The trend analysis and optimization results for the quarterly parameters are summarized in Table 2. (As noted above, no ROC is calculated for arsenic, or for MW-1000R, MW-1004, MW-1015A and MW-1015B with all quarterly parameters since no well-specific data prior to ore-removal is available for those cases.) Most of the quarterly trends have a low ROC with both the previous 5-year and previous 2-year data. In addition, a large majority of the trend results have either no statistical trend or a statistically decreasing trend. The noted increasing trends in Table 2 have low ROCs with respect to observed concentrations prior to ore removal. Based on trend graphs presented in Attachment 3, the only visually apparent recent trends are for hardness, manganese and TDS in MW-1005, which have shown increases between 2013 and 2017. However, as stated, compared to pre-ore removal concentration levels, these trends still have low change rates. In addition, as stated in the *2017 Annual Report* (Foth, 2018a), the increase in these parameters may be due to application of road salt on State Highway 27, which is proximal to the well location. Additional contributing factors may include rising water levels and evaporative concentration effects, which was supported in the 2018 data where lower water levels corresponded to lower observed concentrations of these parameters.

Little additional information is therefore gained from collecting samples on a quarterly basis, and it is recommended the monitoring program be reduced to annual frequency rather than quarterly.

The trend analysis and optimization results for the annual parameters are summarized in Table 3. (As noted above, no ROC is calculated for the annual parameters since no data prior to ore-removal is available to use as a basis for the calculation.) With the annual parameters, the vast majority of parameter trends were either decreasing or no trend. A review of the annual water chemistry data trends (Attachment 4) shows that concentrations generally have either no trend or decreasing trends, with the exception of barium, calcium, chloride, magnesium and sodium in MW-1005. As discussed above with the quarterly parameters, this well may be affected by local conditions including road salting.

5 Conclusions

Water level results in the intervention boundary and other non-in-pit wells have been consistent generally since 2003, and variation has been comparable with that observed in the pre-construction (January 1989 through April 1991) and pre-ore removal (July 1991 through January 1993) datasets. Few significant trends are occurring in water chemistry for these wells, with the only visually apparent recent trends being for certain parameters in upgradient well MW-1005 as noted in the 2016 and 2017 Annual Report and the results of Section 4 above. Temporal optimization results indicate that information collected more than annually is redundant for most of these wells.

In addition, geochemical modeling indicates that conditions of equilibrium or near equilibrium are prevalent in the backfilled pit (Foth, 2018a). Further, results presented in Sections 4 and 5 in the November 9, 2018 technical memorandum (Foth, 2018b) indicate that the regulatory conditions defined for Flambeau to obtain approval for a reduced groundwater monitoring plan for the in-pit wells have been met and a reduction in groundwater monitoring at the Reclaimed Flambeau Mine Site is hydrologically appropriate.

6 Recommendations to Reduce Groundwater Monitoring

The current and proposed monitoring plans are provided in Table 4 for the intervention boundary and other non-in-pit wells. A monitoring reduction of all parameters and water levels from quarterly to annual sampling is recommended. Annual sampling, proposed to take place in the third quarter, will allow for a sufficient evaluation of the continuation of steady state conditions. Additionally, as presented in Foth 2018b, it is recommended that barium, cadmium, chromium, mercury, selenium, silver, and laboratory pH be dropped from the monitoring program. Furthermore, it is recommended that groundwater elevation measurements only be collected at the locations specified in Table 4.

7 References

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Tables

Table 2

Results of Trend Analysis and Rate of Change Analysis
Quarterly Parameters

Analyte		Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)				Analysis of 2016Q4 Through 2018Q3 (Previous 2 Years)		
		Trend Conclusion	Rate of Change Conclusion	% Detects		Trend Conclusion	Rate of Change Conclusion	% Detects
MW-1000PR								
	Alkalinity	S	Low	100%		NT	Low	100%
	Arsenic	I	N/A	100%		NT	N/A	100%
	Copper	NT	Low	80%		NT	LM	75%
	Hardness	D	Low	100%		D	Low	100%
	Iron	NT	Low	100%		PI	LM	100%
	Manganese	D	Low	100%		D	Low	100%
	Sulfate	PD	Low	100%		NT	High	100%
	TDS	D	Low	100%		S	Low	100%
MW-1000R								
	Alkalinity	D	N/A	100%		S	N/A	100%
	Arsenic	NT	N/A	30%		NT	N/A	13%
	Copper	D	N/A	100%		PD	N/A	100%
	Hardness	D	N/A	100%		S	N/A	100%
	Iron	NT	N/A	20%		NT	N/A	13%
	Manganese	D	N/A	100%		D	N/A	100%
	Sulfate	D	N/A	100%		D	N/A	100%
	TDS	D	N/A	100%		S	N/A	100%
MW-1002								
	Alkalinity	NT	Low	100%		S	Low	100%
	Arsenic	NT	N/A	5%		S	N/A	0%
	Copper	NT	Low	40%		NT	Low	38%
	Hardness	PD	Low	100%		D	Low	100%
	Iron	NT	Low	20%		NT	Low	25%
	Manganese	NT	Low	25%		NT	Low	25%
	Sulfate	D	Low	100%		D	Low	100%
	TDS	NT	Low	100%		D	Low	100%
MW-1002G								
	Alkalinity	I	Low	100%		I	Low	100%
	Arsenic	S	N/A	0%		S	N/A	0%
	Copper	NT	Low	25%		PD	Low	25%
	Hardness	I	Low	100%		S	Low	100%
	Iron	NT	Low	20%		NT	Medium	25%
	Manganese	NT	Low	35%		PD	Low	25%
	Sulfate	I	Low	100%		NT	Low	100%
	TDS	I	Low	100%		S	Low	100%
MW-1004								
	Alkalinity	NT	N/A	100%		PI	N/A	100%
	Arsenic	NT	N/A	5%		S	N/A	0%
	Copper	D	N/A	100%		D	N/A	100%
	Hardness	NT	N/A	100%		NT	N/A	100%
	Iron	NT	N/A	60%		PD	N/A	50%
	Manganese	NT	N/A	65%		D	N/A	63%
	Sulfate	S	N/A	100%		NT	N/A	100%
	TDS	NT	N/A	100%		NT	N/A	100%

Table 2

Results of Trend Analysis and Rate of Change Analysis
Quarterly Parameters

Analyte		Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)				Analysis of 2016Q4 Through 2018Q3 (Previous 2 Years)		
		Trend Conclusion	Rate of Change Conclusion	% Detects		Trend Conclusion	Rate of Change Conclusion	% Detects
MW-1004P								
	Alkalinity	I	Low	100%		S	Low	100%
	Arsenic	I	N/A	60%		S	N/A	88%
	Copper	NT	Low	10%		NT	Low	13%
	Hardness	I	Low	100%		S	Low	100%
	Iron	NT	Low	100%		S	Low	100%
	Manganese	NT	Low	100%		S	Low	100%
	Sulfate	I	Low	70%		NT	Low	100%
	TDS	I	Low	100%		PD	Low	100%
MW-1004S								
	Alkalinity	D	Low	100%		I	Low	100%
	Arsenic	NT	N/A	5%		S	N/A	0%
	Copper	PI	Low	100%		NT	Low	100%
	Hardness	D	Low	100%		I	Low	100%
	Iron	NT	Low	10%		NT	Low	13%
	Manganese	I	Low	40%		NT	Low	50%
	Sulfate	D	Low	100%		I	Low	100%
	TDS	D	Low	100%		S	Low	100%
MW-1005								
	Alkalinity	I	Low	100%		NT	Low	100%
	Arsenic	S	N/A	95%		S	N/A	100%
	Copper	D	Low	70%		NT	Low	50%
	Hardness	I	Low	100%		NT	Low	100%
	Iron	I	Low	100%		S	Low	100%
	Manganese	I	Low	100%		S	Low	100%
	Sulfate	I	Low	100%		I	Low	100%
	TDS	I	Low	100%		S	Low	100%
MW-1005P								
	Alkalinity	I	Low	100%		PD	Low	100%
	Arsenic	NT	N/A	35%		NT	N/A	38%
	Copper	NT	Low	30%		PD	Low	25%
	Hardness	I	Low	100%		S	Low	100%
	Iron	I	Low	100%		NT	Low	100%
	Manganese	S	Low	100%		S	Low	100%
	Sulfate	NT	Low	10%		S	Low	0%
	TDS	NT	Low	100%		NT	Low	100%
MW-1005S								
	Alkalinity	D	Low	100%		D	Low	100%
	Arsenic	S	N/A	100%		S	N/A	100%
	Copper	NT	Low	5%		S	Low	0%
	Hardness	D	Low	100%		D	Low	100%
	Iron	D	Low	100%		S	Low	100%
	Manganese	D	Low	100%		D	Low	100%
	Sulfate	I	Low	40%		NT	Low	63%
	TDS	D	Low	100%		S	Low	100%

Table 2

Results of Trend Analysis and Rate of Change Analysis
Quarterly Parameters

Analyte	Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years) Trend Conclusion	Rate of Change Conclusion	% Detects		Analysis of 2016Q4 Through 2018Q3 (Previous 2 Years) Trend Conclusion	Rate of Change Conclusion	% Detects
MW-1010P							
Alkalinity	I	Low	100%		S	Low	100%
Arsenic	NT	N/A	100%		S	N/A	100%
Copper	I	Low	40%		NT	Low	63%
Hardness	PI	Low	100%		S	Low	100%
Iron	NT	Low	10%		NT	Low	13%
Manganese	PI	Low	100%		S	Low	100%
Sulfate	I	Low	100%		S	Low	100%
TDS	I	Low	100%		NT	Low	100%
MW-1015A							
Alkalinity	I	N/A	100%		PI	N/A	100%
Arsenic	S	N/A	0%		S	N/A	0%
Copper	NT	N/A	25%		NT	N/A	25%
Hardness	I	N/A	100%		PD	N/A	100%
Iron	NT	N/A	20%		NT	N/A	13%
Manganese	I	N/A	100%		I	N/A	100%
Sulfate	S	N/A	100%		PI	N/A	100%
TDS	I	N/A	100%		S	N/A	100%
MW-1015B							
Alkalinity	NT	N/A	100%		S	N/A	100%
Arsenic	NT	N/A	25%		NT	N/A	13%
Copper	NT	N/A	5%		NT	N/A	13%
Hardness	NT	N/A	100%		S	N/A	100%
Iron	NT	N/A	95%		S	N/A	88%
Manganese	D	N/A	100%		S	N/A	100%
Sulfate	NT	N/A	25%		NT	N/A	25%
TDS	NT	N/A	100%		S	N/A	100%

Notes:
Trend conclusion based on Mann-Kendall nonparametric test. Trend designators are as follows:
D = Decreasing; PD = Probably Decreasing; I = Increasing; PI = Probably Increasing;
S = Stable; NT = No Trend.

Rate of change (ROC) designator based on the results of a linear regression trend line.
LM = Low to Medium; MH = Medium to High.
No ROC is calculated for arsenic, or for MW-1000R, MW-1004, MW-1015A and MW-1015B with all parameters since no well-specific data prior to ore-removal is available.

(Blue) Either stable, no trend or decreasing trend and low rate of change.

(Green) Either a decreasing trend with a medium or high rate of change; or an increasing trend with a low rate of change.

Note that no increasing trends with a medium or high rate of change exist.

Prepared by: SGL
Checked by: ASH1

Table 3
Results of Trend Analysis and Rate of Change Analysis
Annual Parameters

Analyte	Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)			Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)	
	Trend Conclusion	% Detects		Trend Conclusion	% Detects
	MW-1000PR			MW-1000R	
Barium	NT	100%		S	100%
Cadmium	NT	60%		NT	60%
Calcium	S	100%		D	100%
Chloride	PD	100%		S	100%
Chromium	NT	80%		D	60%
Lead	NT	40%		S	0%
Magnesium	S	100%		D	100%
Mercury	NT	20%		S	0%
Potassium	S	100%		D	100%
Selenium	I	60%		NT	40%
Silver	NT	20%		S	0%
Sodium	D	100%		D	100%
Zinc	NT	100%		NT	20%
	MW-1002			MW-1002G	
Barium	S	100%		PI	100%
Cadmium	S	0%		S	0%
Calcium	S	100%		I	100%
Chloride	S	100%		I	100%
Chromium	S	80%		NT	20%
Lead	S	0%		S	0%
Magnesium	S	100%		I	100%
Mercury	S	0%		S	0%
Potassium	S	100%		NT	100%
Selenium	S	0%		S	0%
Silver	S	0%		S	0%
Sodium	S	100%		I	100%
Zinc	S	0%		S	0%
	MW-1004			MW-1004P	
Barium	S	100%		S	100%
Cadmium	S	0%		S	0%
Calcium	NT	100%		I	100%
Chloride	NT	60%		NT	60%
Chromium	NT	40%		S	0%
Lead	NT	20%		S	0%
Magnesium	NT	100%		NT	100%
Mercury	S	0%		S	0%
Potassium	NT	100%		NT	100%
Selenium	NT	20%		S	0%
Silver	S	0%		S	0%
Sodium	S	100%		D	100%
Zinc	NT	20%		S	0%

Table 3
Results of Trend Analysis and Rate of Change Analysis
Annual Parameters

Analyte	Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years) Trend Conclusion	% Detects		Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years) Trend Conclusion	% Detects
	MW-1004S			MW-1005	
Barium	S	100%		I	100%
Cadmium	S	0%		NT	20%
Calcium	S	100%		I	100%
Chloride	D	100%		I	100%
Chromium	S	80%		NT	40%
Lead	S	0%		S	0%
Magnesium	S	100%		I	100%
Mercury	S	0%		S	0%
Potassium	S	100%		NT	100%
Selenium	NT	20%		S	0%
Silver	S	0%		S	0%
Sodium	D	100%		I	100%
Zinc	S	0%		NT	20%
	MW-1005P			MW-1005S	
Barium	NT	100%		D	100%
Cadmium	S	0%		NT	20%
Calcium	NT	100%		S	100%
Chloride	S	100%		NT	80%
Chromium	S	0%		NT	20%
Lead	NT	20%		NT	20%
Magnesium	NT	100%		PD	100%
Mercury	S	0%		S	0%
Potassium	NT	100%		S	100%
Selenium	S	0%		NT	20%
Silver	S	0%		NT	20%
Sodium	S	100%		D	100%
Zinc	S	0%		S	0%
	MW-1010P			MW-1015A	
Barium	NT	100%		S	100%
Cadmium	S	0%		S	0%
Calcium	NT	100%		NT	100%
Chloride	S	100%		NT	100%
Chromium	S	0%		NT	20%
Lead	S	0%		S	0%
Magnesium	NT	100%		NT	100%
Mercury	S	0%		S	0%
Potassium	NT	100%		S	100%
Selenium	S	0%		S	0%
Silver	S	0%		S	0%
Sodium	D	100%		D	100%
Zinc	NT	40%		S	0%

Table 3
Results of Trend Analysis and Rate of Change Analysis
Annual Parameters

Analyte	Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)			Analysis of 2013Q4 Through 2018Q3 (Previous 5 Years)	
	Trend Conclusion	% Detects		Trend Conclusion	% Detects
	MW-1015B				
Barium	NT	100%			
Cadmium	NT	20%			
Calcium	NT	100%			
Chloride	NT	100%			
Chromium	NT	20%			
Lead	S	0%			
Magnesium	NT	100%			
Mercury	S	0%			
Potassium	NT	100%			
Selenium	S	0%			
Silver	S	0%			
Sodium	NT	100%			
Zinc	S	0%			

Notes:
Trend conclusion based on Mann-Kendall nonparametric test. Trend designators are as follows:
D = Decreasing; PD = Probably Decreasing; I = Increasing; PI = Probably Increasing;
S = Stable; NT = No Trend.

Rate of change designator based on the results of a linear regression trend line.
LM = Low to Medium; MH = Medium to High.
No ROC is calculated for the annual parameters since no data prior to ore-removal is available to use as a basis for the calculation.

Either stable, no trend or decreasing trend and low rate of change.

Either a decreasing trend with a medium or high rate of change; or an increasing trend with a low rate of change.

Note that no increasing trends with a medium or high rate of change exist.

Prepared by: SGL
Checked by: ASH1

Table 4
Current and Proposed Monitoring Plan

Current Monitoring Plan		Proposed Monitoring Plan (see notes)
Quarterly	**Annual**	**Annual**
Field	**Field**	**Field**
Color	Color	Color
Odor	Odor	Odor
ORP	ORP	ORP
pH	pH	pH
Water Level	Water Level	Water Level
Specific Conductivity	Specific Conductivity	Specific Conductivity
Temperature	Temperature	Temperature
Turbidity	Turbidity	Turbidity
Laboratory	**Laboratory**	**Laboratory**
Alkalinity	Alkalinity	Alkalinity
Arsenic	Arsenic	Arsenic
Copper	Barium	Calcium
Iron	Cadmium	Chloride
Manganese	Calcium	Copper
Sulfate	Chloride	Iron
TDS	Chromium	Lead
Total Hardness	Copper	Magnesium
pH	Iron	Manganese
	Lead	Potassium
	Magnesium	Sodium
	Manganese	Sulfate
	Mercury	Zinc
	Potassium	TDS
	Selenium	Total Hardness
	Silver	
	Sodium	
	Sulfate	
	TDS	
	Total Hardness	
	Zinc	
	pH	

Notes:

Proposed Monitoring Well Network:

Water Quality Wells (Annual)

Intervention Boundary Wells – MW-1000R, MW-1000PR, MW-1002, MW-1002G, MW-1004, MW-1004P, MW-MW-1005, MW-1005P, MW-1005S, MW-1010P

Other Monitored Wells – MW-1015A, MW-15B

Water Level Wells (Annual)

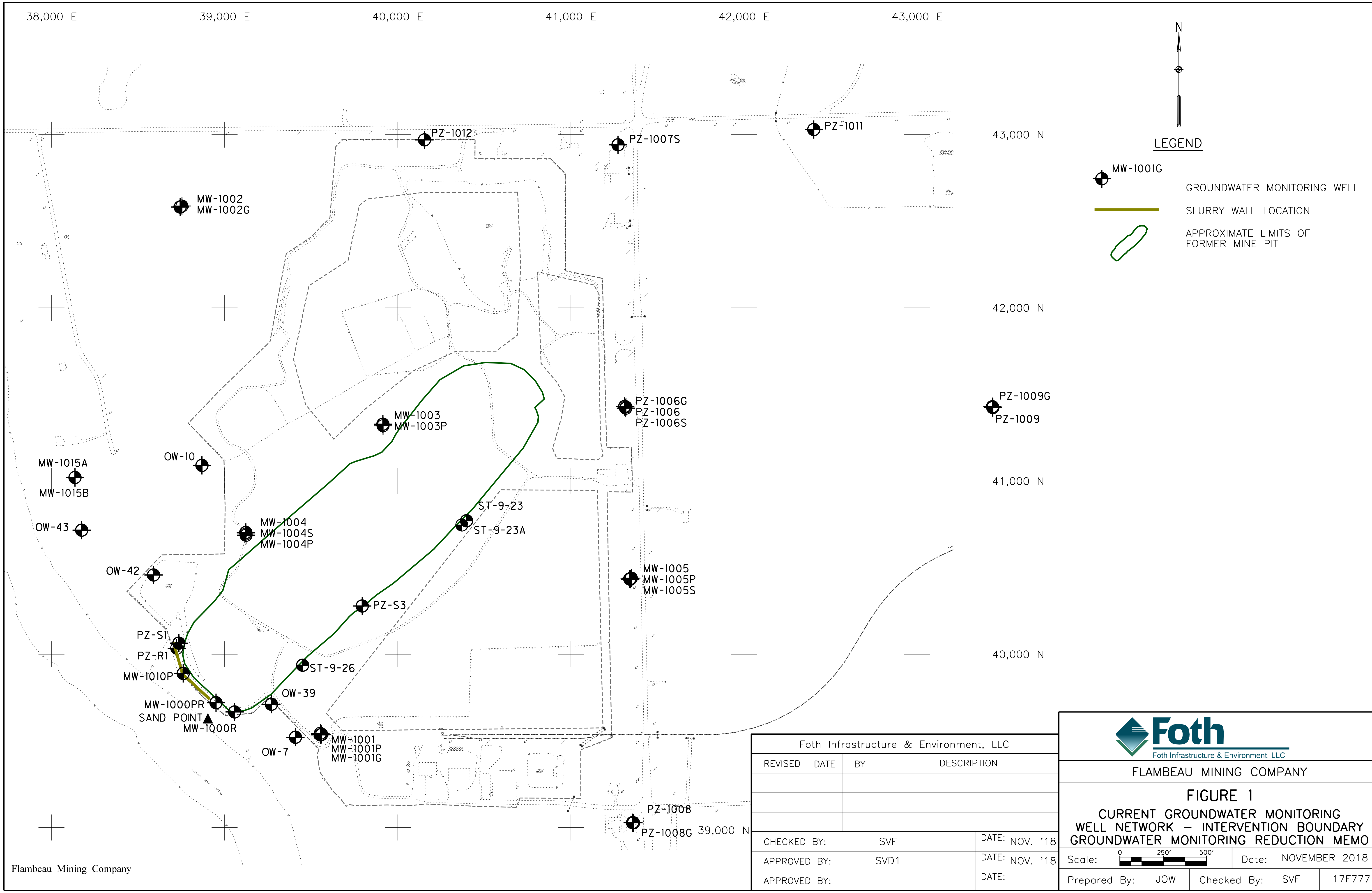
ST-9-23, ST-9-23A, PZ-S3, ST-9-26, OW-39, MW-1001, MW-1001G, MW-1001P

Wells to be Abandoned:

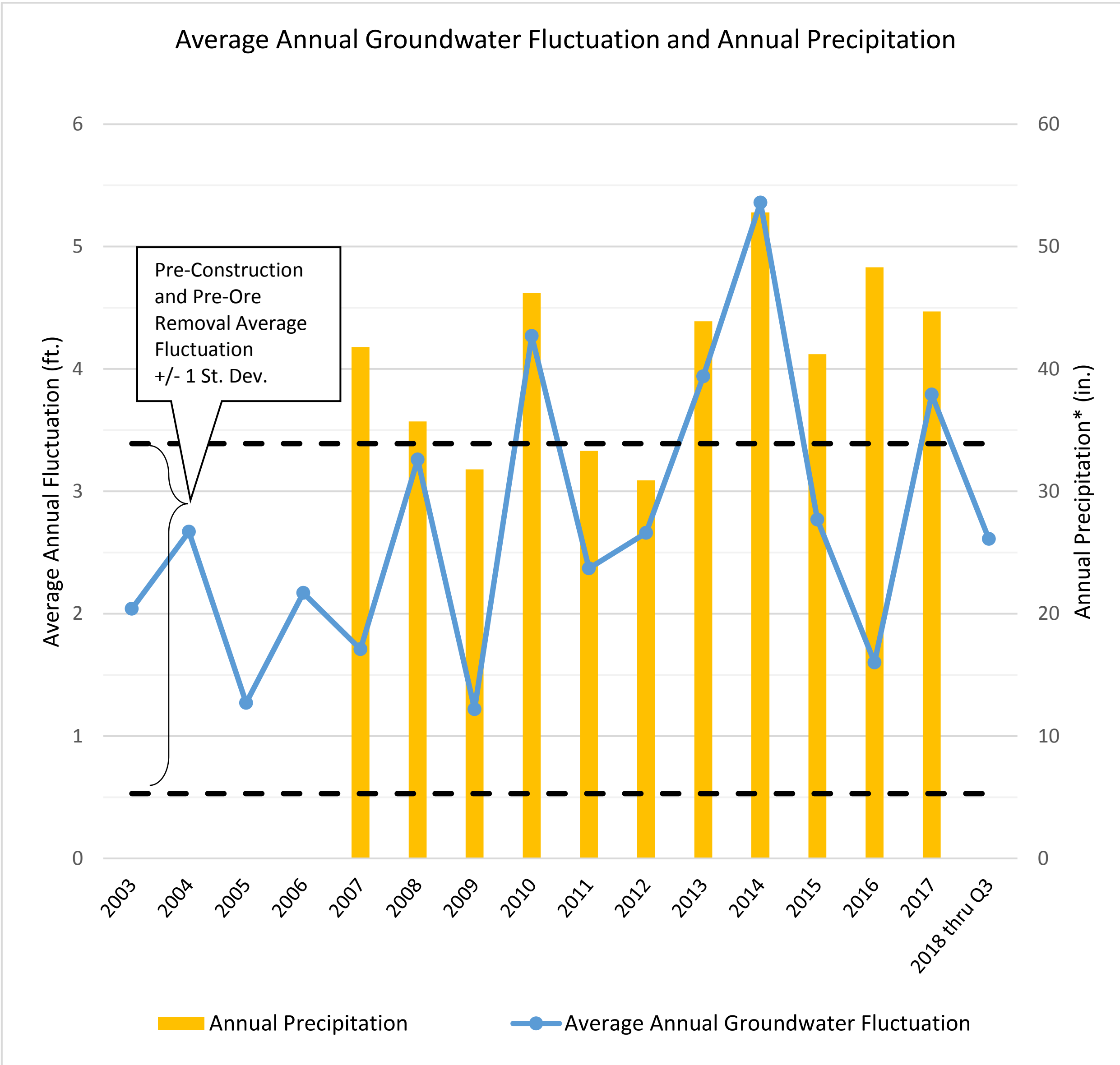
MW-1003, MW-1003P, PZ-1006, PZ-1006G, PZ-1006S, PZ-1007S, PZ-1008, PZ-1008G, PZ-1009, PZ-1009G, PZ-1011, PZ-1012, PZ-R1, PZ-S1, Sandpoint, OW-7, OW-10, OW-42, OW-43, Clay Pipe, WT-5

Prepared by: SVF
Checked by: SGL

Figures



pw:\\PW-APS1.foth.com:PW_IE\Documents\Clients\Flambeau Mining\0017F777.00\CAD\Figures\Groundwater Monitoring Reduction Memo\Figure 1 - Current GW MW Network - Intervention Boundary.dgn
11/5/2018 dat



*Note: Annual precipitation represents the total rain and snowfall, assuming a 10:1 density ratio between snow and rain.

Precipitation data obtained from NOAA station number USC00474391 (LADYSMITH 3 W, WI US). Data for January, May and July of 2011 was missing from the dataset, so 2011 precipitation totals for these months were taken as the average value of these months from years where data existed.

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FIGURE 2
AVERAGE ANNUAL GROUNDWATER FLUCTUATION AND ANNUAL PRECIPITATION

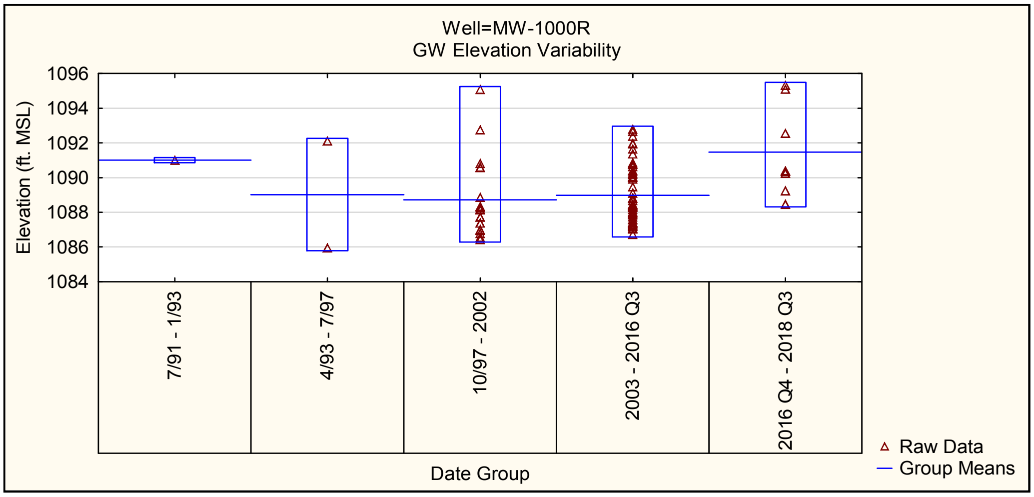
Scale: NA	Date: November 2018

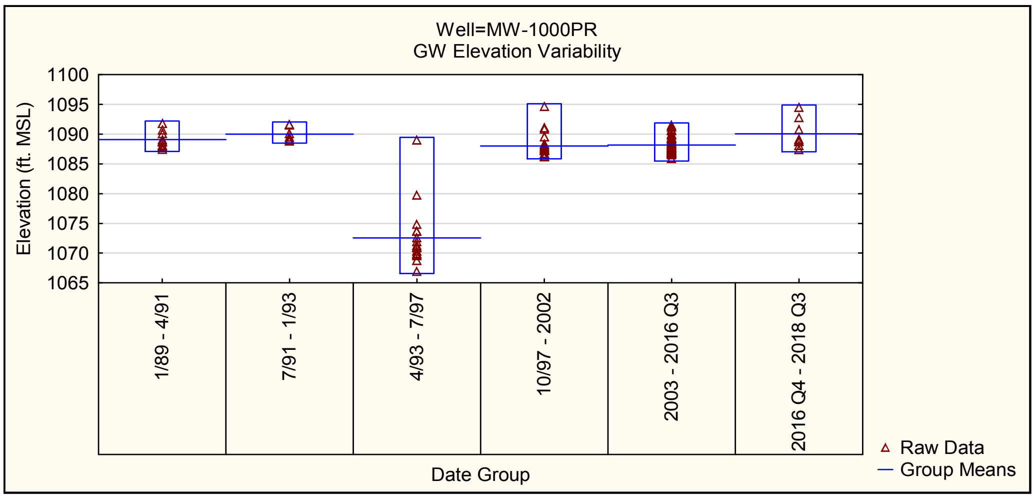
Prepared By: SGL	Checked By: SVF	Project No: 17F777

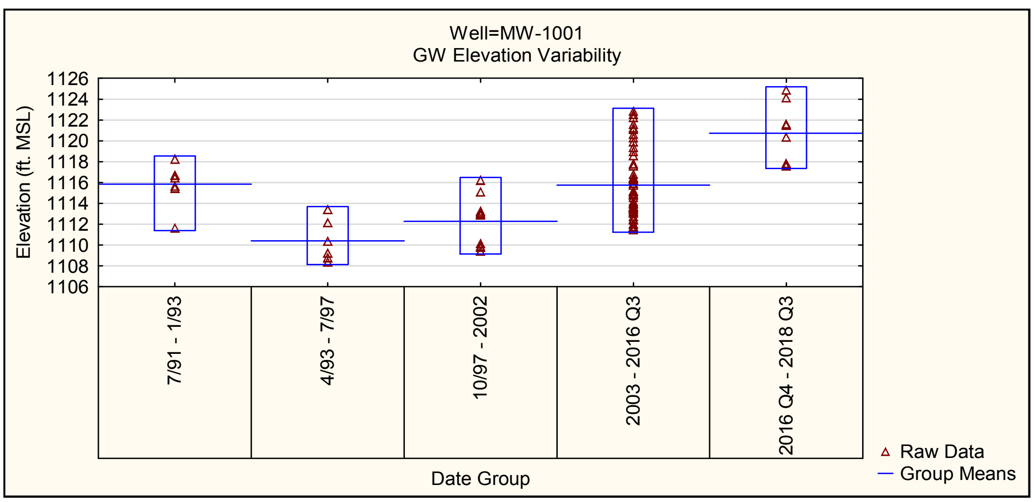
Attachment 1

Groundwater Elevation Variation Graphs and Hydrographs

Intervention Boundary Wells and Other Wells Used for Groundwater Elevation Monitoring







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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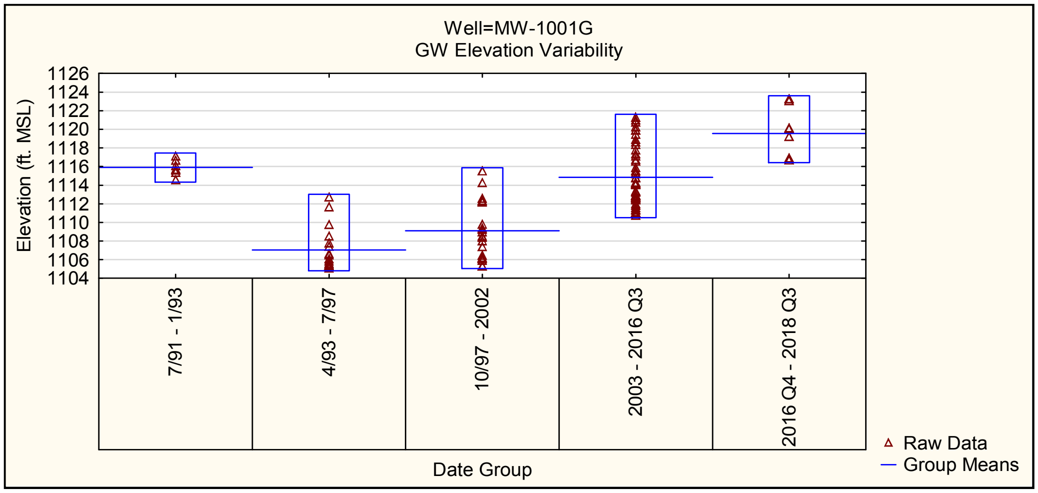
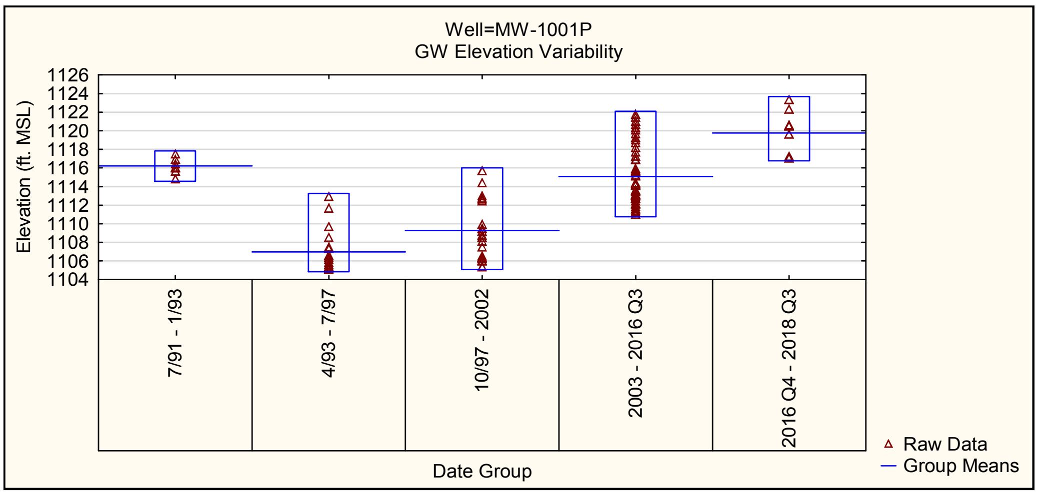
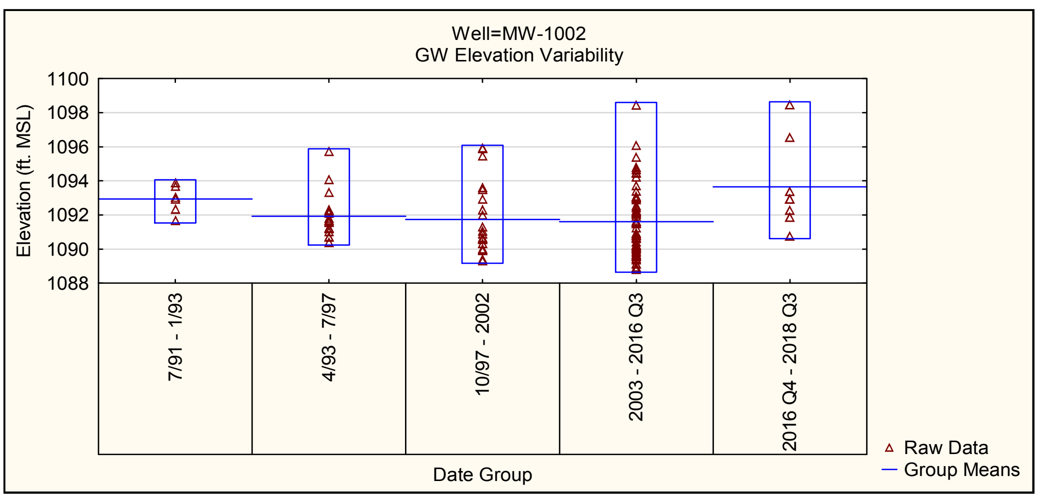
FIGURE 1-1a
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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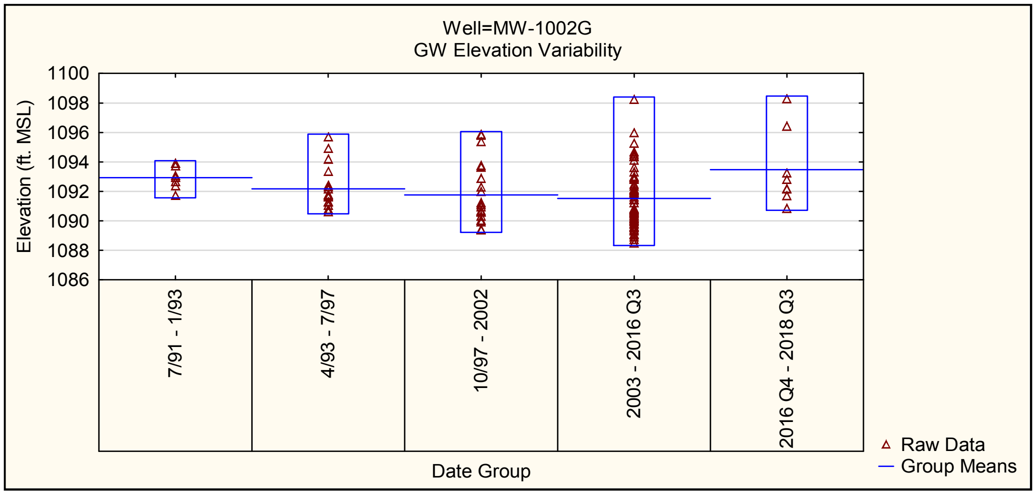
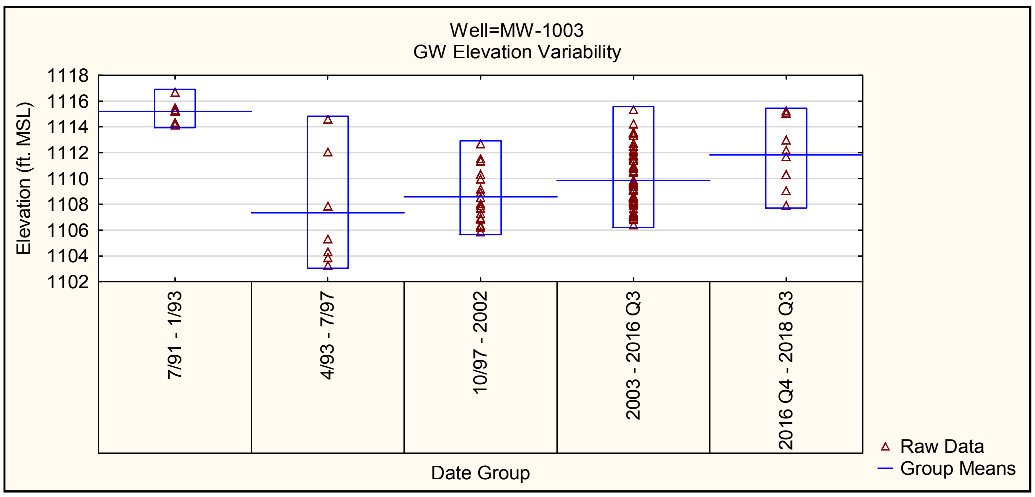
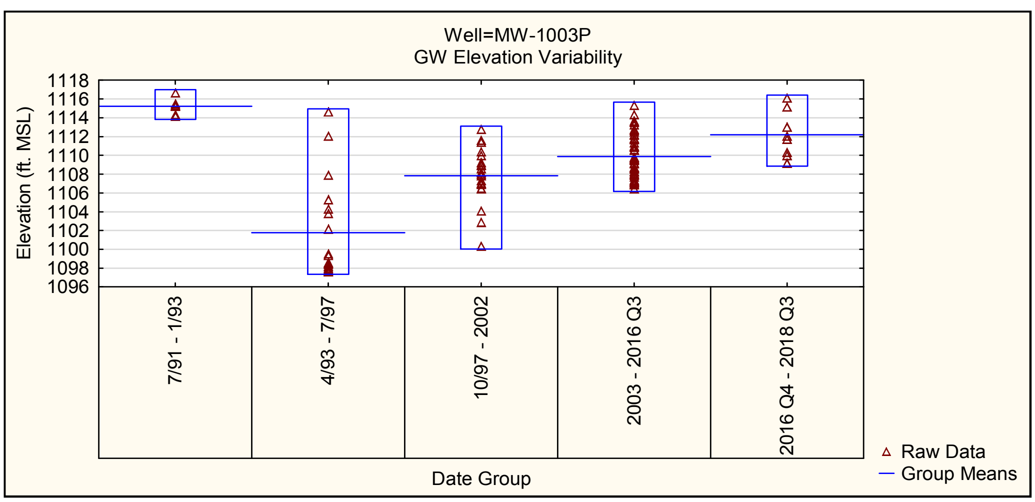
FIGURE 1-1b
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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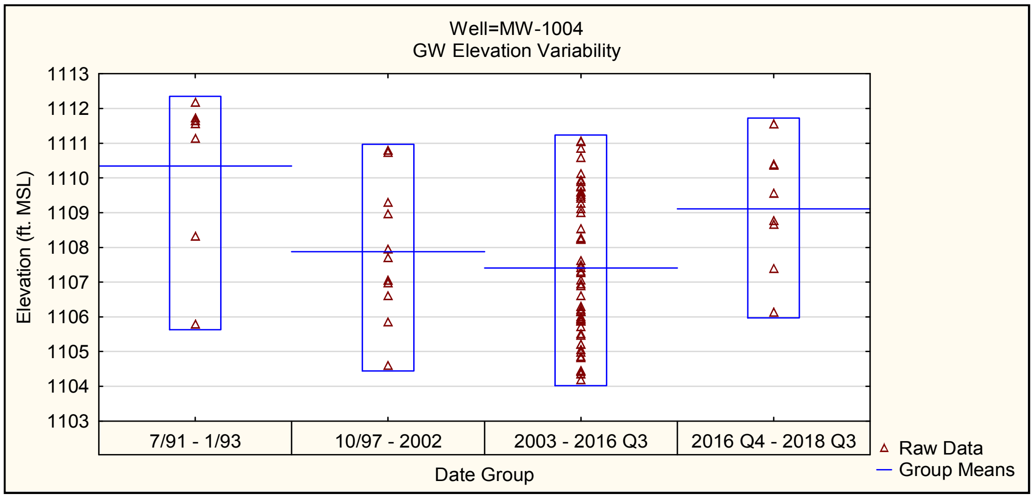
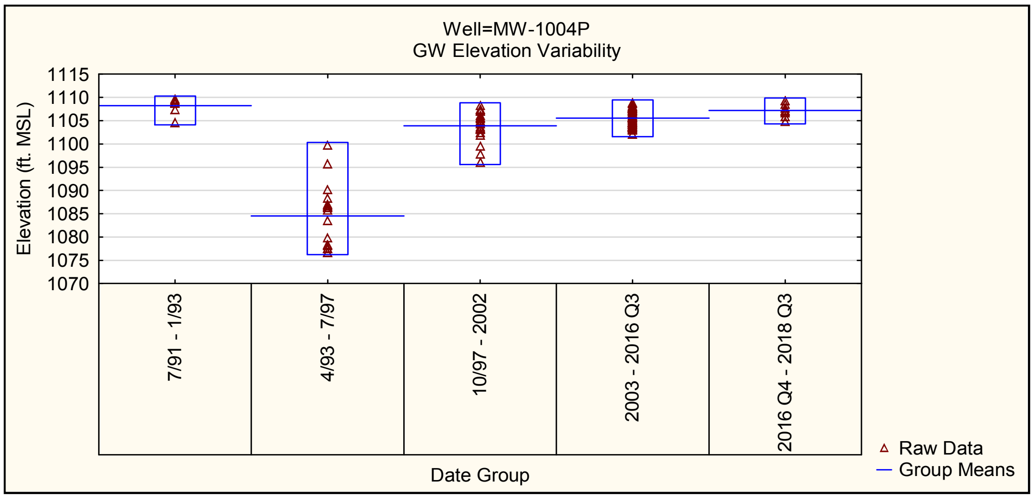
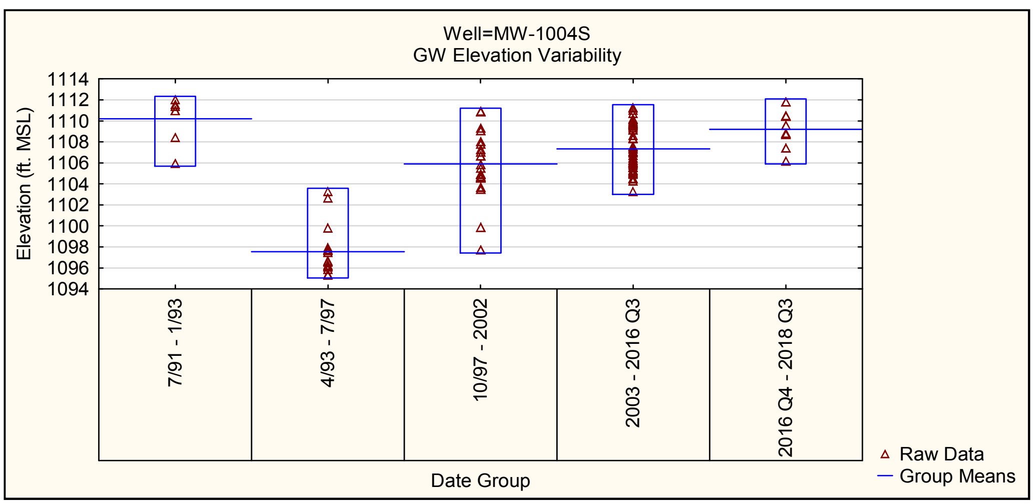
FIGURE 1-1c
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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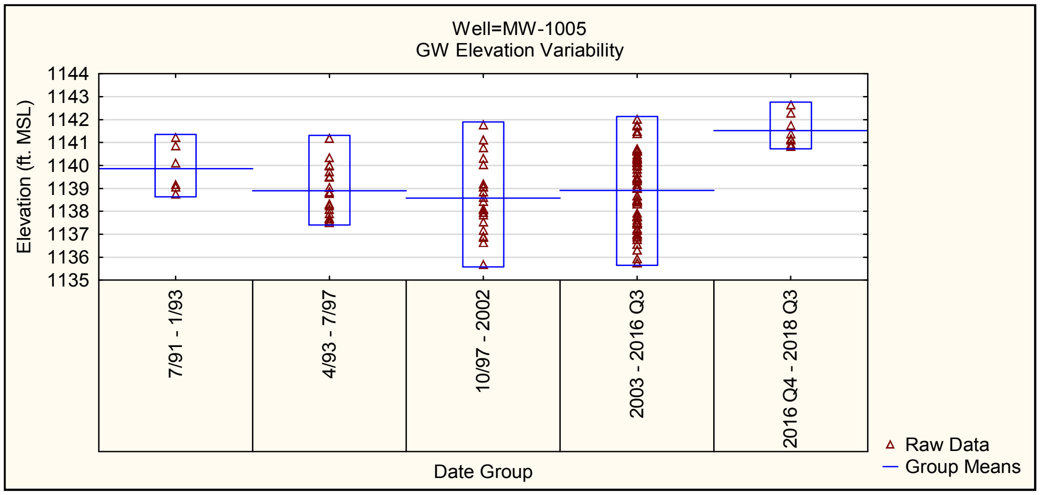
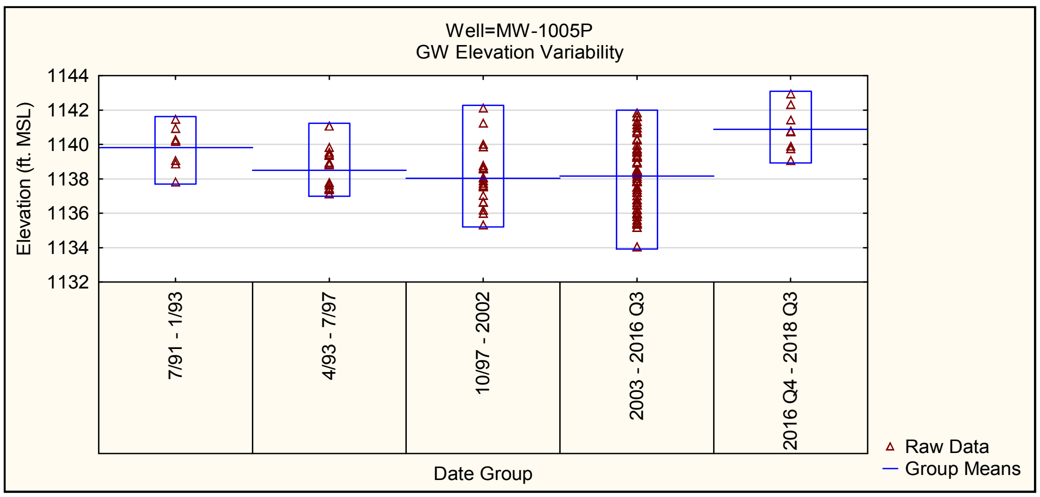
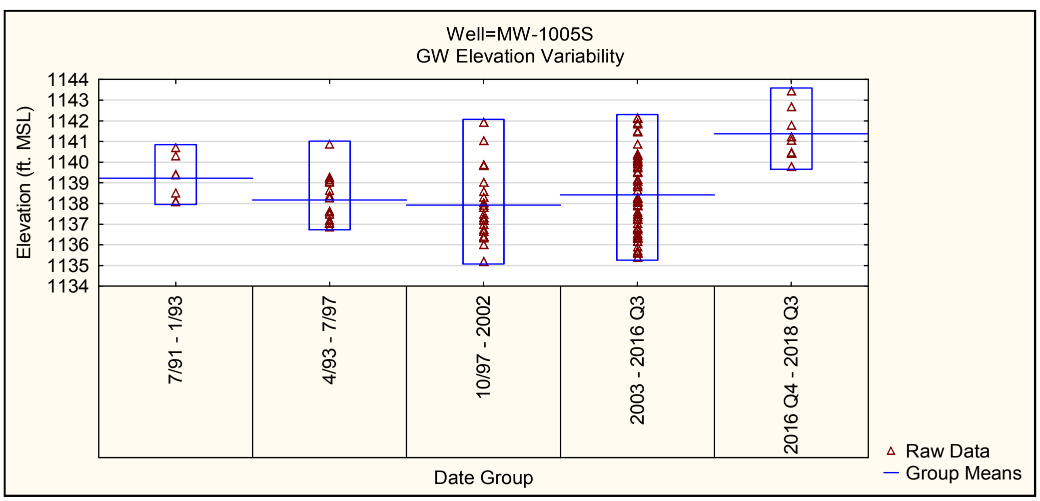
FIGURE 1-1d
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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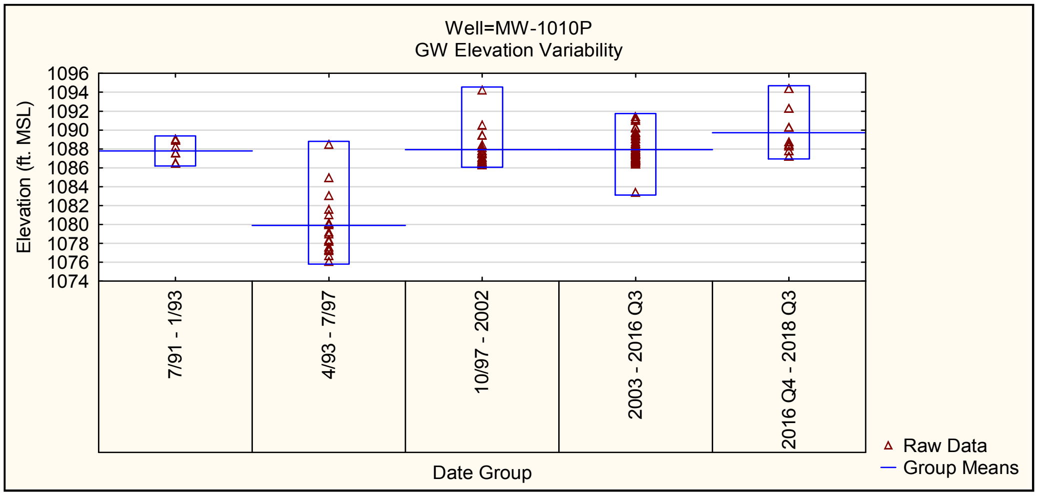
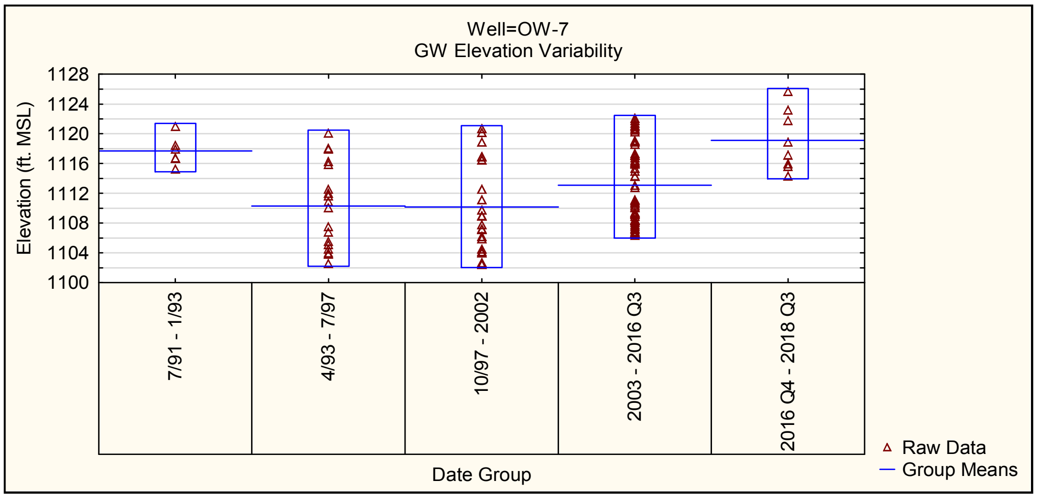
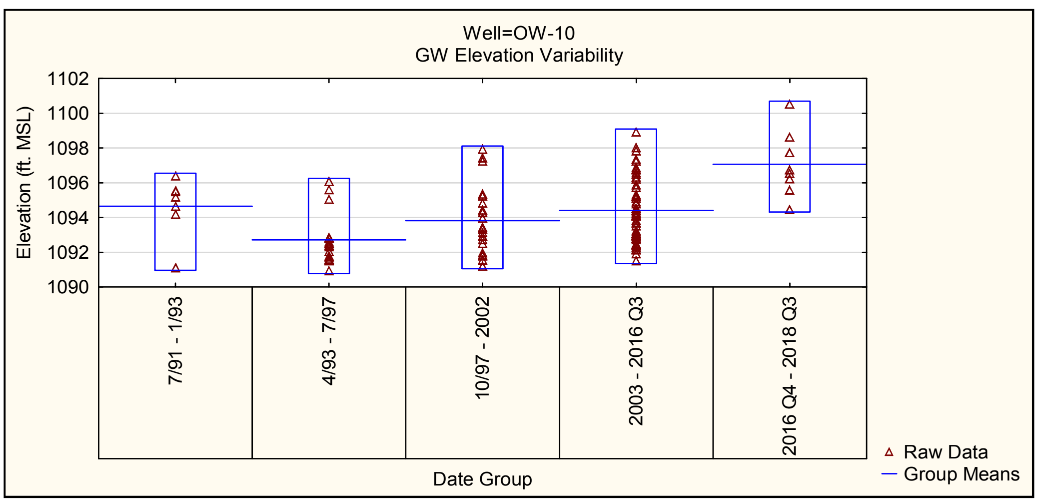
FIGURE 1-1e
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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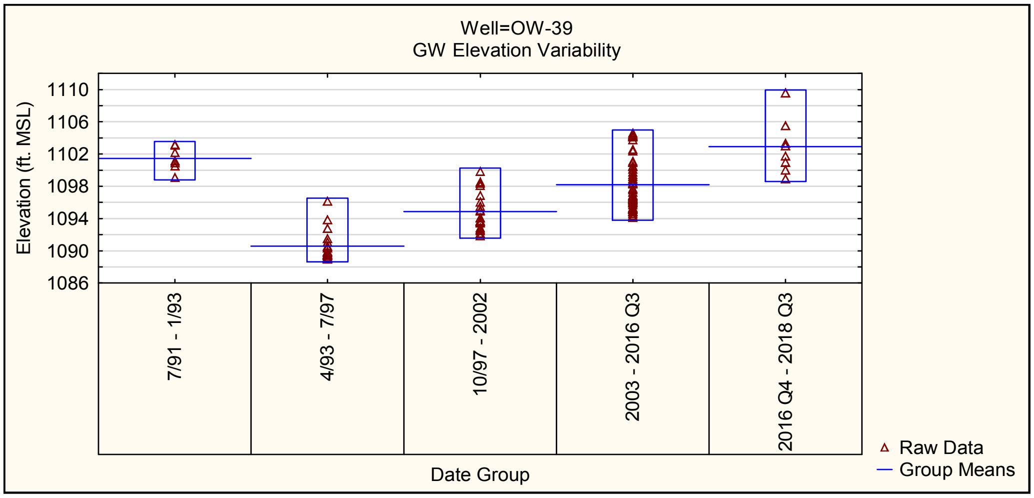
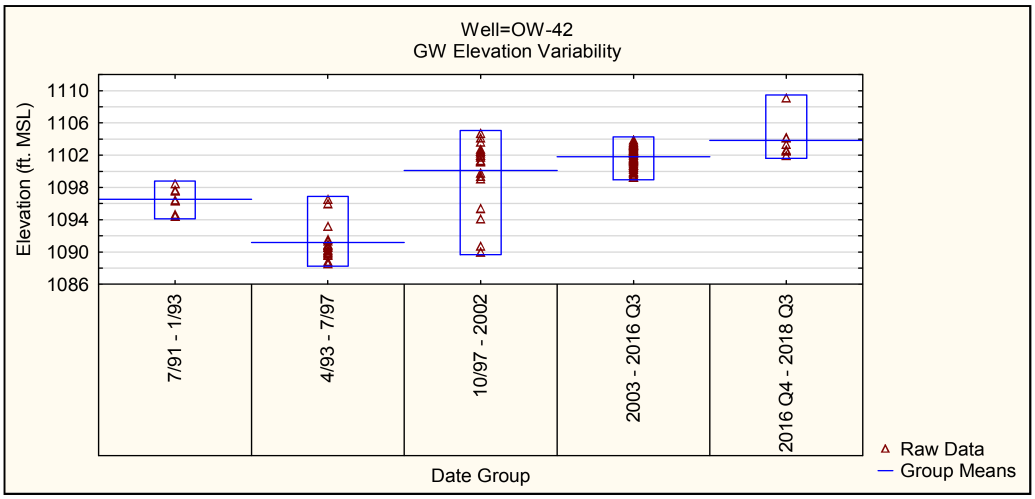
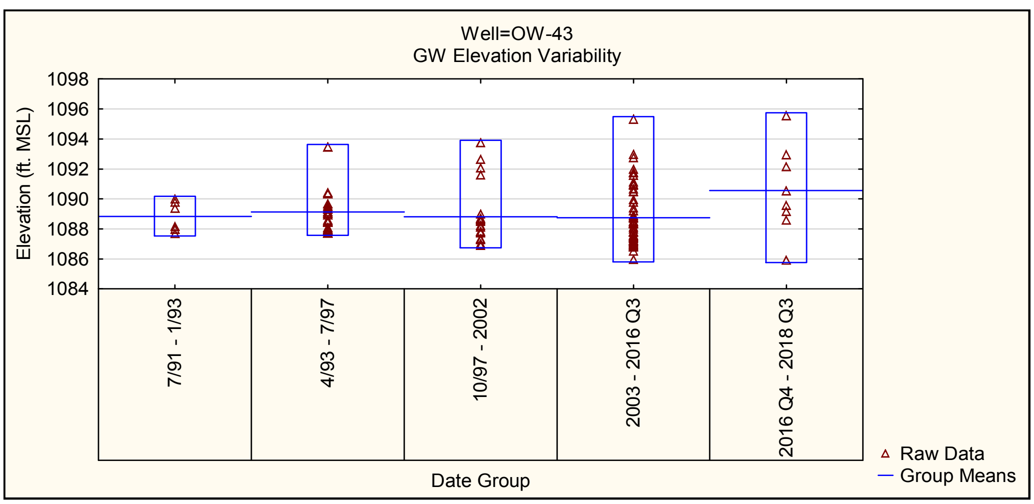
FIGURE 1-1f
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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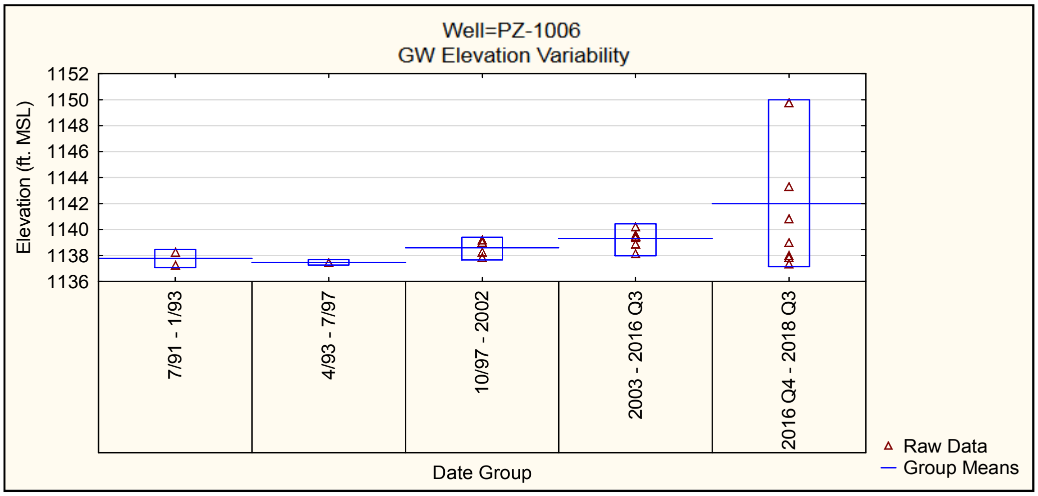
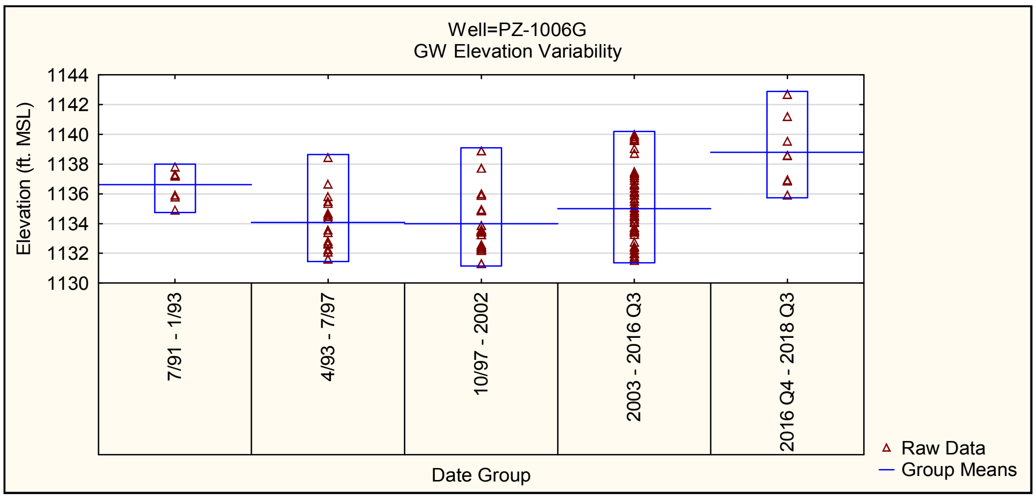
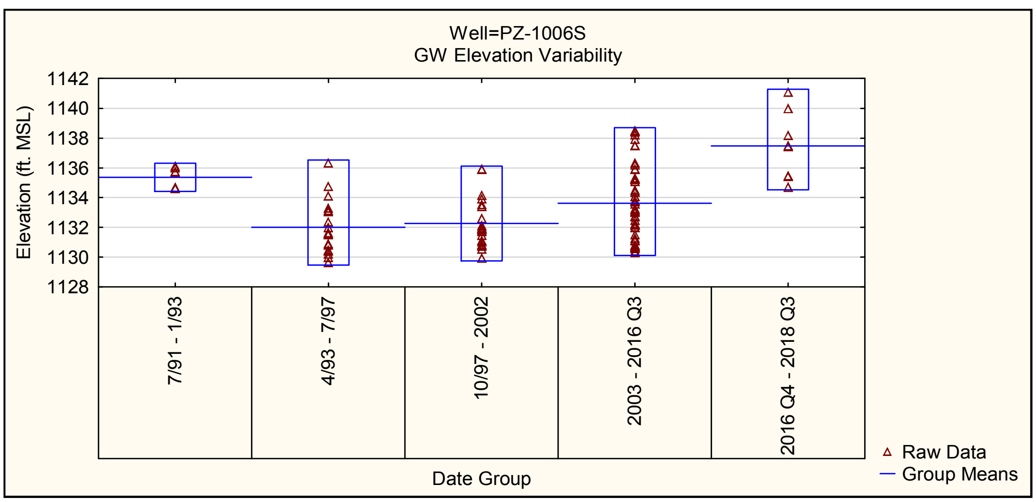
FIGURE 1-1g
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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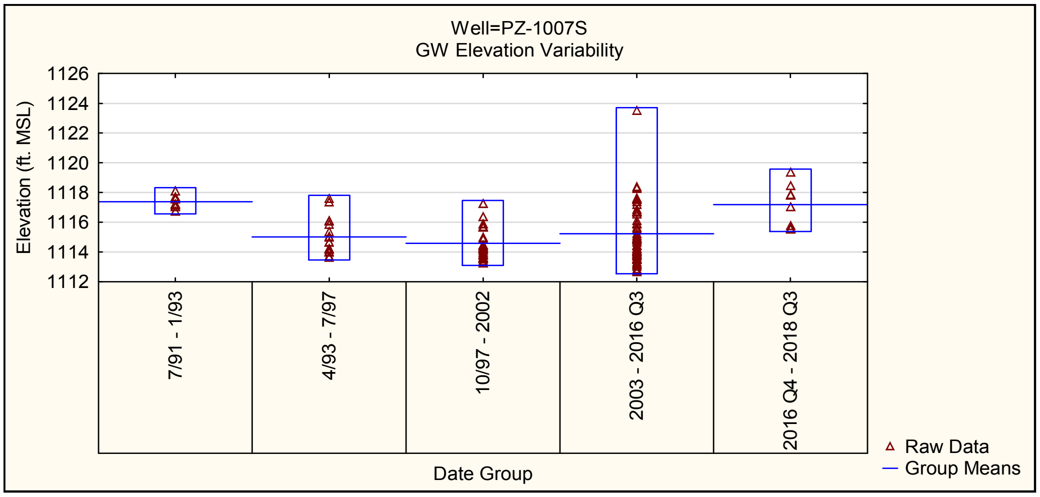
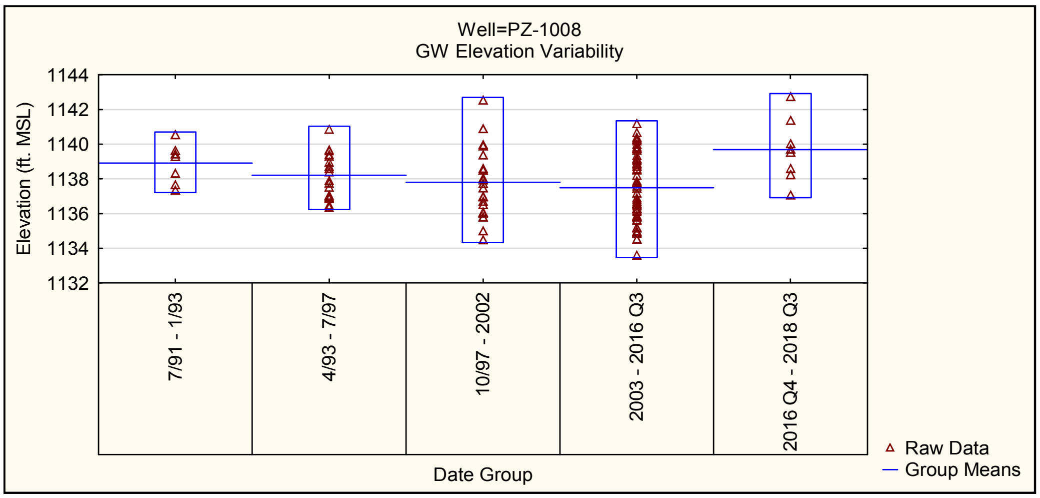
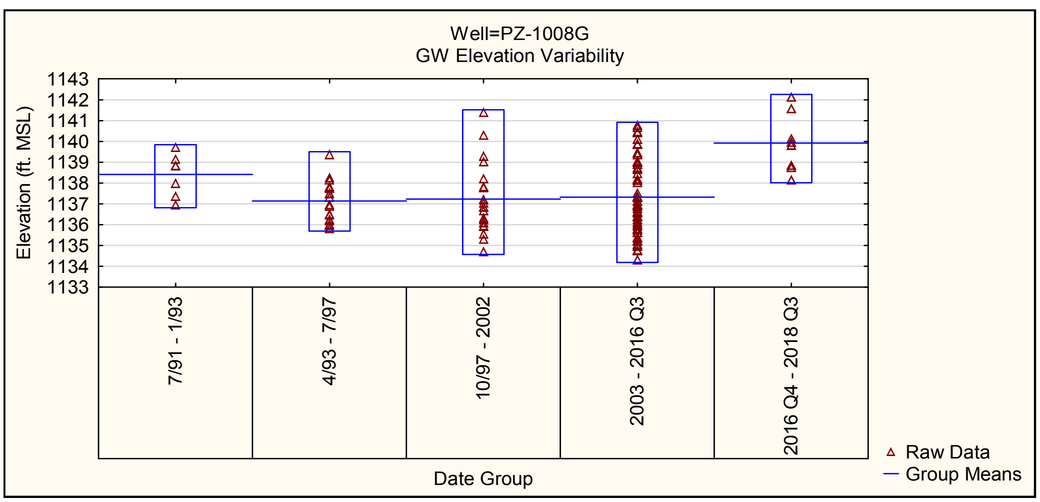
FIGURE 1-1h
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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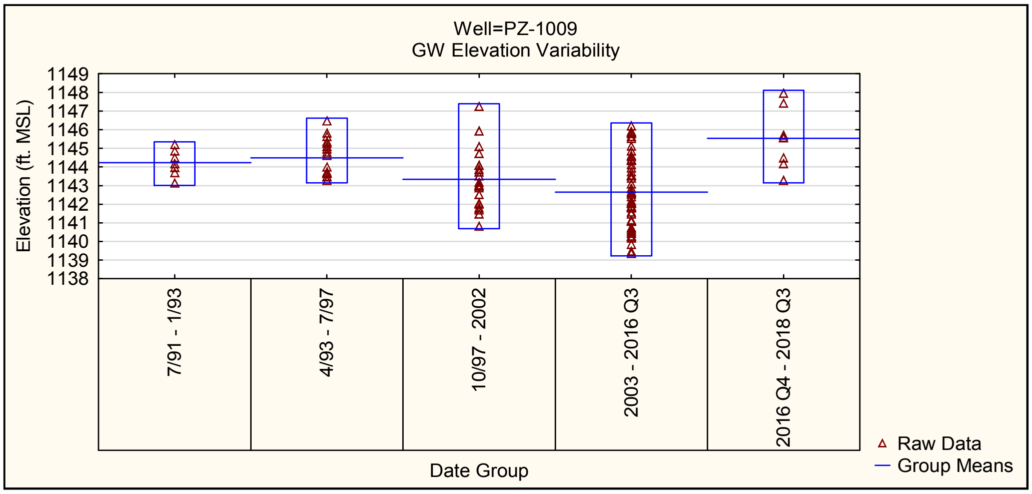
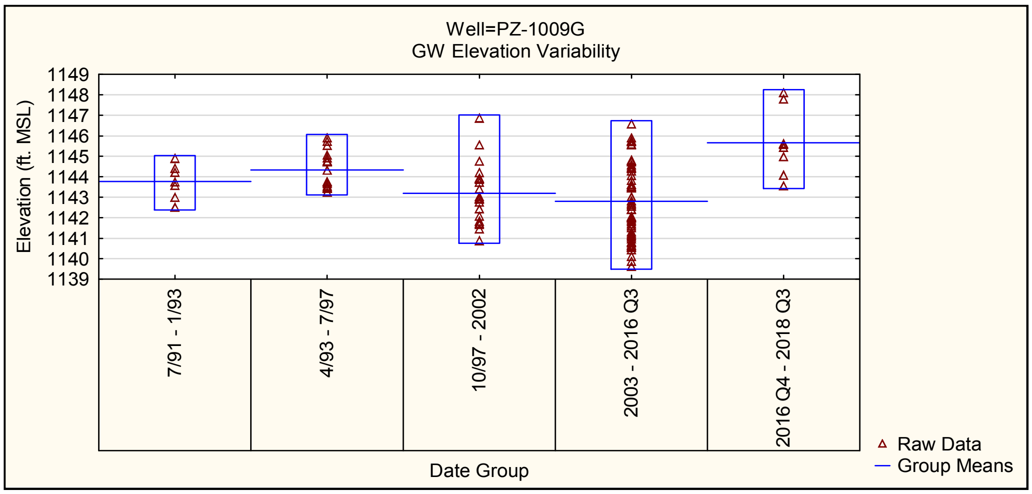
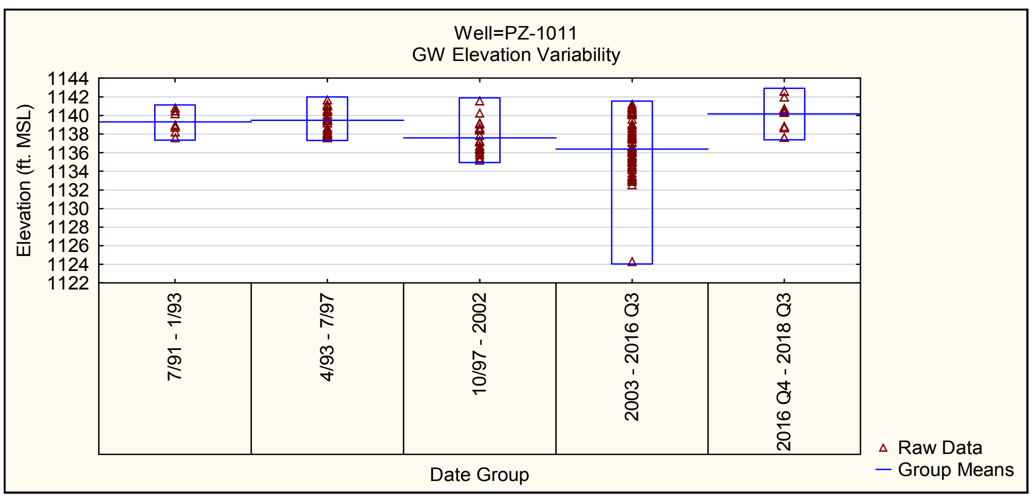
FIGURE 1-1i
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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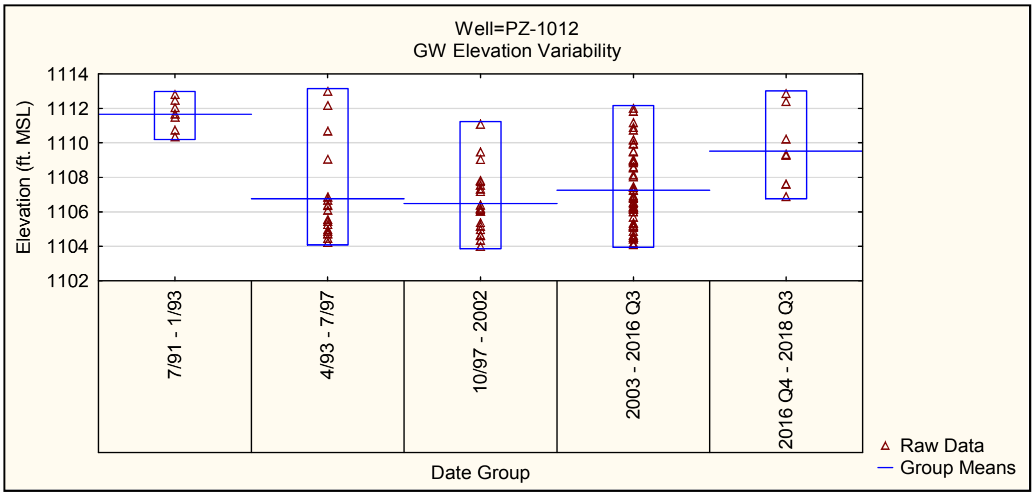
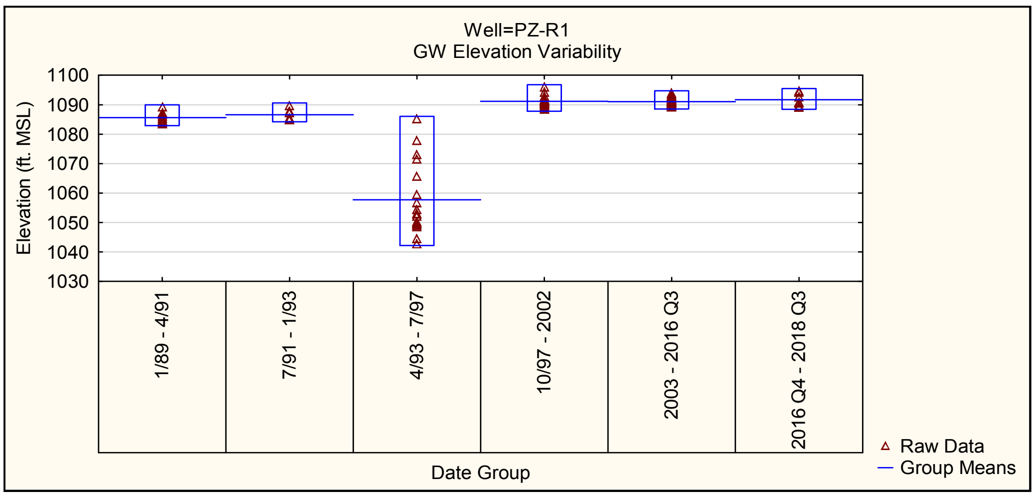
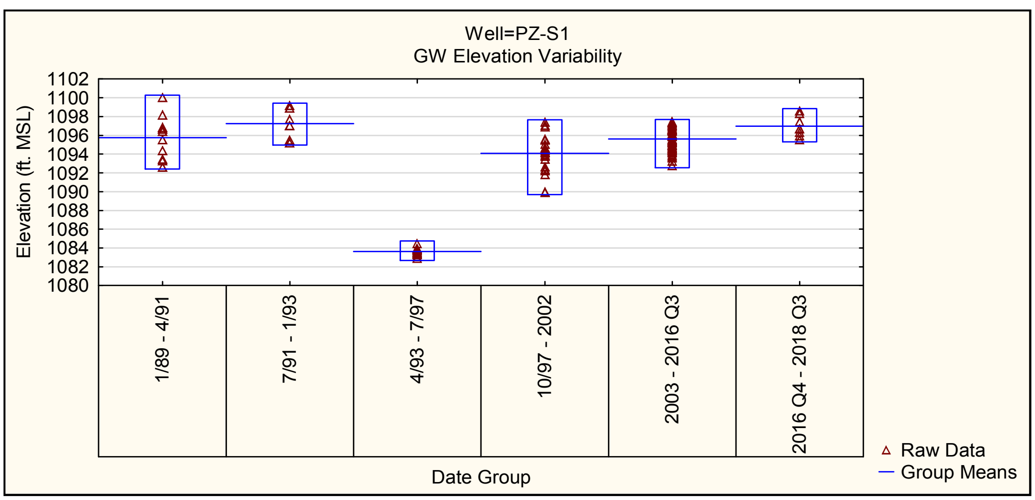
FIGURE 1-1j
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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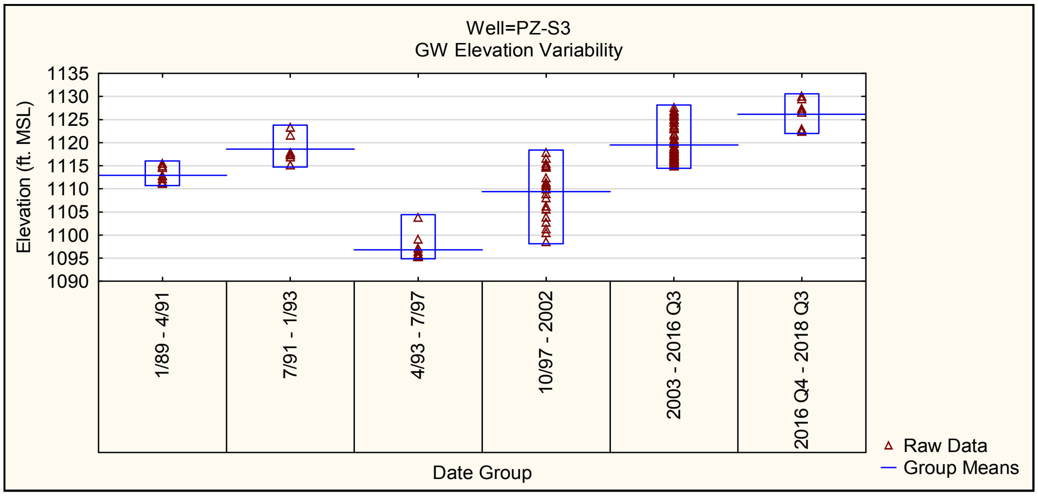
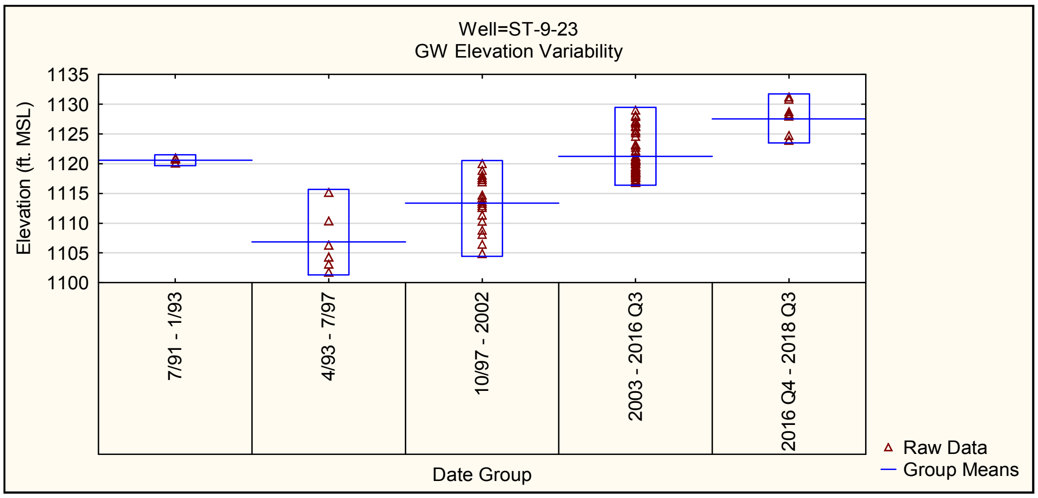
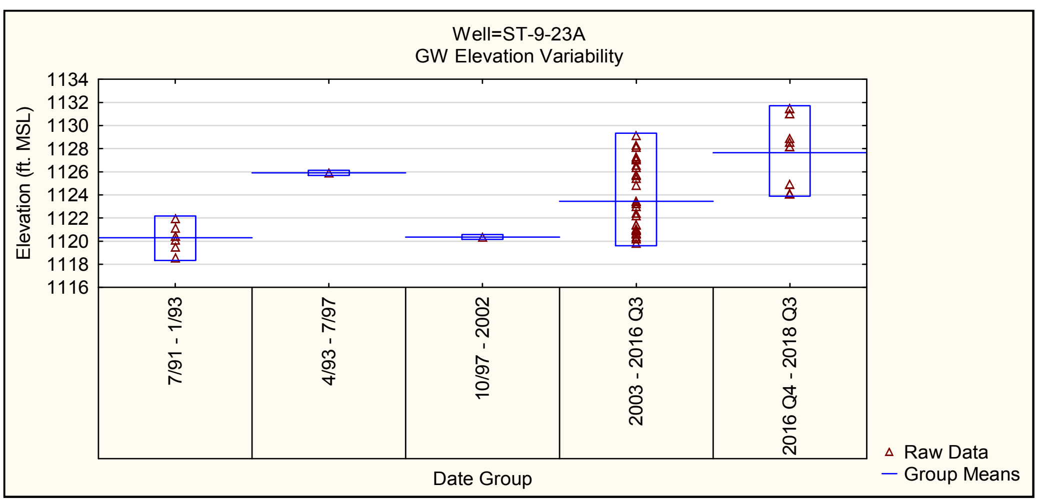
FIGURE 1-1k
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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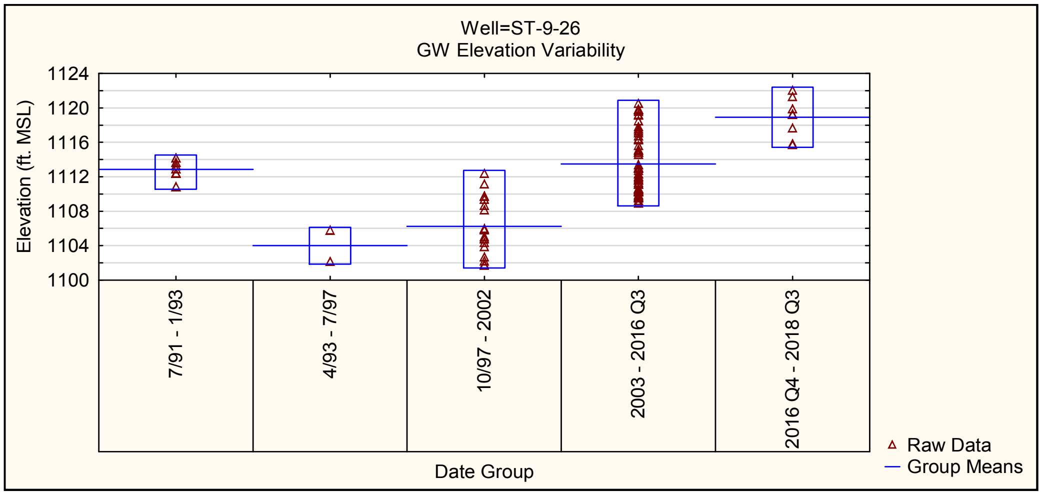
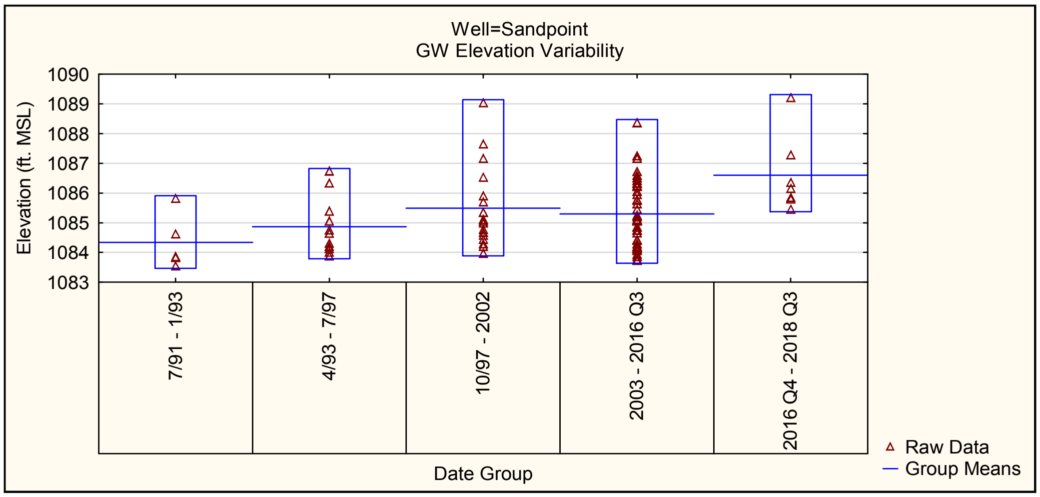
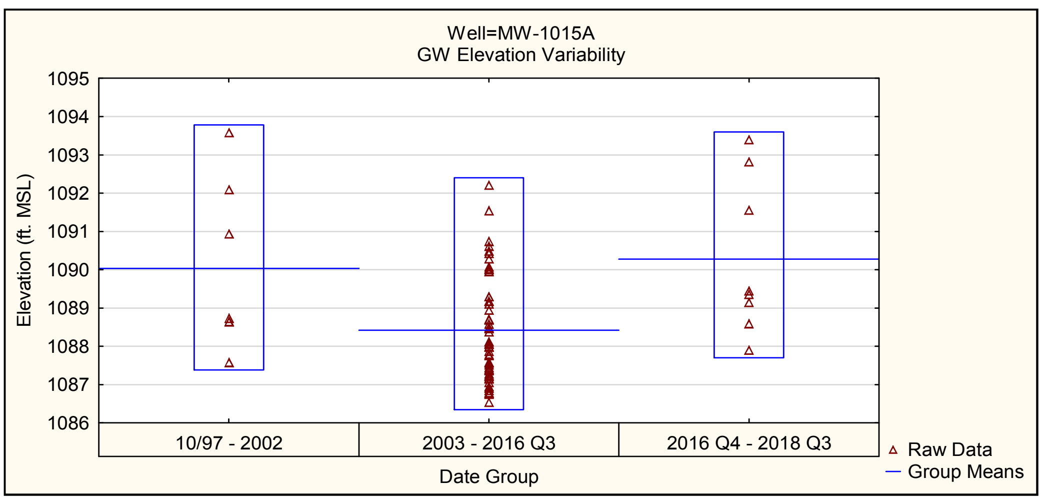
FIGURE 1-1I
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00







Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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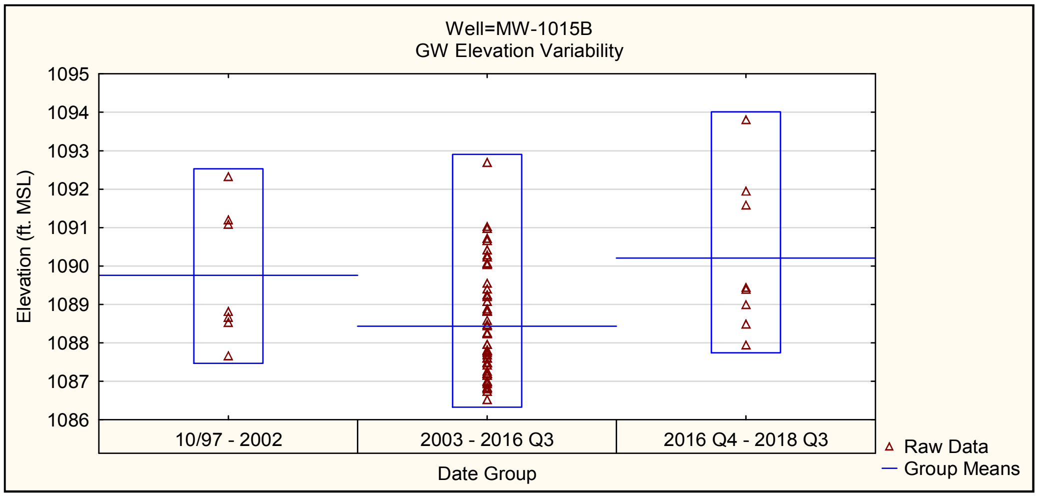
FIGURE 1-1m
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00



Note that date groups represent the following periods:
1/89 - 4/91: Pre-Construction Period
7/91 - 1/93: Pre-Ore Removal Period
4/93 - 7/97: Mining Period
10/97 - 10/17: Post-Mining Period

The time period of 2016 Q4 - 2018 Q3 was called out as a separate date group for comparison of the most recent two-year time frame to pre-mining conditions.

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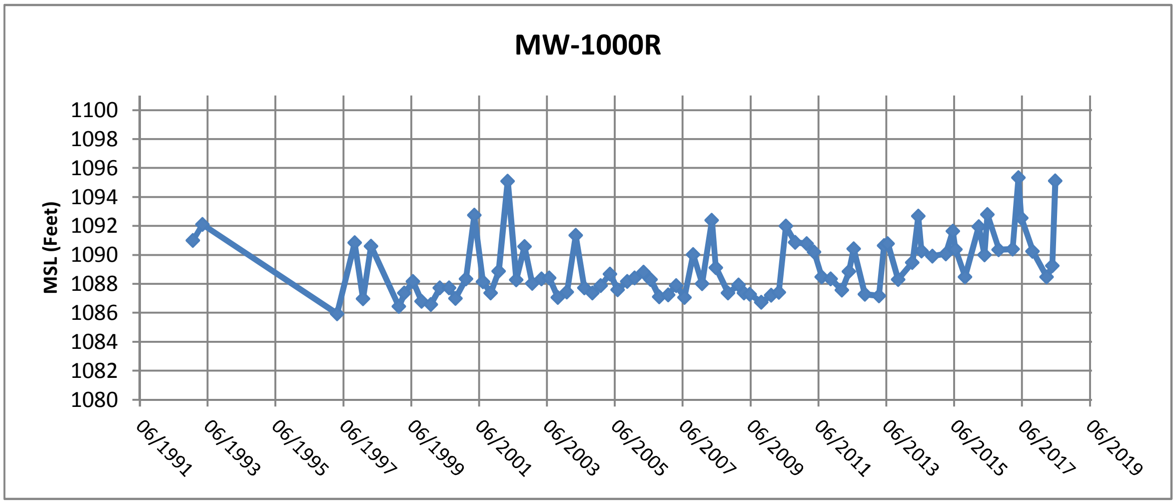
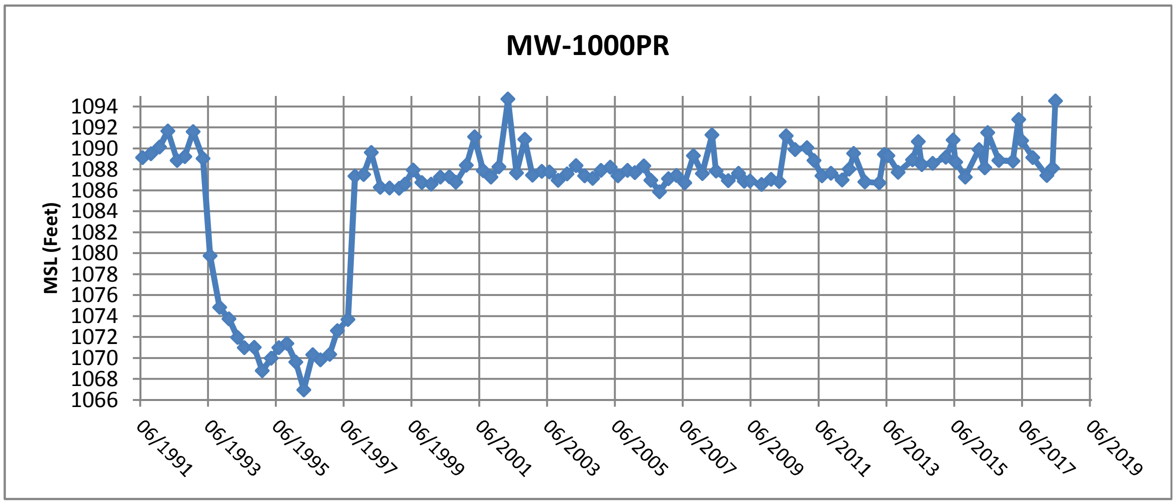
FIGURE 1-1n
GROUNDWATER ELEVATION VARIABILITY BY DATE GROUP

Scale: NA		Date: July 2018
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





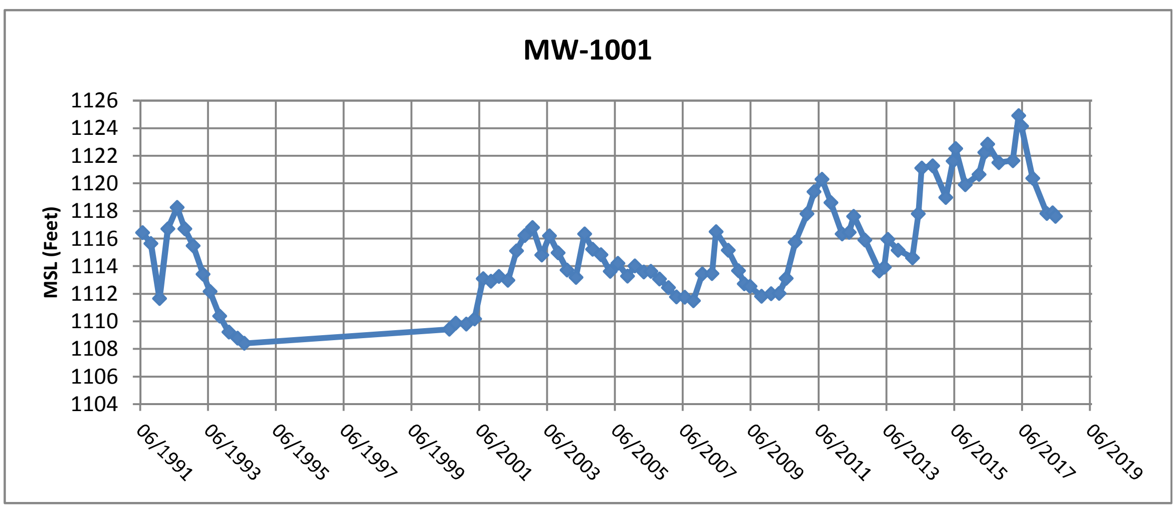


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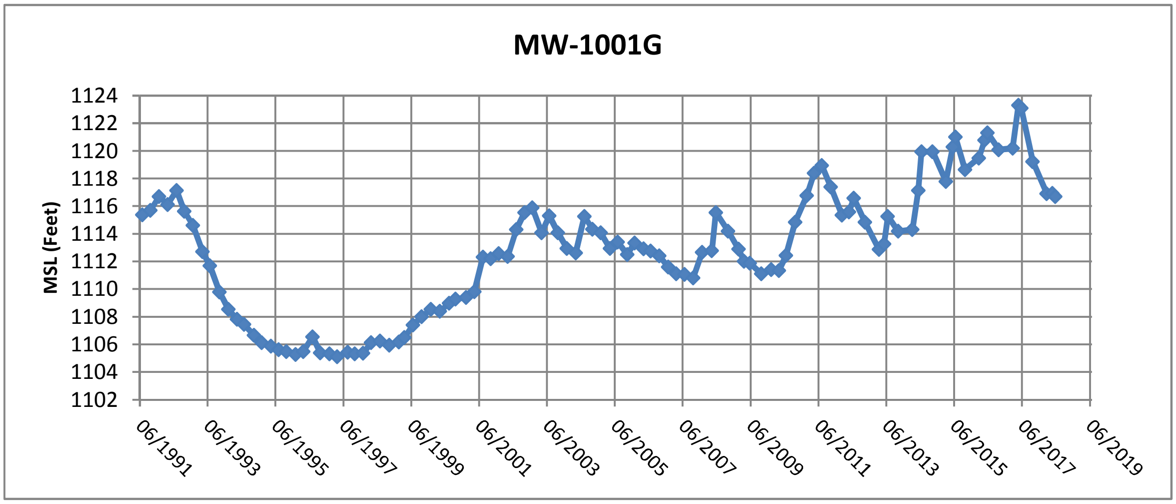
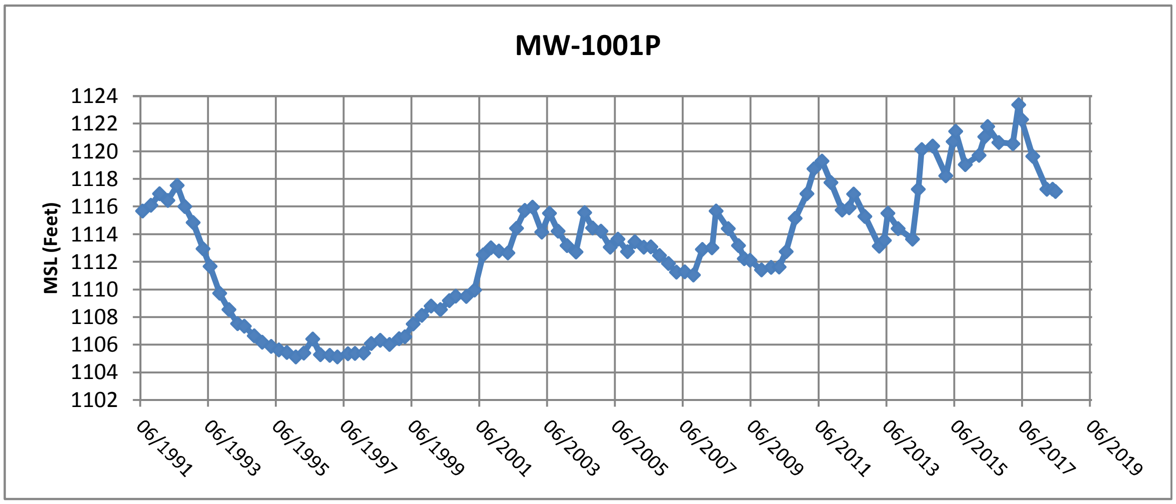
FIGURE 1-2a
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





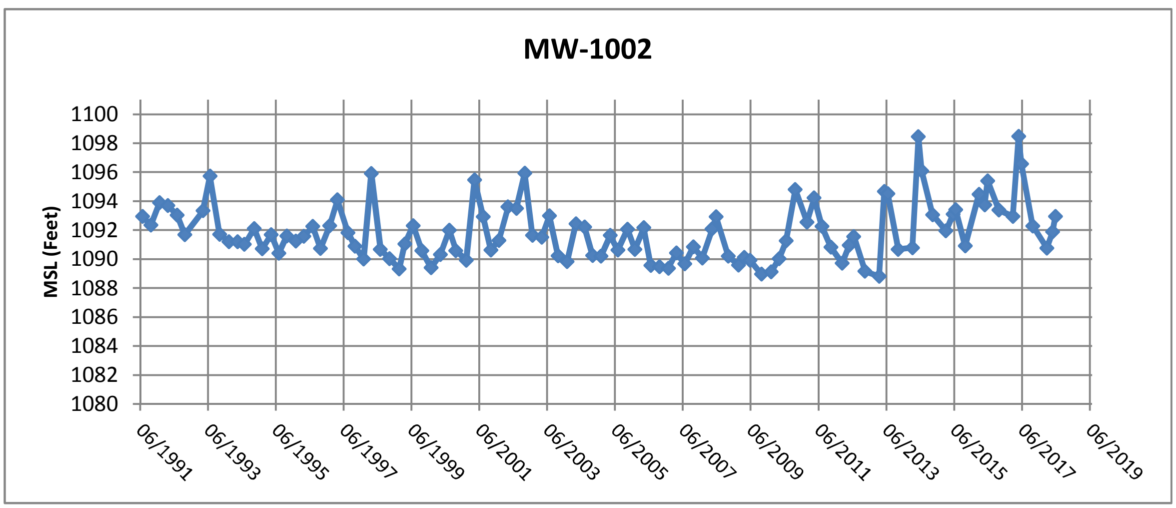


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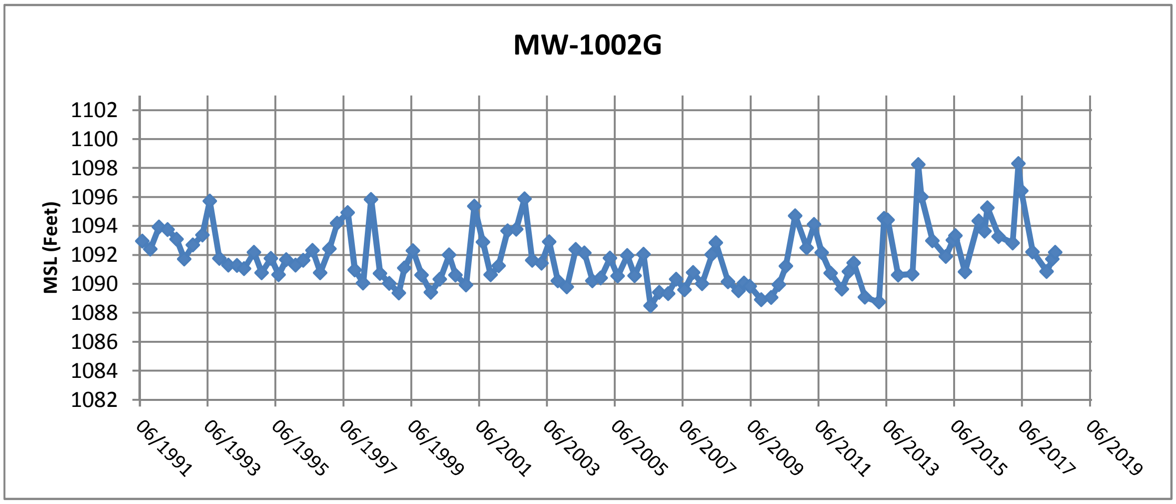
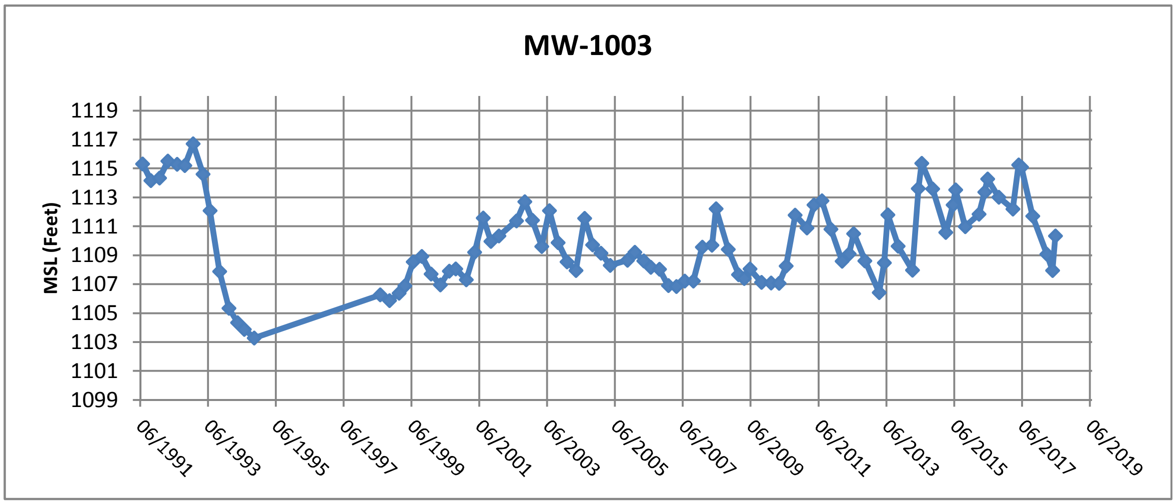
FIGURE 1-2b
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





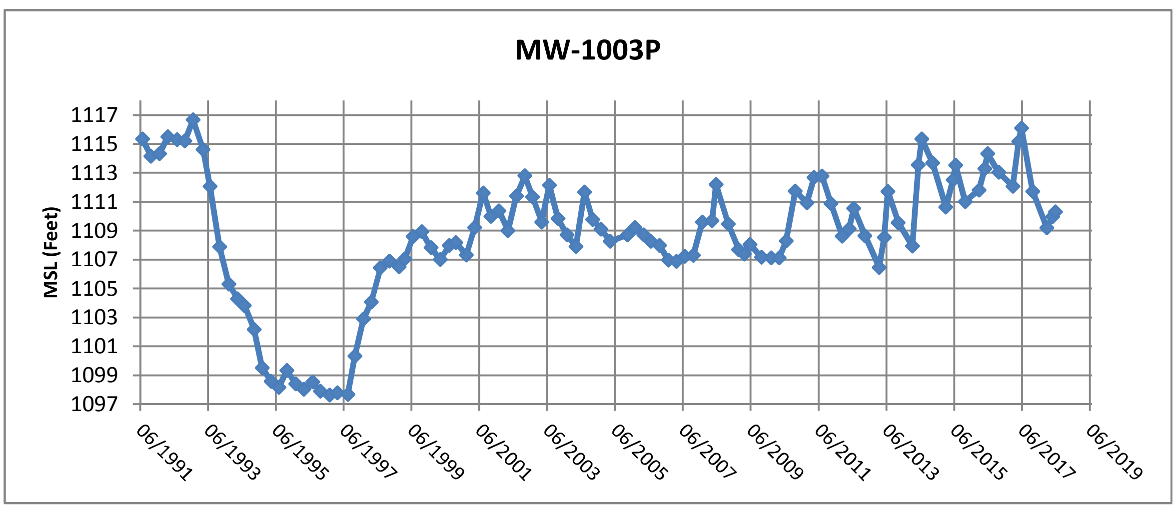


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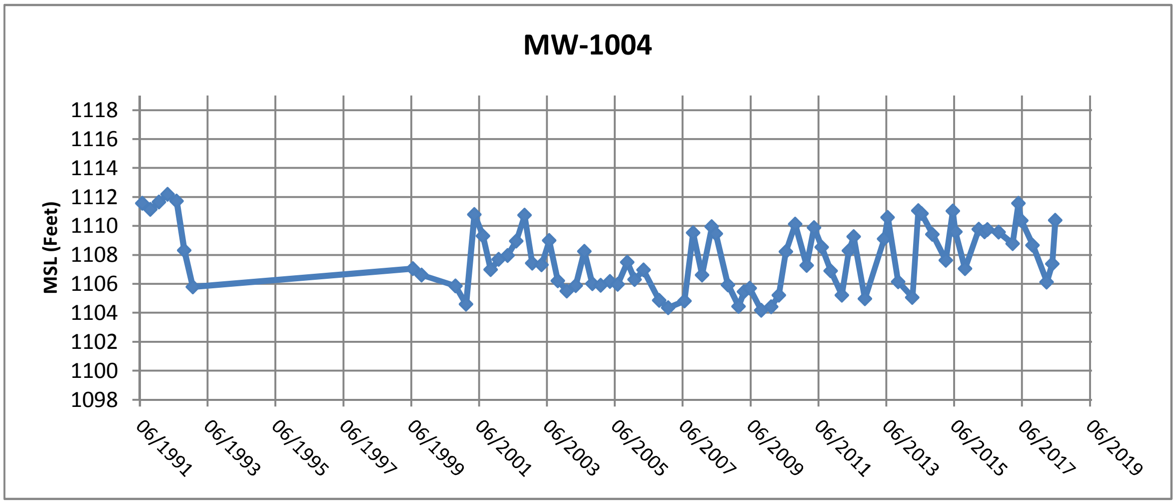
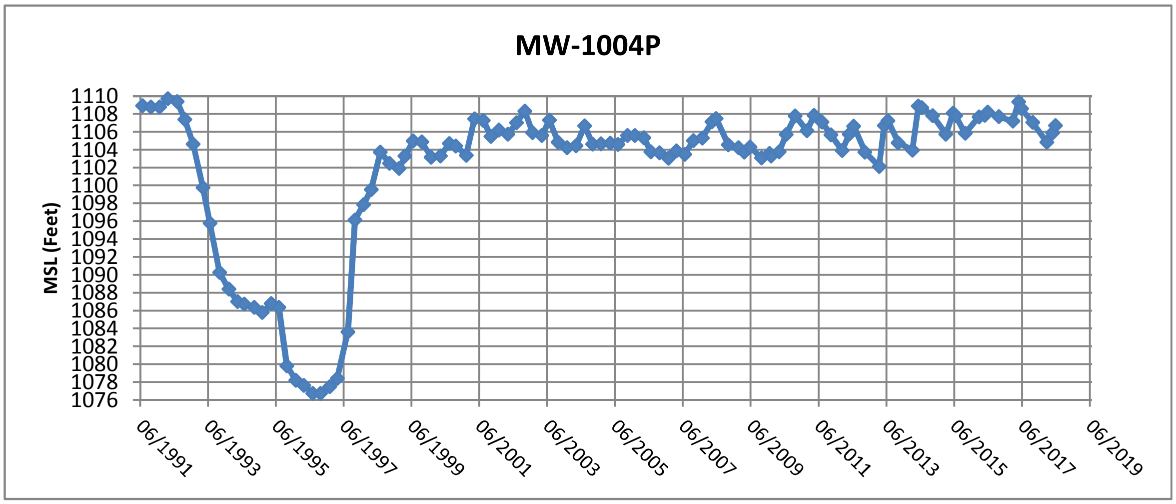
FIGURE 1-2c
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





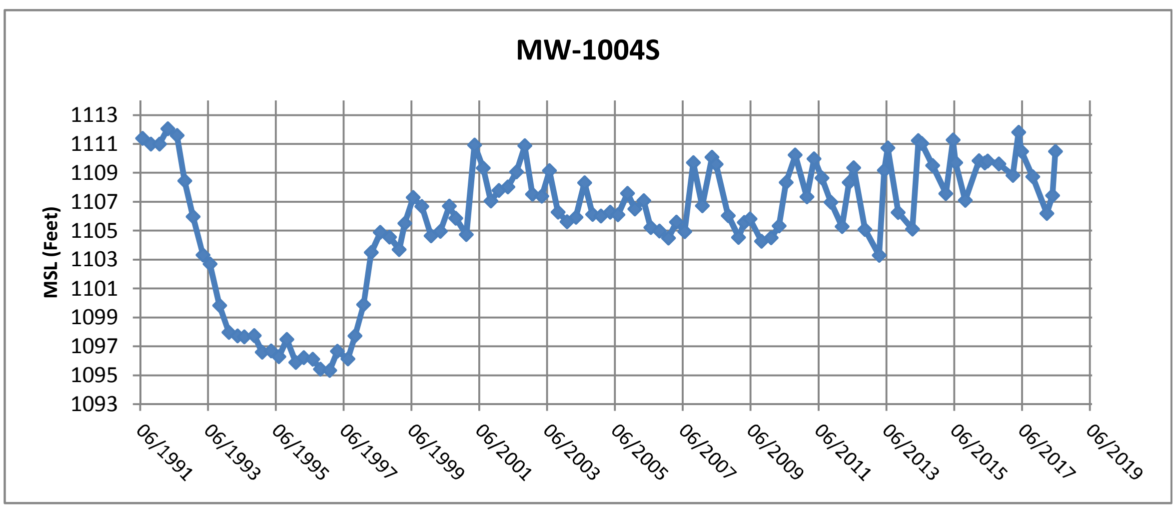


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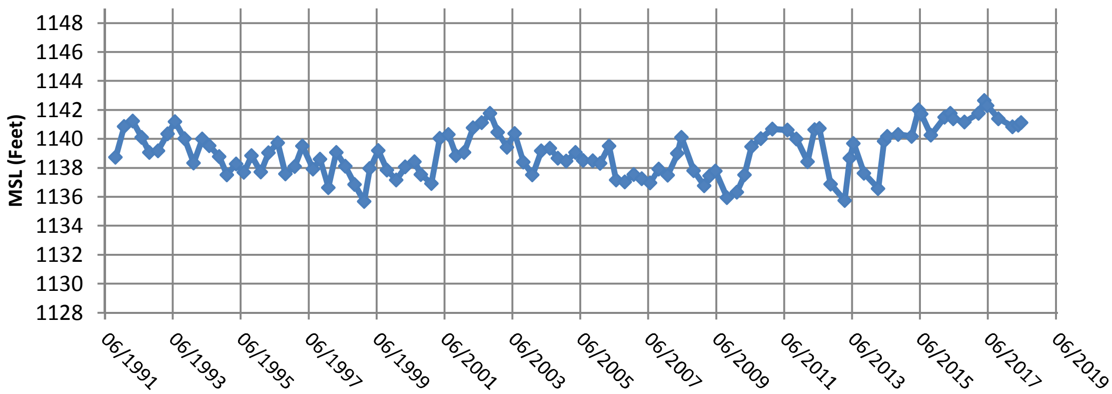
FIGURE 1-2d
HYDROGRAPHS

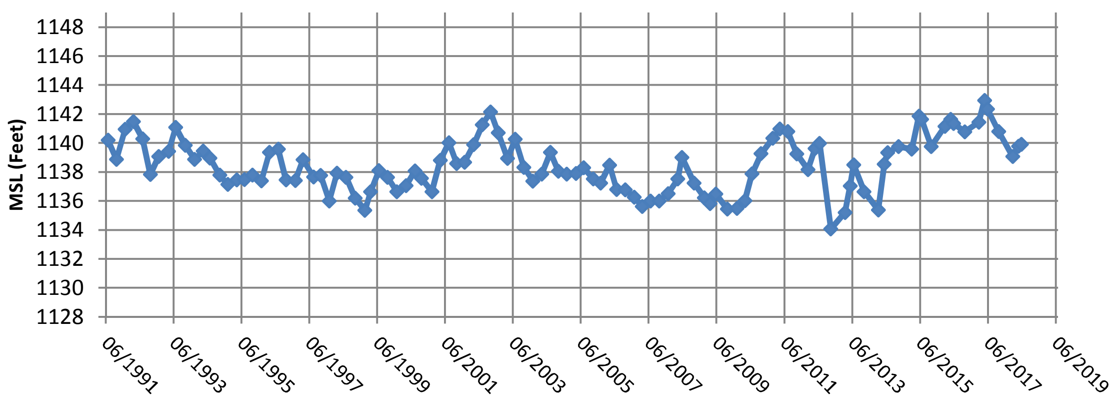
Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm

MW-1005



MW-1005P



MW-1005S

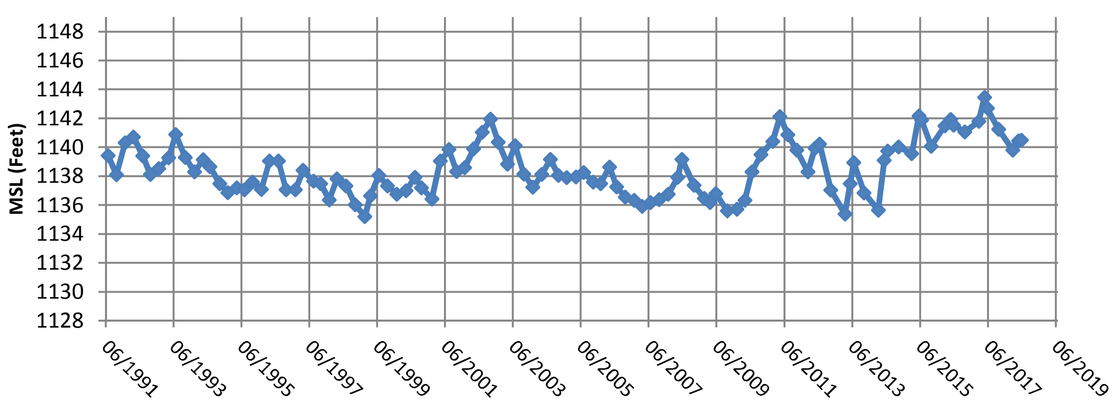


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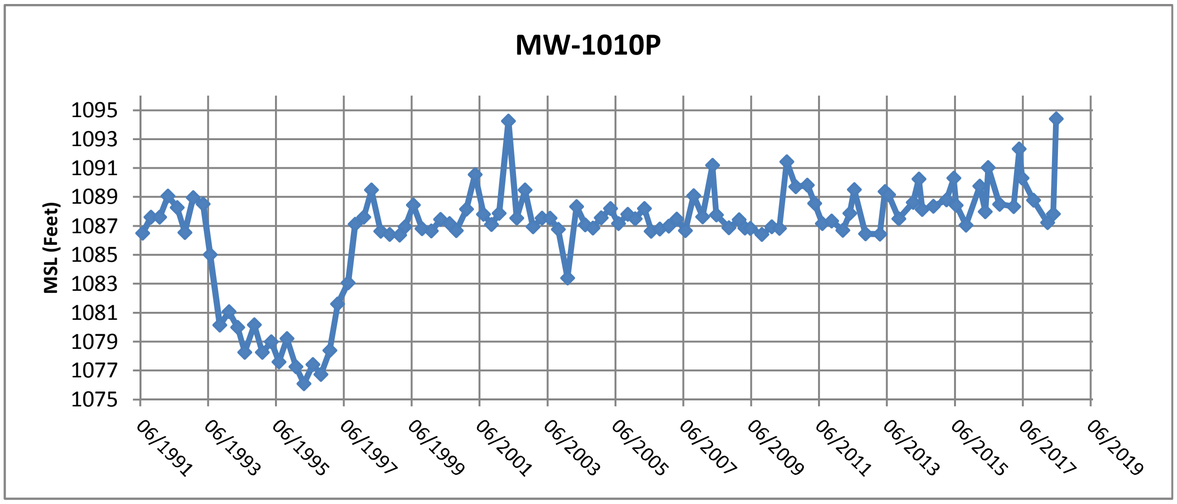
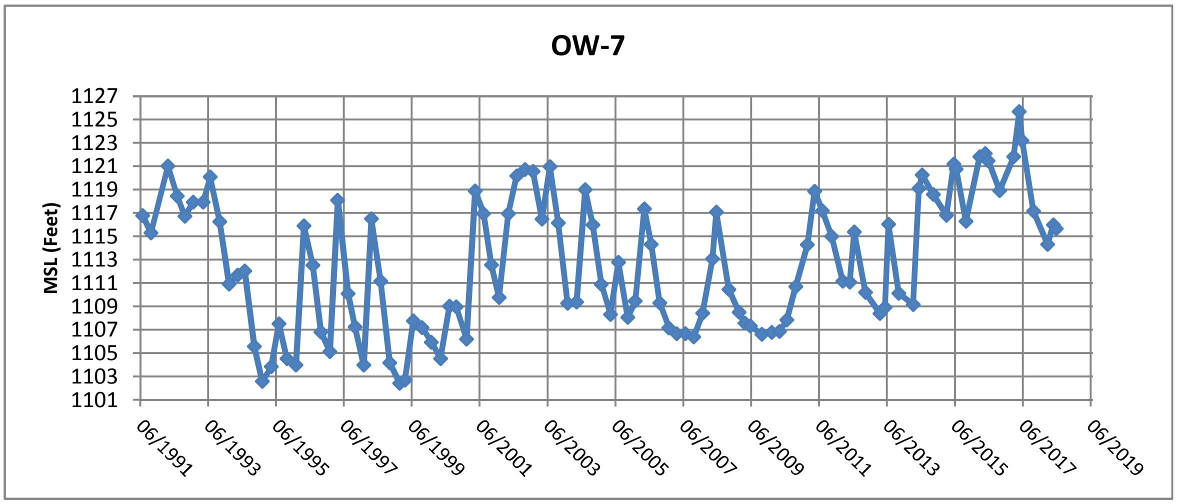
FIGURE 1-2e
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





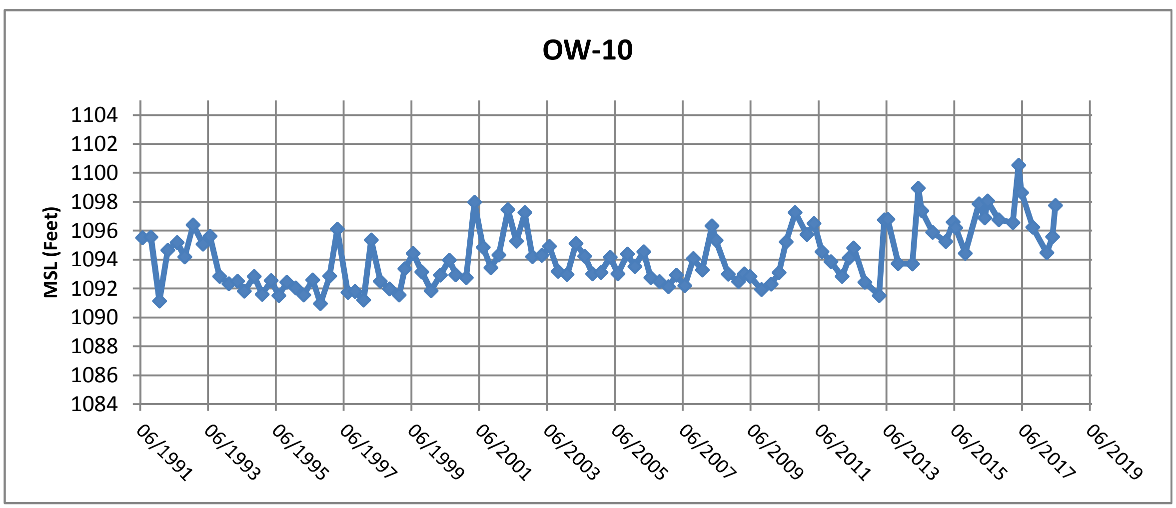


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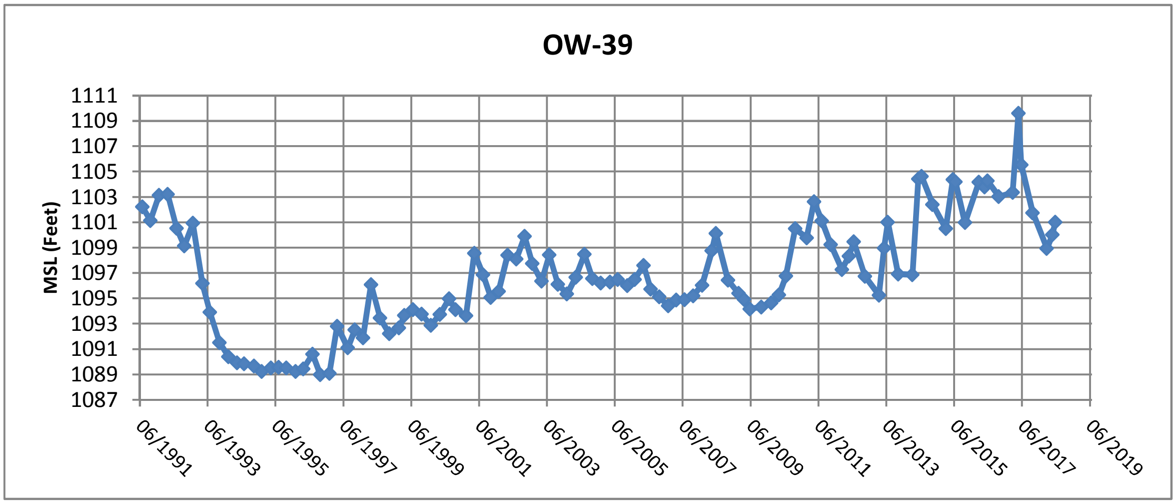
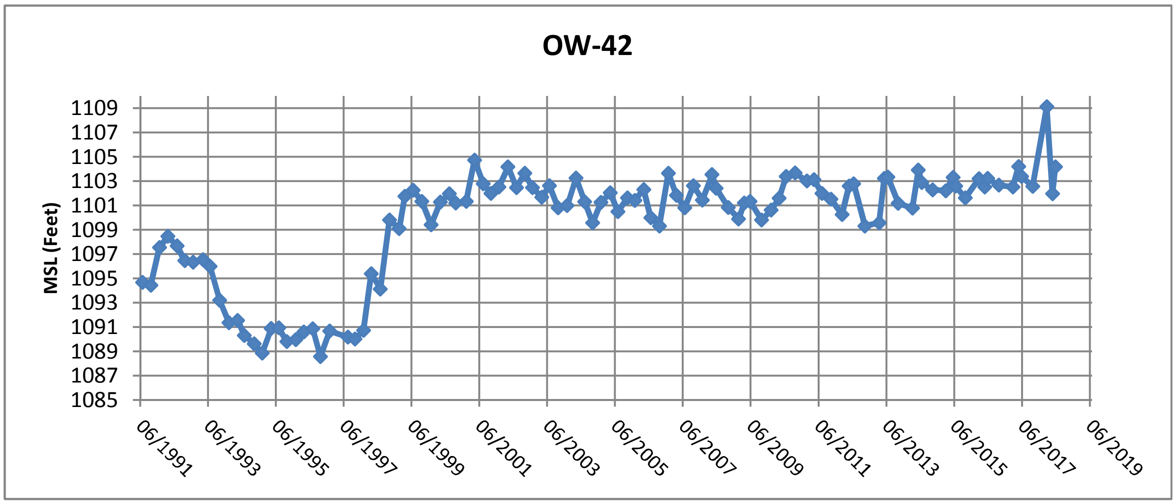
FIGURE 1-2f

HYDROGRAPHS

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





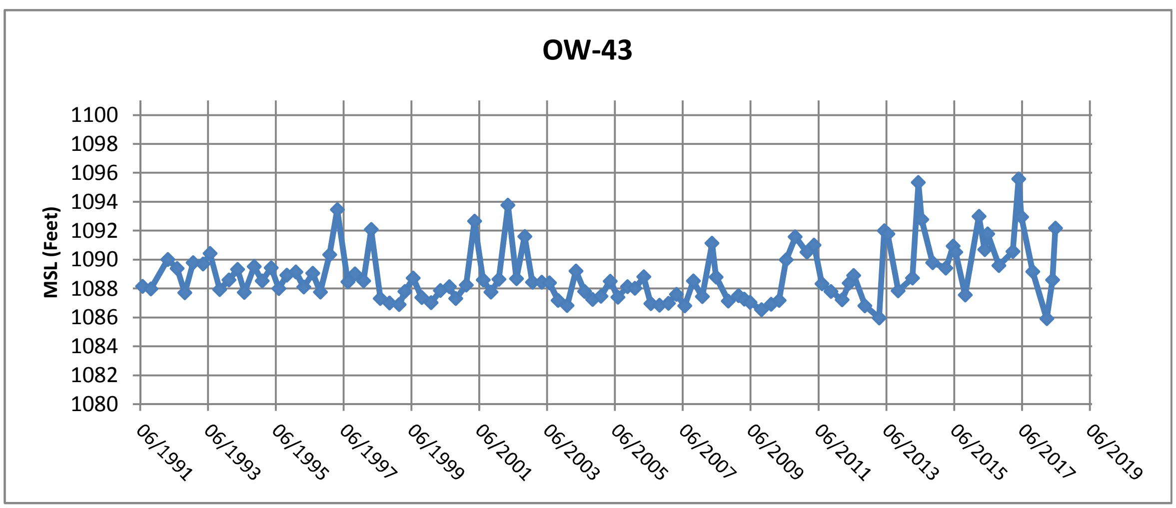


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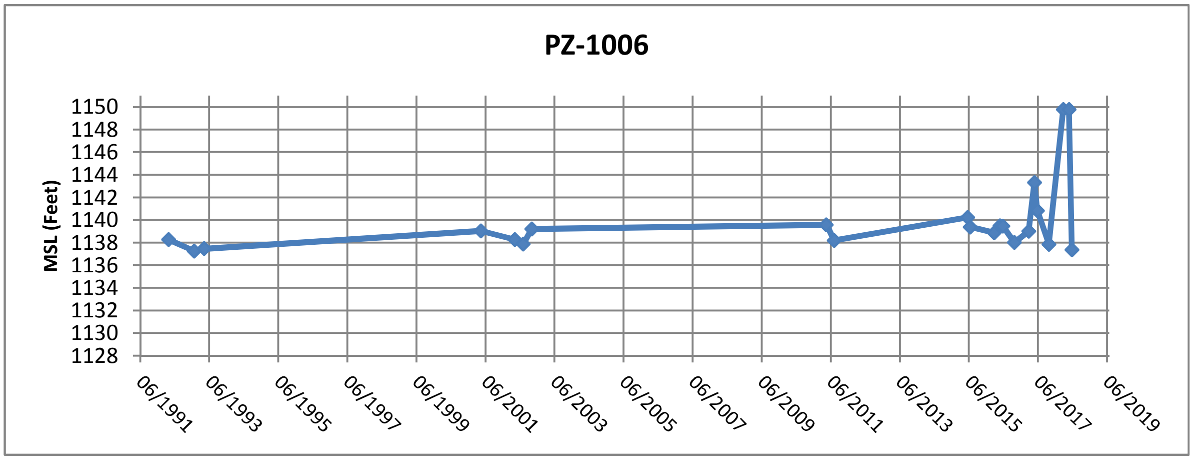
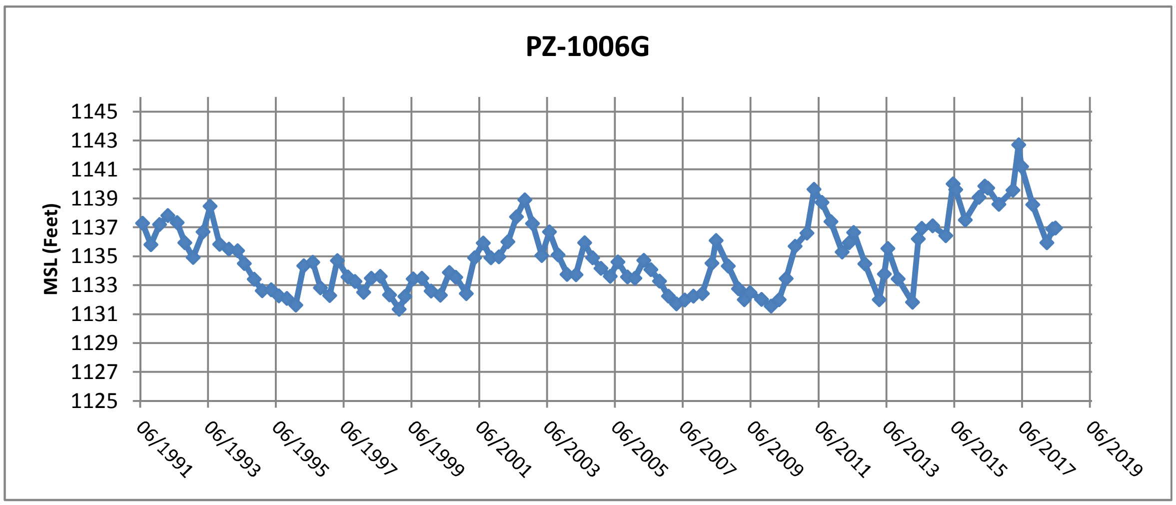
FIGURE 1-2g
HYDROGRAPHS

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm



Note: Gaps between collected data are due to dry well.



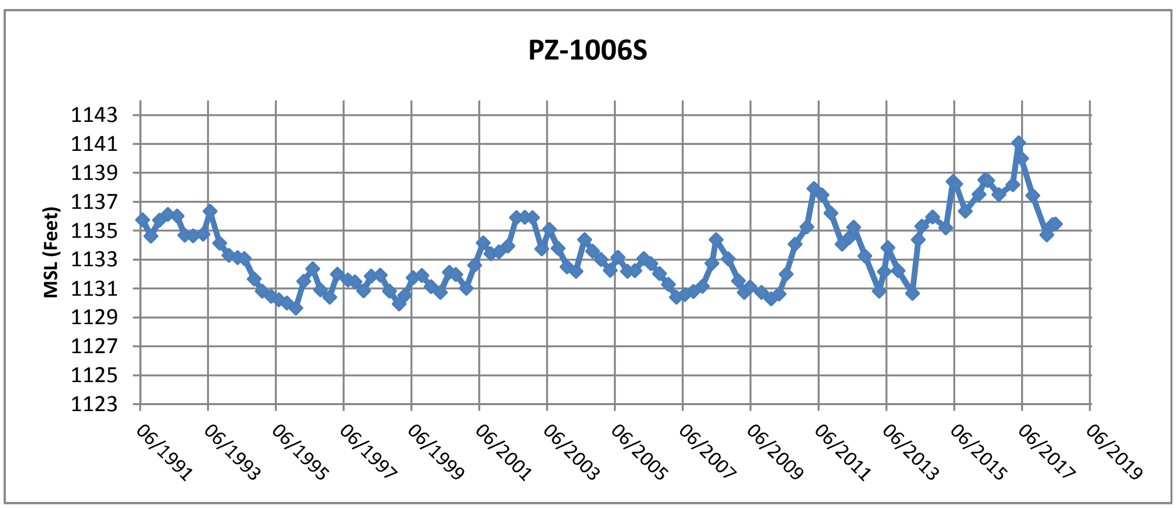


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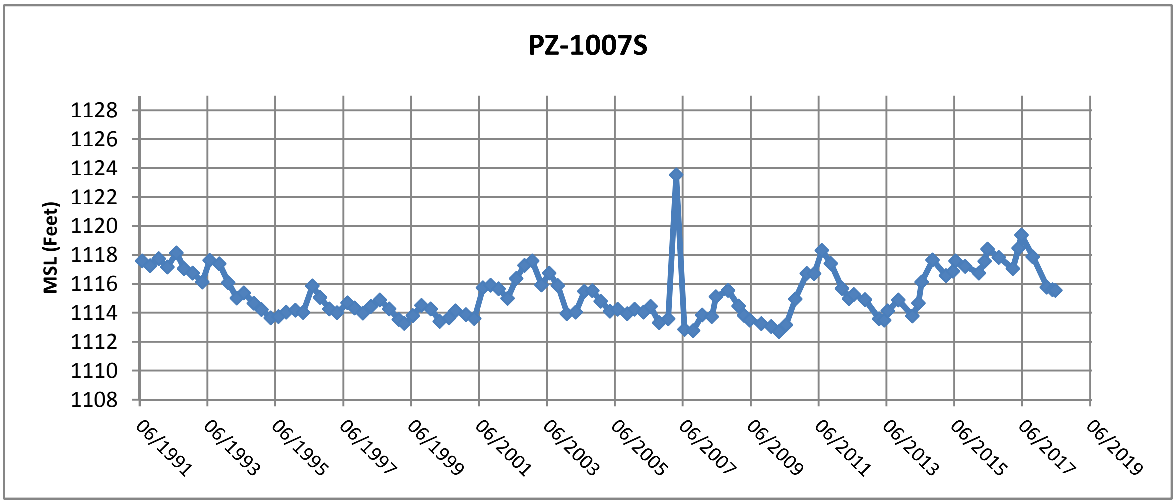
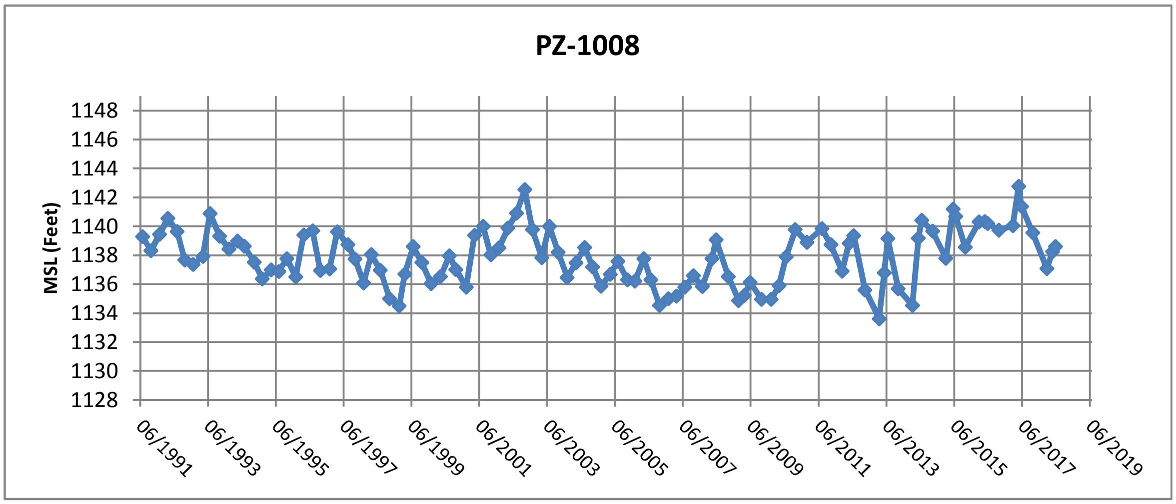
FIGURE 1-2h HYDROGRAPHS		
Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





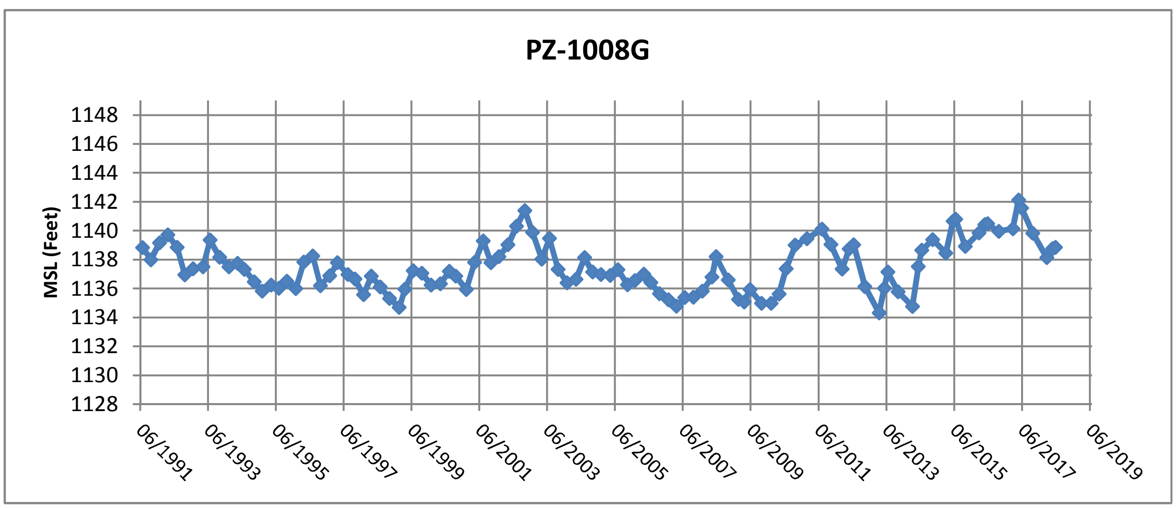


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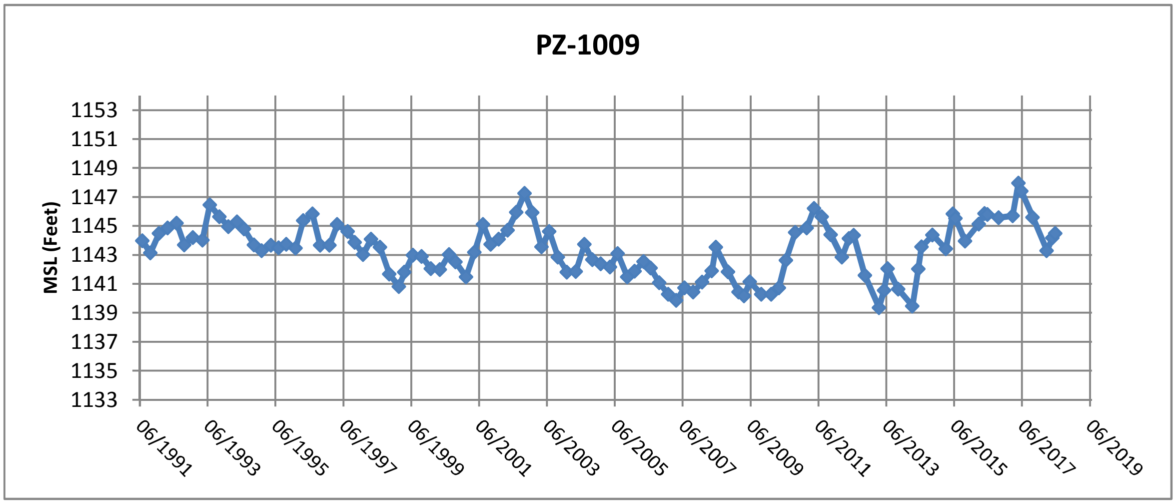
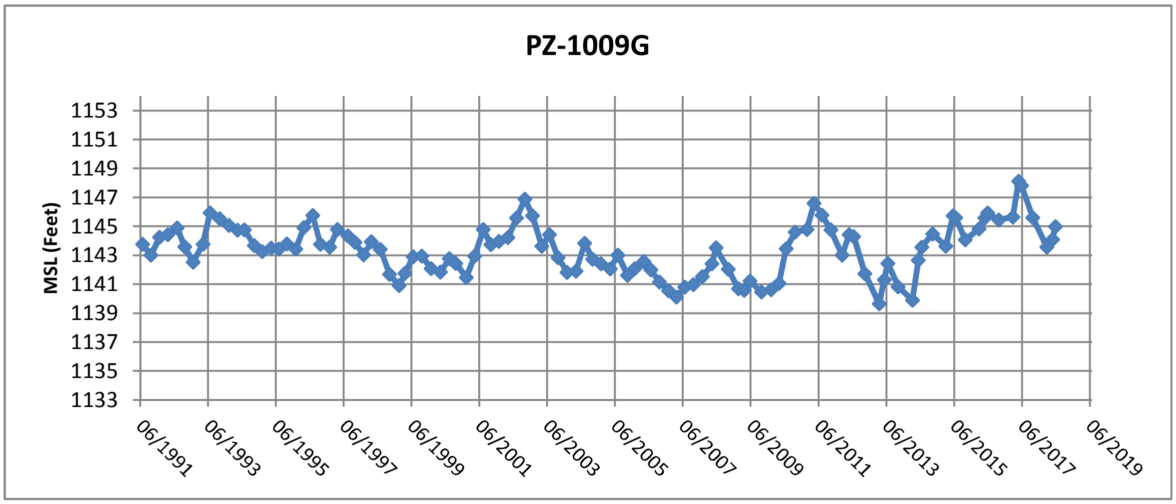
FIGURE 1-2i

HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





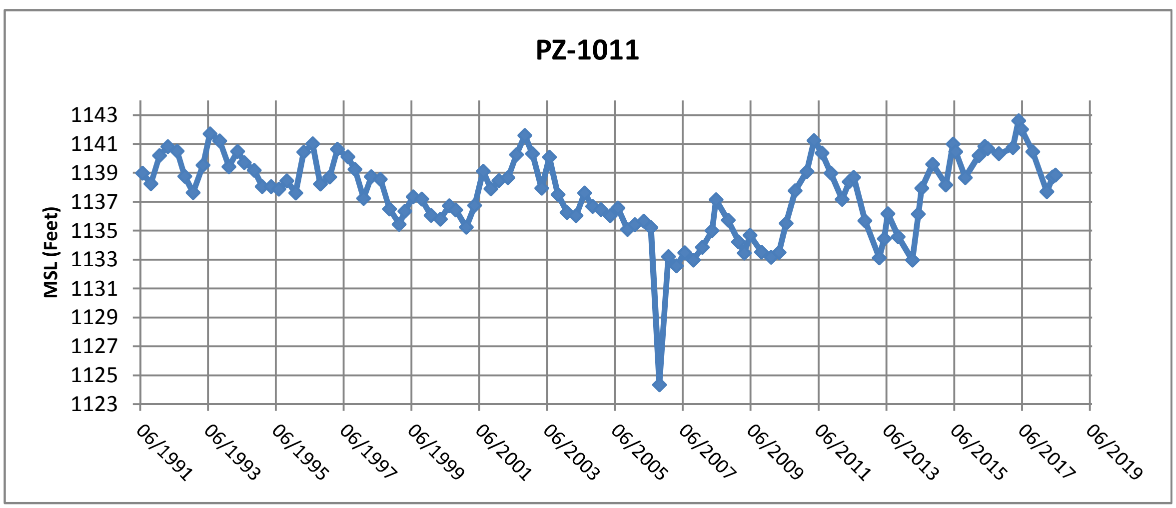


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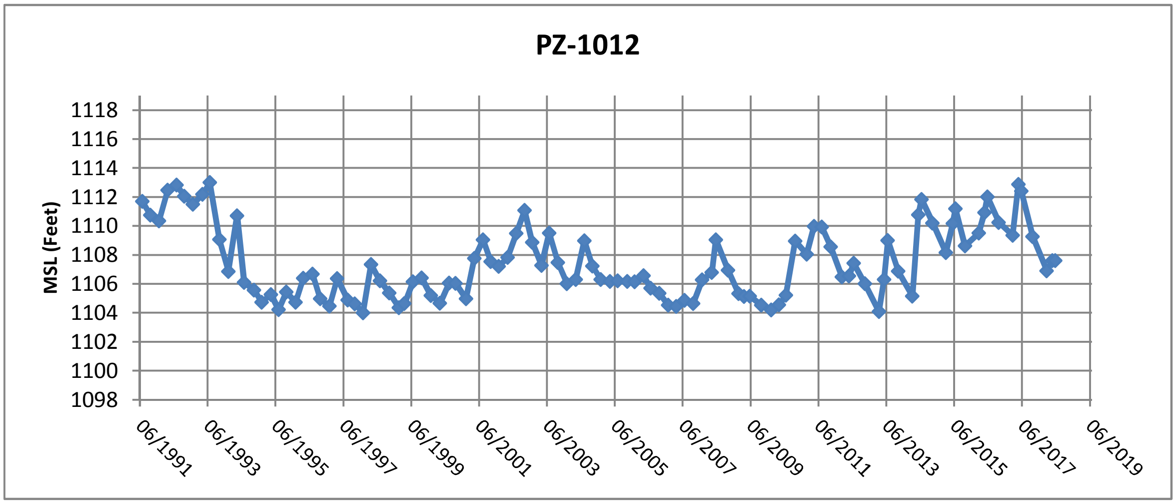
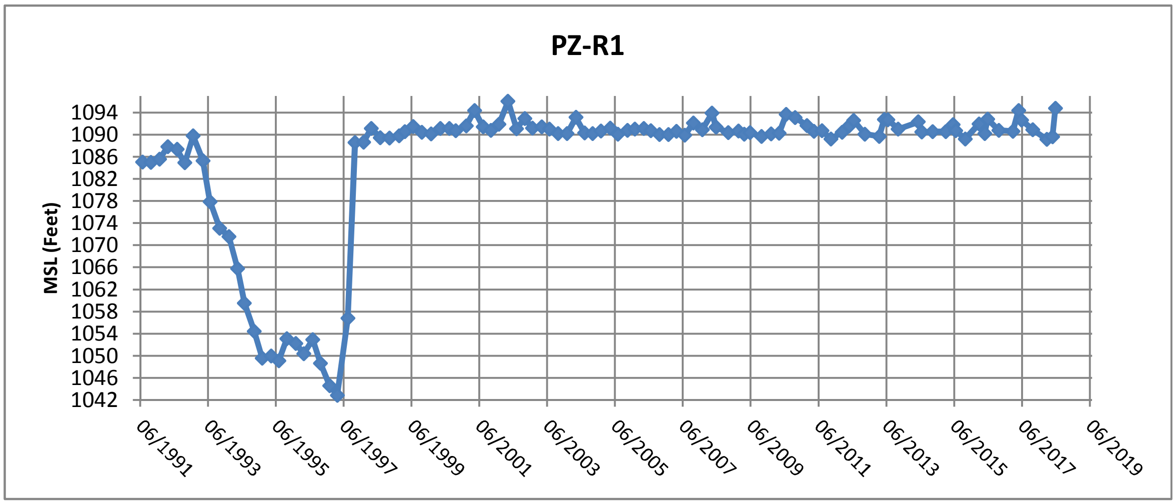
FIGURE 1-2j
HYDROGRAPHS

Scale: NA	Date: July 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





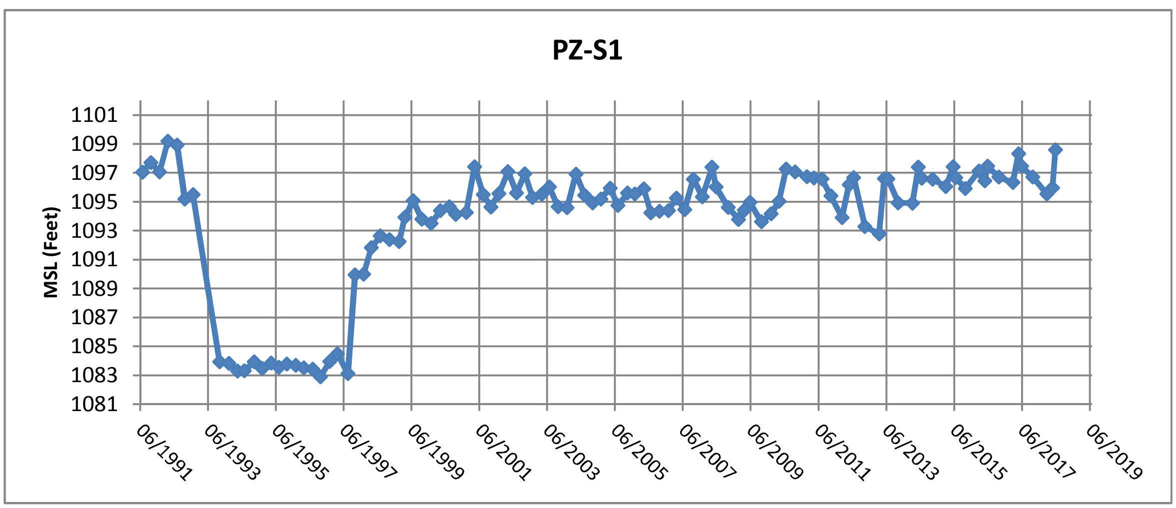


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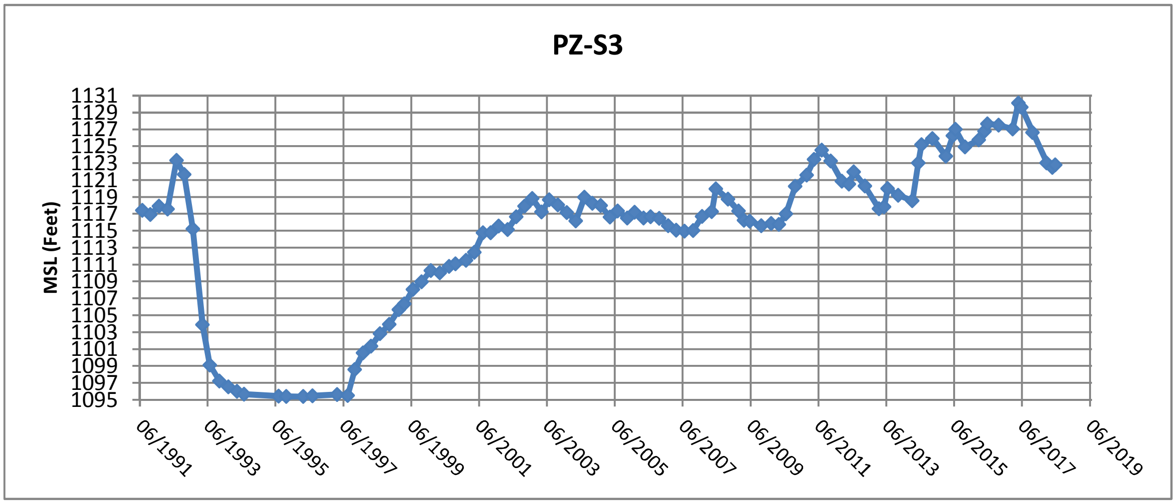
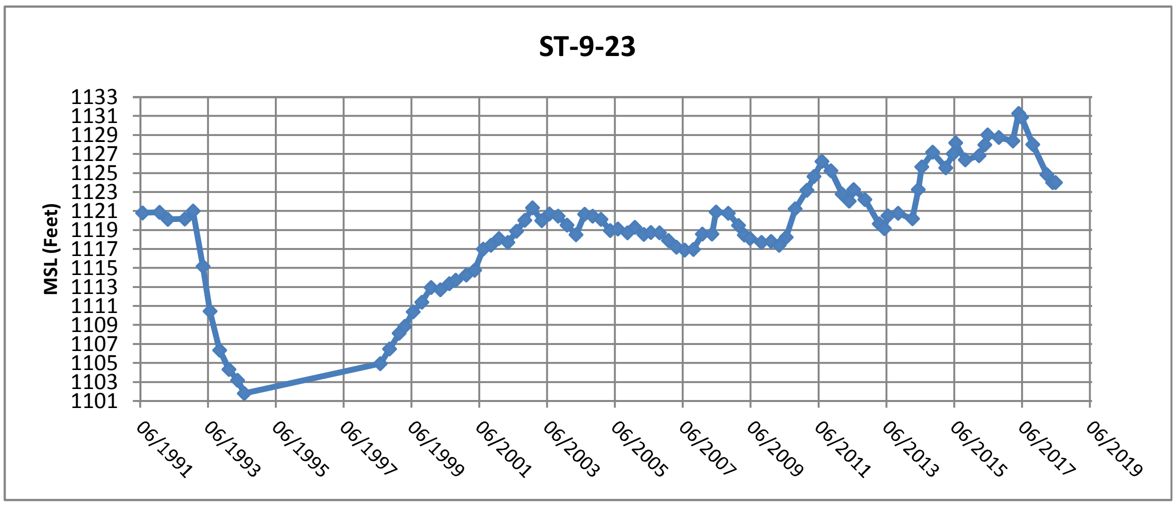
FIGURE 1-2k
HYDROGRAPHS

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\Hydrographs thru 2018Q3.xlsm





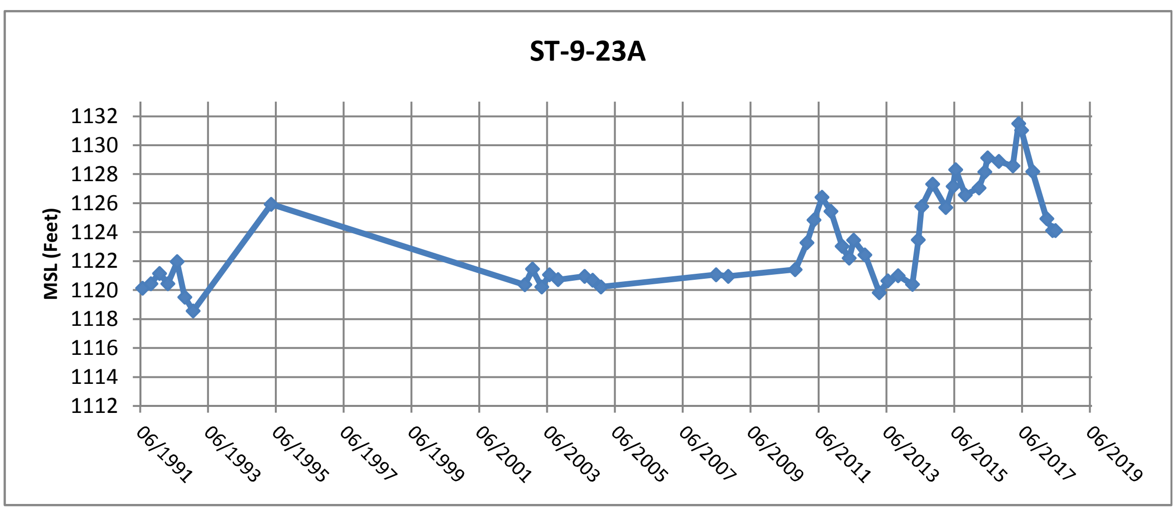


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FIGURE 1-2I
HYDROGRAPHS

Scale: NA	Date: July 2018

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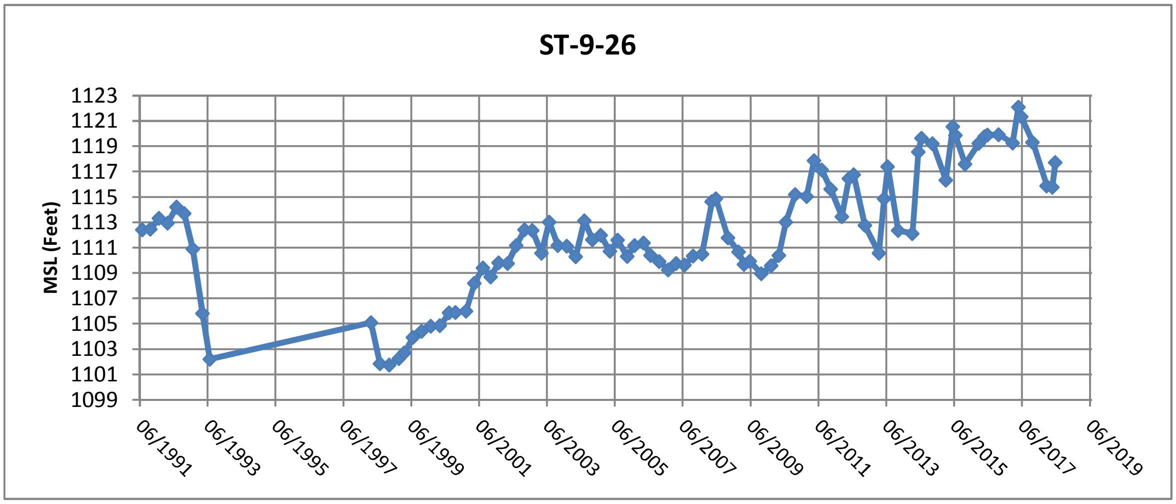

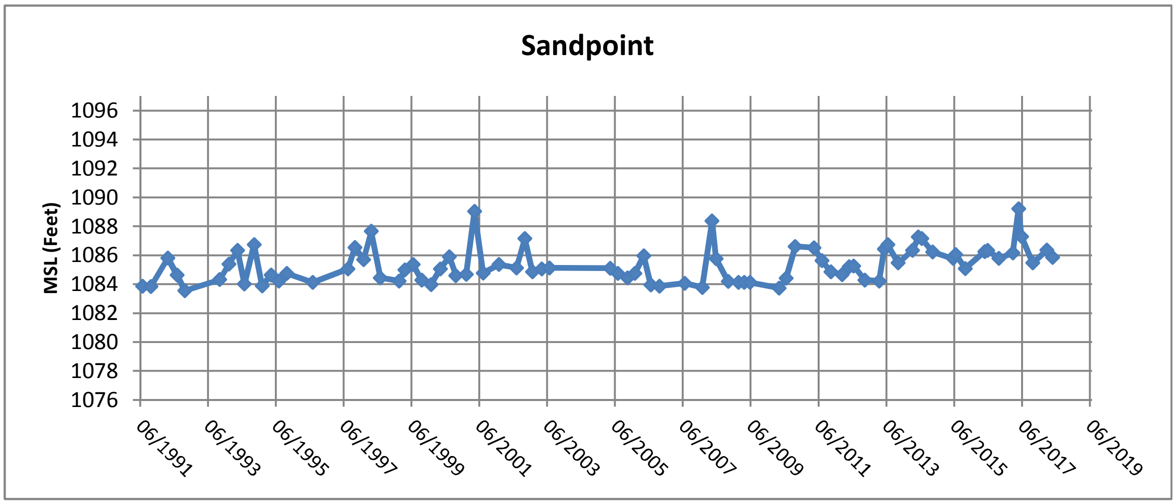

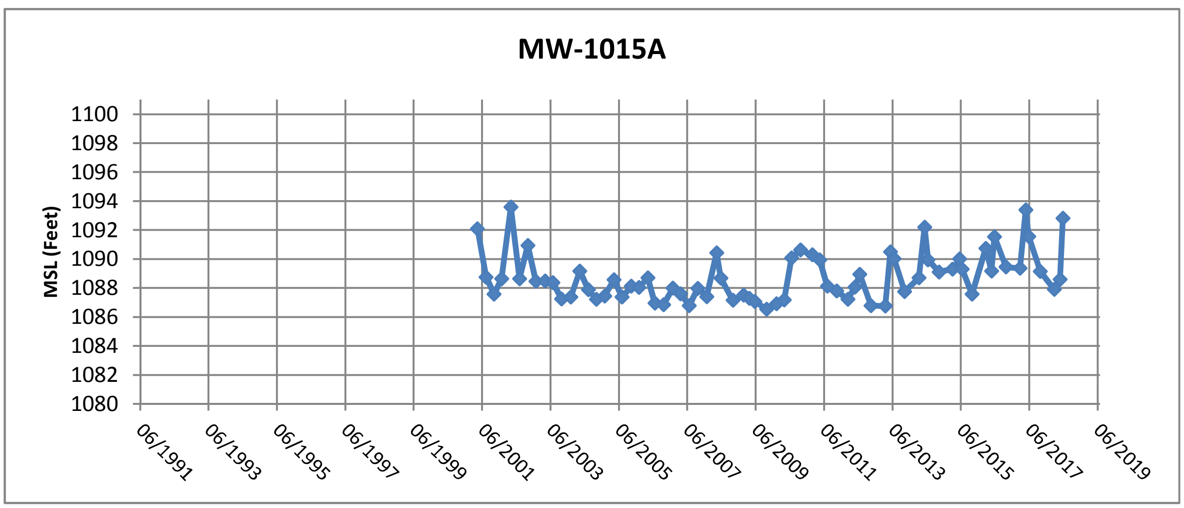

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FIGURE 1-2m

HYDROGRAPHS

Scale: NA	Date: July 2018

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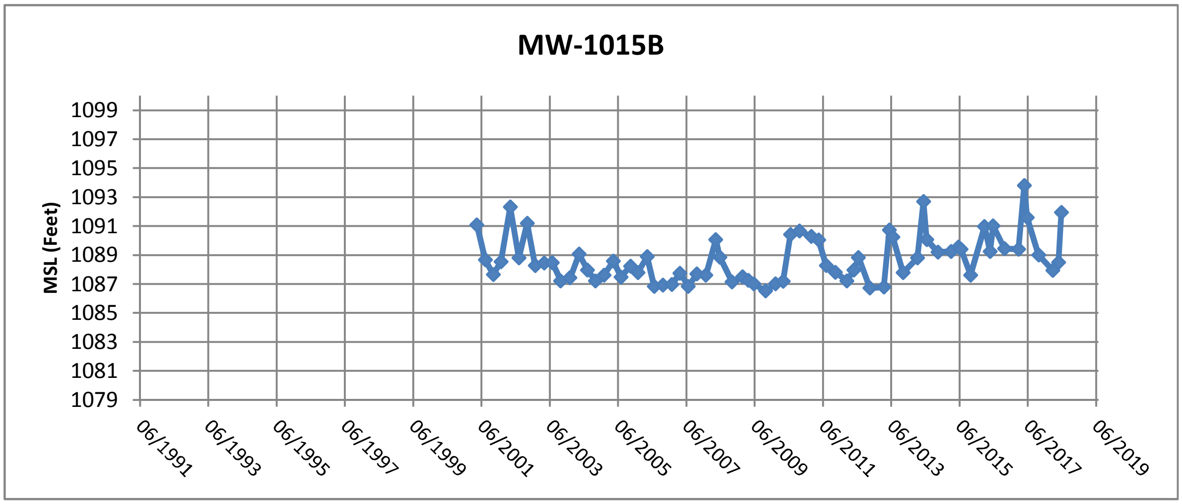

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FIGURE 1-2n

HYDROGRAPHS

Scale: NA	Date: July 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

Attachment 2

Overview of Temporal Optimization Algorithm Based on Chemistry Samples

Overview of Temporal Optimization Algorithm Based on Chemistry Samples

The Modified CES algorithm (MAROS, AFCEE, 2012) optimizes sampling frequencies based on statistics describing 1) the trend; 2) the rate of change (ROC); and 3) the magnitude of concentrations. While the trend indicates whether concentrations are statistically increasing or decreasing, the ROC refers to the actual rate of concentration change within the trend. For example, a statistically increasing or decreasing trend may be present, but at only a minimal concentration ROC.

The concentration trend (i.e., either increasing, decreasing or no trend) is defined by the result of the Mann-Kendall nonparametric trend test, based on the decision criteria given in Table A2-1. The conclusions of increasing/decreasing or probably increasing/probably decreasing are made when high statistical confidence (i.e., low *p*-level) indicates that a trend exists. If less certainty of an existing trend is present, a conclusion of either no trend or stable is made.

Table A2-1

Modified CES Mann-Kendall Decision Criteria

Mann-Kendall Statistic	*p*-Level (probability of no trend)	Coefficient of Variation	Trend Conclusion
S > 0	< 0.05	Not Restricted	I (Increasing)
S > 0	0.05 – 0.10	Not Restricted	PI (Probably Increasing)
S > 0	> 0.10	Not Restricted	NT (No Trend)
S ≤ 0	> 0.10	≥ 1	NT (No Trend)
S ≤ 0	> 0.10	< 1	S (Stable)
S < 0	0.05 – 0.10	Not Restricted	PD (Probably Decreasing)
S < 0	< 0.05	Not Restricted	D (Decreasing)

Note: Adapted from Table 2.1 of AFCEE (2012)

Prepared by: SGL
Checked by: ASH1

The ROC is estimated by the slope of a fitted trend line from a linear regression analysis. The ROC is considered to be low if the concentration trend during a one-year period is less than half of a given threshold value (further defined below). A medium ROC indicates a concentration trend during a one-year period that is equal to the threshold value, and a high ROC indicates a concentration trend during a one-year period that is twice the threshold value. Therefore, for some concentration threshold, C, a low ROC = 0.5×C per year, medium ROC = 1.0×C per year and high ROC = 2.0×C per year. Using the ROC and Mann-Kendall trend results, general sampling frequency recommendations of quarterly, semiannual or annual are provided in the MAROS (AFCEE, 2012) and illustrated in Table A2-2.

Table A2-2

Summary of Optimal Sampling Frequency Flowchart

		Rate of Change (Linear Regression)					
		← High→	←MH→	←Med.→	←LM→	←Low	→
Mann-Kendall Trend	I	Q	Q	S	S	A	A
	PI	Q	Q	S	S	A	A
	NT	Q	Q	S	S	A	A
	S	Q	S	S	A	A	A
	PD	Q	S	S	A	A	A
	D	Q	S	S	A	A	A

Q = Quarterly Sampling
S = Semi-Annual Sampling
A = Annual Sampling
Note: Adapted from Figure 5.1 of AFCEE (2012)

Prepared by: SGL
Checked by: ASH1

In calculating the ROC, the concentration threshold (C) is generally taken as a groundwater standard. Since groundwater standards are only defined for on-site compliance boundary wells, and Wisconsin Administrative Code Chapter NR 140 groundwater standards are not applicable, a consistent set of standards is not available for this calculation. Instead, the concentration threshold for this analysis was taken as the well-specific concentration average prior to ore-removal (prior to April 1993) if available. Where no well-specific data prior to ore-removal exists (i.e., MW-1000R, MW-1004, MW-1015A and MW-1015B for all quarterly parameters, arsenic in all wells and annual parameters in all wells), no ROC was calculated since no number was available to use as a basis for the calculation.

Attachment 3

Groundwater Chemistry Temporal Optimization Results and Concentration Trend Charts

Quarterly Parameters

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1000PR	Arsenic ug/l MW-1000PR	Copper ug/l MW-1000PR	Hardness mg/l MW-1000PR	Iron mg/l MW-1000PR	Manganese ug/l MW-1000PR	Sulfate mg/l MW-1000PR	Total Dissolved Solids mg/l MW-1000PR
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	84	5.6	8	100	0.84	800	9.1	140
2013-10	210	6.6	10	420	0.72	2300	210	560
2014-03	230	4.4	6.5	420	1.6	2100	210	540
2014-05	220	4.6	7	420	1.1	2000	210	520
2014-06	220	2.8	15	410	0.57	2100	210	520
2014-10	230	6.6	0	410	2.4	2300	200	570
2015-03	220	8.7	1.1	410	3.6	2300	190	560
2015-05	200	6.5	4.3	410	0.73	2100	190	580
2015-06	220	5.5	8.3	390	0.48	2100	190	540
2015-10	225	6.8	2.7	434	0.642	2150	68.3	534
2016-03	217	5.5	4.4	410	0.25	1930	187	514
2016-05	228	14.4	0	459	3.78	2320	188	524
2016-06	212	6.1	4.3	396	0.465	1800	186	562
2016-10	221	8.9	3.9	427	0.842	2340	149	536
2017-03	208	6.6	9.7	416	0.235	2110	199	514
2017-05	216	6.6	10.3	397	0.59	2080	195	514
2017-06	221	10.1	0	407	2.85	2220	172	546
2017-10	219	9.4	0	396	0.803	1970	192	502
2018-03	222	12.5	1.7	405	1.43	1840	189	514
2018-05	216	3.2	1.2	396	1.24	1960	208	538
2018-06	217	20.3	34.8	384	3.07	1870	207	512
2013 Q4 - 2018 Q3 Analysis								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	-22	75	-25	-78	12	-53	-49	-69
p-Level	0.25	0.0075	0.2205	0.006	0.362	0.046	0.06	0.013
MK Conclusion	S	I	NT	D	NT	D	PD	D
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0016	N/A	0.0014	-0.0117	0.0002	-0.1399	-0.0052	-0.0197
ROC	0.0069	N/A	0.0637	0.0428	0.0937	0.0638	0.2077	0.0514
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	80%	100%	100%	100%	100%	100%
2016 Q4 - 2018 Q3 Analysis								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	2	9	1	-21	14	-20	10	-5
p-Level	0.452	0.1685	0.476	0.0045	0.054	0.007	0.138	0.317
MK Conclusion	NT	NT	NT	D	PI	D	NT	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0024	N/A	0.0172	-0.0499	0.0023	-0.7100	0.0654	-0.0159
ROC	0.0103	N/A	0.7868	0.1821	0.9972	0.3239	2.6214	0.0414
ROC Conclusion	Low	N/A	LM	Low	LM	Low	High	Low
Percent Detects	100%	100%	75%	100%	100%	100%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1000R	Arsenic ug/l MW-1000R	Copper ug/l MW-1000R	Hardness mg/l MW-1000R	Iron mg/l MW-1000R	Manganese ug/l MW-1000R	Sulfate mg/l MW-1000R	Total Dissolved Solids mg/l MW-1000R
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	250	1.4	74	320	0.045	7700	87	430
2013-10	320	0	88	400	0	4500	93	510
2014-03	420	0	140	440	0	15000	51	560
2014-05	100	0	26	210	0.08	720	120	270
2014-06	200	0	76	430	0	12000	280	630
2014-10	230	0	83	360	0	11000	160	500
2015-03	200	0	70	320	0	9600	88	470
2015-05	110	0.53	40	200	0	2800	72	330
2015-06	160	0	57	260	0	7300	120	410
2015-10	247	0.29	89.7	336	0.0183	10600	69.2	450
2016-03	204	0.32	80.4	295	0.0184	7810	75.1	440
2016-05	182	0.36	71.7	296	0	9380	91.4	396
2016-06	149	0.3	59.6	244	0	8050	106	424
2016-10	218	0.32	94.4	329	0.0196	13800	90.1	468
2017-03	165	0	62.4	251	0	9310	76.8	336
2017-05	85.7	0	13.2	134	0	82.1	51	202
2017-06	104	0	40.8	203	0	5410	107	340
2017-10	168	0	60.5	233	0	5820	47.5	318
2018-03	175	0	51.7	225	0	3070	37.3	306
2018-05	174	0	41.3	245	0	1110	65.6	348
2018-06	72	0	11.9	71	0	70	36.6	144
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	-67	-4	-72	-96	-14	-68	-80	-100
p-Level	0.0155	0.462	0.01	0.001	0.339	0.014	0.005	0
MK Conclusion	D	NT	D	D	NT	D	D	D
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	30%	100%	100%	20%	100%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-4	-7	-14	-10	-7	-18	-16	-10
p-Level	0.36	0.2365	0.054	0.138	0.2365	0.016	0.031	0.138
MK Conclusion	S	NT	PD	S	NT	D	D	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	13%	100%	100%	13%	100%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1002	Arsenic ug/l MW-1002	Copper ug/l MW-1002	Hardness mg/l MW-1002	Iron mg/l MW-1002	Manganese ug/l MW-1002	Sulfate mg/l MW-1002	Total Dissolved Solids mg/l MW-1002
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	49	0.73	7	72	0.17	4.7	6.7	120
2013-10	52	0	0	120	0	0	4.8	81
2014-03	64	0	0	71	0	0	5.3	84
2014-05	60	0	0	76	0.019	0	6	69
2014-06	64	0	0	77	0	0	6	110
2014-10	69	0	0	80	0	0	5.6	95
2015-03	53	0	1.2	61	0	0	2.7	43
2015-05	54	0.57	0	60	0	0	2.6	73
2015-06	58	0	0	64	0	0	2.8	110
2015-10	61.2	0	0.67	67.8	0	0	4.6	96
2016-03	71.2	0	1.5	76.9	0.025	0.94	5.4	128
2016-05	77.4	0	0.56	85.7	0	2.1	6.1	132
2016-06	71.5	0	0.86	86.5	0	1.7	4.9	138
2016-10	71.1	0	0.69	84.8	0.0169	0.36	4.6	118
2017-03	62.7	0	0.76	72.3	0	0.5	4.2	96
2017-05	68.9	0	0	75.9	0	0	3.7	122
2017-06	66.6	0	0	77.3	0	0	4.2	112
2017-10	78.5	0	0	68.4	0	0	3.1	104
2018-03	44	0	1.3	61.9	0.232	0	2.2	86
2018-05	56.5	0	0	60.4	0	0	2.2	86
2018-06	60.1	0	0	58	0	0	2.1	88
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	27	-7	20	-44	6	11	-88	37
p-Level	0.202	0.4235	0.271	0.082	0.436	0.3745	0.002	0.1235
MK Conclusion	NT	NT	NT	PD	NT	NT	D	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0019	N/A	0.0002	-0.0113	0.0000	0.0001	-0.0015	0.0120
ROC	0.0139	N/A	0.0089	0.0571	0.0624	0.0077	0.0831	0.0365
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	5%	40%	100%	20%	25%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-10	0	-6	-22	-3	-11	-24	-15
p-Level	0.138	0.5	0.274	0.002	0.406	0.1135	0.001	0.0425
MK Conclusion	S	S	NT	D	NT	NT	D	D
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0269	N/A	-0.0004	-0.0413	0.0001	-0.0006	-0.0046	-0.0540
ROC	0.2004	N/A	0.0206	0.2093	0.2335	0.0489	0.2481	0.1643
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	0%	38%	100%	25%	25%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1002G	Arsenic ug/l MW-1002G	Copper ug/l MW-1002G	Hardness mg/l MW-1002G	Iron mg/l MW-1002G	Manganese ug/l MW-1002G	Sulfate mg/l MW-1002G	Total Dissolved Solids mg/l MW-1002G
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	82	0.73	7	120	0.028	2.5	11	180
2013-10	80	0	0	61	0	0	7.9	150
2014-03	88	0	0	120	0	0	7.6	140
2014-05	92	0	0	130	0	1.9	8	120
2014-06	91	0	0	120	0	0	8.5	160
2014-10	93	0	0	120	0	0	7.8	170
2015-03	93	0	0	130	0	0	7.9	150
2015-05	91	0	0	130	0	0	7.2	180
2015-06	95	0	0	130	0	0	7.3	200
2015-10	98.2	0	0.35	144	0	0.23	9.2	190
2016-03	98.5	0	0.52	141	0	0.86	9.3	192
2016-05	96.2	0	0	142	0.0138	5.9	9.9	204
2016-06	97	0	0.48	142	0.0238	0.28	8.9	220
2016-10	102	0	0.53	148	0.0186	0.45	9.2	192
2017-03	98.3	0	0.39	142	0	0.35	10.3	202
2017-05	101	0	0	150	0.21	0	9.7	194
2017-06	103	0	0	143	0	0	9.7	214
2017-10	108	0	0	148	0	0	10.8	204
2018-03	111	0	0	147	0	0	9.4	192
2018-05	104	0	0	140	0	0	10.3	190
2018-06	107	0	0	150	0	0	10.2	204
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	158	0	13	128	22	-6	114	106
p-Level	0	0.5	0.3505	0	0.25	0.436	0	0
MK Conclusion	I	S	NT	I	NT	NT	I	I
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0128	N/A	0.0000	0.0271	0.0000	-0.0001	0.0017	0.0373
ROC	0.0571	N/A	0.0023	0.0824	0.2281	0.0185	0.0573	0.0755
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	0%	25%	100%	20%	35%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	16	0	-13	0	-9	-13	6	0
p-Level	0.031	0.5	0.0715	0.5	0.1685	0.0715	0.274	0.5
MK Conclusion	I	S	PD	S	NT	PD	NT	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0130	N/A	-0.0007	-0.0008	-0.0001	-0.0006	0.0009	-0.0027
ROC	0.0581	N/A	0.0385	0.0024	1.2335	0.0930	0.0315	0.0054
ROC Conclusion	Low	N/A	Low	Low	Medium	Low	Low	Low
Percent Detects	100%	0%	25%	100%	25%	25%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1004	Arsenic ug/l MW-1004	Copper ug/l MW-1004	Hardness mg/l MW-1004	Iron mg/l MW-1004	Manganese ug/l MW-1004	Sulfate mg/l MW-1004	Total Dissolved Solids mg/l MW-1004
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	36	0.72	3.9	48	0.081	2.4	15	61
2013-10	40	0	3.1	59	0.028	0	22	77
2014-03	51	0	6.7	82	0.026	8.3	32	50
2014-05	26	0	5.3	34	0.15	2.6	12	10
2014-06	28	0	5.8	37	0.087	2.1	11	59
2014-10	35	0	5.3	40	0.021	0	10	80
2015-03	30	0	4.9	40	0.04	1.2	13	67
2015-05	30	0	4.2	39	0	0	11	26
2015-06	30	0	4.7	34	0	0	8.4	79
2015-10	41.3	0	4.2	58.9	0	1.4	20.5	92
2016-03	34.3	0	3.6	37	0	3.3	12	76
2016-05	23.3	0	5.1	30.4	0.206	2.8	9.9	62
2016-06	29.1	0.26	5.4	34.3	0.205	2.9	9.7	70
2016-10	30.8	0	4.7	43.3	0.0778	1.3	12.5	80
2017-03	31.7	0	4.1	36.3	0.0551	6.7	10.6	58
2017-05	22.3	0	7.1	32.1	0.392	6.1	9.5	62
2017-06	29	0	5.9	37.7	0.265	5.3	11.9	68
2017-10	39.7	0	4.1	55	0	2.9	20.1	80
2018-03	42.5	0	3.7	56.4	0	0	20	80
2018-05	37.3	0	3.1	46.6	0	0	16.1	66
2018-06	37.4	0	3.2	43.9	0	0	14.3	72
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	13	3	-55	1	-20	4	-8	35
p-Level	0.3505	0.4745	0.04	0.4935	0.271	0.462	0.411	0.137
MK Conclusion	NT	NT	D	NT	NT	NT	S	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	5%	100%	100%	60%	65%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	12	0	-17	10	-14	-17	8	5
p-Level	0.089	0.5	0.0235	0.138	0.054	0.0235	0.199	0.317
MK Conclusion	PI	S	D	NT	PD	D	NT	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	0%	100%	100%	50%	63%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1004P	Arsenic ug/l MW-1004P	Copper ug/l MW-1004P	Hardness mg/l MW-1004P	Iron mg/l MW-1004P	Manganese ug/l MW-1004P	Sulfate mg/l MW-1004P	Total Dissolved Solids mg/l MW-1004P
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	170	0.78	7	160	0.33	130	5	210
2013-10	150	0	0	140	0.21	96	0	150
2014-03	160	0	0	140	0.12	78	0	140
2014-05	160	0	0	140	0.11	74	0	100
2014-06	160	0	0	140	0.4	140	0	80
2014-10	170	0	0	140	0.43	110	0	130
2015-03	160	0	0	140	0.081	100	2.5	190
2015-05	160	0.64	0	140	0.16	94	3	130
2015-06	170	0	0	140	0.36	130	0	160
2015-10	167	0.46	0	156	0.418	149	3.6	160
2016-03	158	0.34	0	143	0.363	93.8	3.6	162
2016-05	160	0.2	0	141	0.313	85	3.7	166
2016-06	164	0.57	0.51	150	0.589	221	2.5	174
2016-10	164	0.32	0	157	0.318	122	2	170
2017-03	166	0.49	0	147	0.298	140	2.1	164
2017-05	169	0.34	0	151	0.484	180	2.9	200
2017-06	163	0	0	152	0.131	67.8	2.4	160
2017-10	161	0.35	0	148	0.207	125	2.5	160
2018-03	183	0.79	0	150	0.511	132	2.2	152
2018-05	166	0.33	1.8	140	0.397	105	2.4	164
2018-06	160	0.32	0	149	0.273	118	2.5	156
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	52	66	21	81	32	33	55	54
p-Level	0.049	0.017	0.2605	0.0045	0.159	0.1515	0.04	0.043
MK Conclusion	I	I	NT	I	NT	NT	I	I
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0055	N/A	0.0003	0.0062	0.0001	0.0178	0.0016	0.0263
ROC	0.0119	N/A	0.0139	0.0142	0.0967	0.0499	0.1140	0.0456
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	60%	10%	100%	100%	100%	70%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-5	-1	5	-10	0	-6	10	-14
p-Level	0.317	0.476	0.317	0.138	0.5	0.274	0.138	0.054
MK Conclusion	S	S	NT	S	S	S	NT	PD
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0056	N/A	0.0013	-0.0144	0.0001	-0.0260	0.0004	-0.0313
ROC	0.0119	N/A	0.0678	0.0329	0.1281	0.0730	0.0264	0.0544
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	88%	13%	100%	100%	100%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1004S	Arsenic ug/l MW-1004S	Copper ug/l MW-1004S	Hardness mg/l MW-1004S	Iron mg/l MW-1004S	Manganese ug/l MW-1004S	Sulfate mg/l MW-1004S	Total Dissolved Solids mg/l MW-1004S
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	62	0.73	7	87	0.028	2	7.6	140
2013-10	46	0	1	75	0.021	0	29	110
2014-03	51	0	1.6	81	0	0	33	130
2014-05	53	0	1.6	89	0	0	38	98
2014-06	52	0	1.2	89	0	0	36	130
2014-10	51	0	1.3	83	0	0	35	110
2015-03	44	0	2.6	66	0	0	26	110
2015-05	42	0	1.9	63	0	0	25	110
2015-06	44	0	1.9	68	0	0	27	96
2015-10	40.9	0.13	1.8	67.2	0	0.73	24.7	106
2016-03	36.7	0	1.8	60.4	0	0.74	24.2	100
2016-05	37.7	0	1.6	61.2	0	0.99	24.2	108
2016-06	34.8	0	1.7	60.6	0	3.3	22.8	112
2016-10	38.7	0	1.6	60.5	0.0151	0.47	21	102
2017-03	32.7	0	1.9	55.8	0	2.2	23.1	96
2017-05	39.3	0	1.8	57.4	0	0	21.2	90
2017-06	39.8	0	1.6	62.5	0	3.2	23.3	106
2017-10	45.4	0	1.6	58.1	0	4.1	23.5	92
2018-03	40.5	0	1.9	60.5	0	0	21.7	92
2018-05	45.1	0	2.1	62	0	0	24.7	90
2018-06	46.4	0	1.8	62.6	0	0	26.2	102
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	-54	-3	49	-98	-15	52	-98	-94
p-Level	0.043	0.4745	0.06	0.001	0.327	0.049	0.001	0.001
MK Conclusion	D	NT	PI	D	NT	I	D	D
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0054	N/A	0.0002	-0.0151	0.0000	0.0009	-0.0069	-0.0141
ROC	0.0319	N/A	0.0128	0.0633	0.0362	0.1653	0.3300	0.0369
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	5%	100%	100%	10%	40%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	22	0	7	15	-7	-6	20	-5
p-Level	0.002	0.5	0.2365	0.0425	0.2365	0.274	0.007	0.317
MK Conclusion	I	S	NT	I	NT	NT	I	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0152	N/A	0.0005	0.0057	0.0000	-0.0022	0.0057	-0.0085
ROC	0.0897	N/A	0.0235	0.0240	0.1954	0.3926	0.2728	0.0221
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	0%	100%	100%	13%	50%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1005	Arsenic ug/l MW-1005	Copper ug/l MW-1005	Hardness mg/l MW-1005	Iron mg/l MW-1005	Manganese ug/l MW-1005	Sulfate mg/l MW-1005	Total Dissolved Solids mg/l MW-1005
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	79	1.7	8.2	420	14	640	16	640
2013-10	57	1	1.8	430	17	470	15	860
2014-03	40	0	2.2	230	7.9	230	13	430
2014-05	41	1.4	1.4	230	10	280	13	450
2014-06	42	2.3	0	270	16	360	15	440
2014-10	53	1.9	0	290	16	410	14	660
2015-03	50	1.1	1.6	340	16	430	14	600
2015-05	49	1.6	1.2	360	14	360	14	870
2015-06	45	0.65	1.6	360	15	480	14	960
2015-10	57.3	1.2	1.6	418	16.2	540	14.9	1070
2016-03	62.3	1.6	0.91	508	19.7	490	21.3	940
2016-05	44.3	0.96	0.78	529	15.5	522	15.4	1220
2016-06	44.6	1.1	0.96	538	20.4	640	14.2	1550
2016-10	62.8	1.5	0.75	641	21.6	607	15.4	1540
2017-03	40.6	1.2	1.1	569	15.8	561	15.8	1170
2017-05	67.5	0.8	0	546	21	725	15	1410
2017-06	64.9	1.1	0	586	24.3	788	16.1	1170
2017-10	79.7	1.5	0	652	21.8	803	17.7	1540
2018-03	50.9	0.97	1.1	653	15.8	674	16.1	1120
2018-05	52	0.75	1.3	560	15	589	16.2	1510
2018-06	86.6	1.3	0	619	20	572	18	1120
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	78	-22	-69	148	65	131	116	111
p-Level	0.006	0.25	0.013	0	0.0185	0	0	0
MK Conclusion	I	S	D	I	I	I	I	I
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0133	N/A	-0.0006	0.2380	0.0042	0.2347	0.0020	0.5487
ROC	0.0616	N/A	0.0261	0.2068	0.1090	0.1338	0.0451	0.3129
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	95%	70%	100%	100%	100%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	8	-7	1	4	-7	-2	19	-9
p-Level	0.199	0.2365	0.476	0.36	0.2365	0.452	0.0115	0.1685
MK Conclusion	NT	S	NT	NT	S	S	I	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0165	N/A	0.0002	0.0196	-0.0065	-0.0539	0.0030	-0.2425
ROC	0.0763	N/A	0.0085	0.0170	0.1707	0.0308	0.0690	0.1383
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	50%	100%	100%	100%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1005P	Arsenic ug/l MW-1005P	Copper ug/l MW-1005P	Hardness mg/l MW-1005P	Iron mg/l MW-1005P	Manganese ug/l MW-1005P	Sulfate mg/l MW-1005P	Total Dissolved Solids mg/l MW-1005P
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	260	0.8	7	240	2.6	150	5	310
2013-10	230	0	0	210	0.92	84	0	250
2014-03	220	0	1.5	220	0.23	18	5.5	280
2014-05	240	0	0	220	1.2	82	0	200
2014-06	230	0	0	220	0.9	98	0	240
2014-10	260	0	0	220	1.5	68	0	220
2015-03	230	0	0	220	1.2	92	0	260
2015-05	240	0.58	0	210	0.89	94	0	240
2015-06	240	0	0	220	1.1	70	0	260
2015-10	251	0.32	0.32	240	1.07	71.6	0	234
2016-03	241	0.35	2.5	224	1.18	57.2	0	260
2016-05	253	0	0	216	0.757	78.9	2	240
2016-06	241	0.26	0.29	226	0.821	64.8	0	262
2016-10	255	1.2	0.97	230	1.55	69.2	0	240
2017-03	254	0.28	0.55	236	0.804	92.3	0	236
2017-05	255	0	0	229	1.37	80.4	0	254
2017-06	251	0	0	235	1.52	64.3	0	258
2017-10	254	0	0	226	1.59	64.2	0	250
2018-03	265	0	0	239	1.66	147	0	272
2018-05	250	0.58	0	225	1.91	79.2	0	238
2018-06	245	0	0	226	1.25	74.7	0	252
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	92	21	-9	87	73	-10	-17	18
p-Level	0.001	0.2605	0.399	0.002	0.009	0.387	0.304	0.293
MK Conclusion	I	NT	NT	I	I	S	NT	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0146	N/A	-0.0001	0.0098	0.0004	0.0107	-0.0007	0.0071
ROC	0.0205	N/A	0.0067	0.0149	0.0608	0.0260	0.0516	0.0084
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	35%	30%	100%	100%	100%	10%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-12	-8	-13	-9	10	-2	0	6
p-Level	0.089	0.199	0.0715	0.1685	0.138	0.452	0.5	0.274
MK Conclusion	PD	NT	PD	S	NT	S	S	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0048	N/A	-0.0013	-0.0066	0.0006	0.0380	0.0000	0.0188
ROC	0.0068	N/A	0.0658	0.0101	0.0783	0.0925	0.0000	0.0221
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	38%	25%	100%	100%	100%	0%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1005S	Arsenic ug/l MW-1005S	Copper ug/l MW-1005S	Hardness mg/l MW-1005S	Iron mg/l MW-1005S	Manganese ug/l MW-1005S	Sulfate mg/l MW-1005S	Total Dissolved Solids mg/l MW-1005S
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	180	2.5	7	220	3.4	210	5.7	240
2013-10	170	2.3	0	160	4.3	240	0	210
2014-03	190	2.3	0	160	3.7	220	0	160
2014-05	170	2.4	0	160	4.4	230	0	180
2014-06	180	2.4	0	160	4.7	230	0	200
2014-10	180	2.5	0	150	4.6	230	0	210
2015-03	180	2.3	0	160	4.4	230	0	240
2015-05	170	3.1	0	160	3.9	230	0	210
2015-06	180	2.4	0	160	4.6	230	0	210
2015-10	179	2.4	0	177	4.29	237	2.3	198
2016-03	168	2.7	0.39	156	4.36	213	0	192
2016-05	184	2.2	0	151	3.98	207	3.1	200
2016-06	167	2.3	0	155	4.09	207	2.1	210
2016-10	168	2.3	0	167	3.83	216	1.9	194
2017-03	161	2.4	0	154	3.94	225	2.5	192
2017-05	159	2.4	0	151	3.98	220	0	194
2017-06	161	2.9	0	152	3.95	211	3.5	198
2017-10	152	2.2	0	145	3.59	198	3.8	184
2018-03	158	2.3	0	142	3.86	200	3.9	180
2018-05	149	2.2	0	140	3.73	192	0	184
2018-06	151	2.2	0	141	3.88	199	0	194
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	-127	-38	-1	-102	-89	-113	68	-54
p-Level	0	0.117	0.4935	0	0.002	0	0.014	0.043
MK Conclusion	D	S	NT	D	D	D	I	D
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0176	N/A	0.0000	-0.0109	-0.0004	-0.0217	0.0015	-0.0072
ROC	0.0358	N/A	0.0000	0.0180	0.0415	0.0378	0.0929	0.0109
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	5%	100%	100%	100%	40%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-21	-11	0	-24	-4	-18	1	-6
p-Level	0.0045	0.1135	0.5	0.001	0.36	0.016	0.476	0.274
MK Conclusion	D	S	S	D	S	D	NT	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	-0.0255	N/A	0.0000	-0.0393	-0.0002	-0.0465	-0.0017	-0.0157
ROC	0.0517	N/A	0.0000	0.0652	0.0198	0.0808	0.1110	0.0239
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	0%	100%	100%	100%	63%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

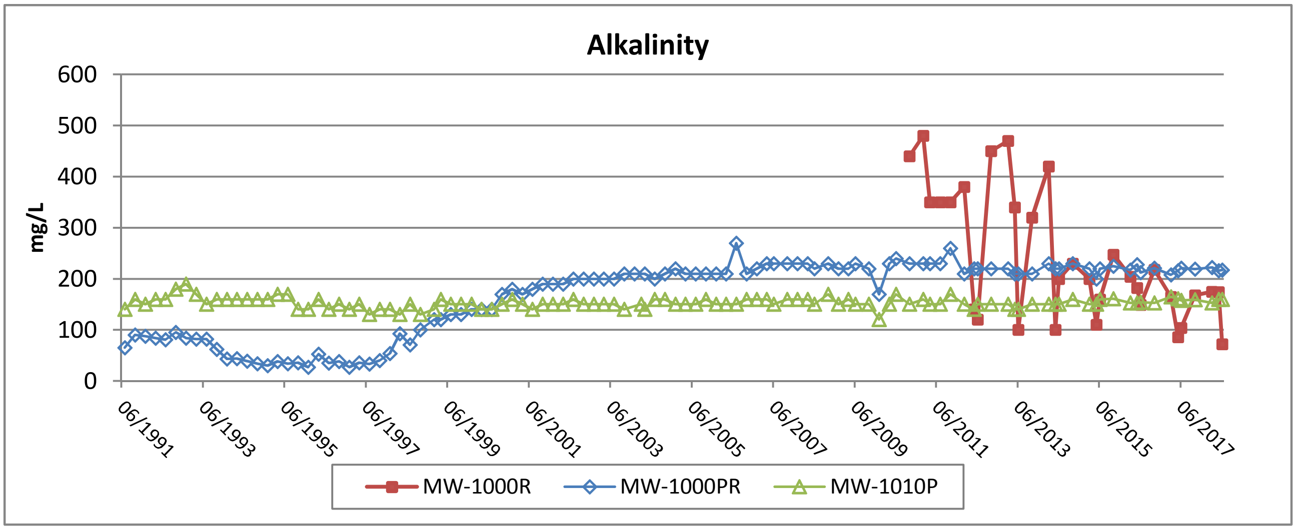
Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1010P	Arsenic ug/l MW-1010P	Copper ug/l MW-1010P	Hardness mg/l MW-1010P	Iron mg/l MW-1010P	Manganese ug/l MW-1010P	Sulfate mg/l MW-1010P	Total Dissolved Solids mg/l MW-1010P
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	160	16	7	140	0.045	180	12	230
2013-10	150	18	0	170	0	60	23	180
2014-03	150	19	0	170	0	32	27	190
2014-05	150	20	0	170	0	48	26	140
2014-06	150	18	0	170	0	22	29	180
2014-10	160	23	0	180	0	29	29	190
2015-03	150	20	0	180	0.039	31	29	220
2015-05	150	25	0	170	0	58	20	210
2015-06	160	22	0	170	0	50	21	220
2015-10	161	23	0.55	185	0	83.4	24.4	188
2016-03	153	18	0.27	178	0	33.7	30.4	180
2016-05	153	21.7	0	183	0	65.3	27.2	214
2016-06	154	22	0.61	167	0	61.8	29.4	212
2016-10	153	18.9	0.6	192	0.0519	61	30.1	212
2017-03	165	18.2	0.45	177	0	75.3	26.5	206
2017-05	161	25.9	0.78	182	0	51.9	34.2	212
2017-06	158	19.6	1.3	192	0	37	35.3	222
2017-10	159	21	0	175	0	62.1	30.1	196
2018-03	153	17.2	0	184	0	39.3	28.7	206
2018-05	160	16.5	1.7	169	0	53.6	26.6	212
2018-06	160	25.4	0	179	0	58.2	31.2	224
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	82	2	66	43	-3	46	70	72
p-Level	0.004	0.487	0.017	0.0875	0.4745	0.073	0.012	0.01
MK Conclusion	I	NT	I	PI	NT	PI	I	I
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0053	N/A	0.0005	0.0057	0.0000	0.0093	0.0035	0.0222
ROC	0.0120	N/A	0.0240	0.0149	0.0047	0.0188	0.1052	0.0352
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	40%	100%	10%	100%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	0	-2	-3	-9	-7	-4	-1	6
p-Level	0.5	0.452	0.406	0.1685	0.2365	0.36	0.476	0.274
MK Conclusion	S	S	NT	S	NT	S	S	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	0.0005	N/A	-0.0002	-0.0213	-0.0001	-0.0173	-0.0033	0.0056
ROC	0.0012	N/A	0.0129	0.0556	0.4179	0.0350	0.1011	0.0089
ROC Conclusion	Low	N/A	Low	Low	Low	Low	Low	Low
Percent Detects	100%	100%	63%	100%	13%	100%	100%	100%

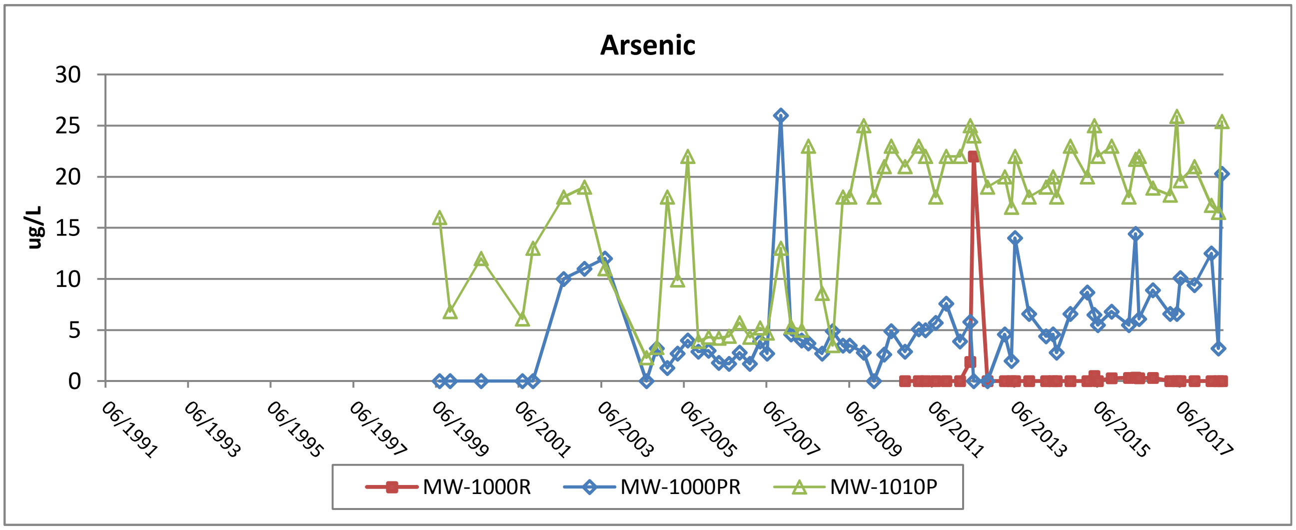
Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1015A	Arsenic ug/l MW-1015A	Copper ug/l MW-1015A	Hardness mg/l MW-1015A	Iron mg/l MW-1015A	Manganese ug/l MW-1015A	Sulfate mg/l MW-1015A	Total Dissolved Solids mg/l MW-1015A
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	79	0.77	1.2	87	0.019	8.8	8.9	110
2013-10	75	0	0	81	0	5.3	9	110
2014-03	80	0	0	86	0	5.9	8.7	66
2014-05	78	0	0	87	0	6.2	8.7	74
2014-06	78	0	0	87	0	4.5	8.6	110
2014-10	80	0	0	83	0.11	7.7	7.8	130
2015-03	78	0	0	89	0	5.5	7.4	100
2015-05	76	0	0	83	0	5.7	7	110
2015-06	80	0	0	85	0	4.5	6.7	120
2015-10	83.5	0	0.46	96.4	0.0101	6.8	8.7	120
2016-03	80.1	0	0.91	90.5	0.0341	16.9	8.3	132
2016-05	74.7	0	0	92.1	0	5.6	8.5	124
2016-06	75.5	0	0.51	88.4	0	7.2	7.2	132
2016-10	79.8	0	0.37	94.4	0.0161	5.4	7.5	128
2017-03	82.2	0	0.41	90.5	0	7.5	8.1	122
2017-05	80.7	0	0	91.3	0	6.9	7.7	124
2017-06	79.9	0	0	91.8	0	6.2	8	130
2017-10	84.7	0	0	89.6	0	7.6	8.1	126
2018-03	87.5	0	0	88	0	9.2	7.8	110
2018-05	83.3	0	0	91.1	0	7.8	8.4	124
2018-06	83.5	0	0	89.5	0	13.3	8.1	128
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	85	0	7	71	-12	86	-37	77
p-Level	0.0025	0.5	0.4235	0.011	0.362	0.002	0.1235	0.0065
MK Conclusion	I	S	NT	I	NT	I	S	I
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	0%	25%	100%	20%	100%	100%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	14	0	-11	-14	-7	20	13	0
p-Level	0.054	0.5	0.1135	0.054	0.2365	0.007	0.0715	0.5
MK Conclusion	PI	S	NT	PD	NT	I	PI	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	0%	25%	100%	13%	100%	100%	100%

Rate of Change Analysis for Trend Results - Quarterly Parameters

Analyte Units Location	Alkalinity as CaCO3 mg/l MW-1015B	Arsenic ug/l MW-1015B	Copper ug/l MW-1015B	Hardness mg/l MW-1015B	Iron mg/l MW-1015B	Manganese ug/l MW-1015B	Sulfate mg/l MW-1015B	Total Dissolved Solids mg/l MW-1015B
Avg of Pre-Ore Removal or All Data (With ND = 1/2 MDL)	180	0.75	1.1	150	0.18	84	1.8	270
2013-10	170	0	0	150	0.12	46	0	280
2014-03	180	0	0	150	0.22	55	0	270
2014-05	180	0	0	150	0.16	58	0	240
2014-06	180	0	0	150	0.22	53	0	330
2014-10	180	0	0	150	0.22	59	0	310
2015-03	180	0	0	150	0.031	47	0	250
2015-05	170	0.57	0	140	0.094	42	0	280
2015-06	180	0	0	150	0.21	61	0	310
2015-10	184	0.16	0	161	0.138	34.3	3.2	252
2016-03	173	0.23	0	153	0.173	43.1	2.4	294
2016-05	189	0	0	140	0.189	46.5	3.4	266
2016-06	172	0.13	0	160	0.0448	46.8	0	326
2016-10	178	0.1	0	167	0.213	46.4	0	296
2017-03	181	0	0	143	0.0822	30.6	1.7	266
2017-05	181	0	0	147	0.264	35.3	1.8	262
2017-06	182	0	0	163	0.214	47.1	0	316
2017-10	185	0	0	163	0.196	46.9	0	280
2018-03	169	0	0	150	0.2	42.3	0	268
2018-05	175	0	2.4	150	0.304	45	0	262
2018-06	173	0	0	147	0	37.9	0	304
2013 Q4 - 2018 Q3 Analys								
(Previous 5-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	20	20	20	20	20	20	20	20
Mann-Kendall S	12	-11	17	15	11	-60	9	2
p-Level	0.362	0.3745	0.304	0.327	0.3745	0.027	0.399	0.487
MK Conclusion	NT	NT	NT	NT	NT	D	NT	NT
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	25%	5%	100%	95%	100%	25%	100%
2016 Q4 - 2018 Q3 Analys								
(Previous 2-Years)								
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	8	8	8	8	8	8	8	8
Mann-Kendall S	-5	-7	5	-5	-2	0	-7	-1
p-Level	0.317	0.2365	0.317	0.317	0.452	0.5	0.2365	0.476
MK Conclusion	S	NT	NT	S	S	S	NT	S
	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results	ROC Results
Linear Slope (units/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
ROC Conclusion	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percent Detects	100%	13%	13%	100%	88%	100%	25%	100%





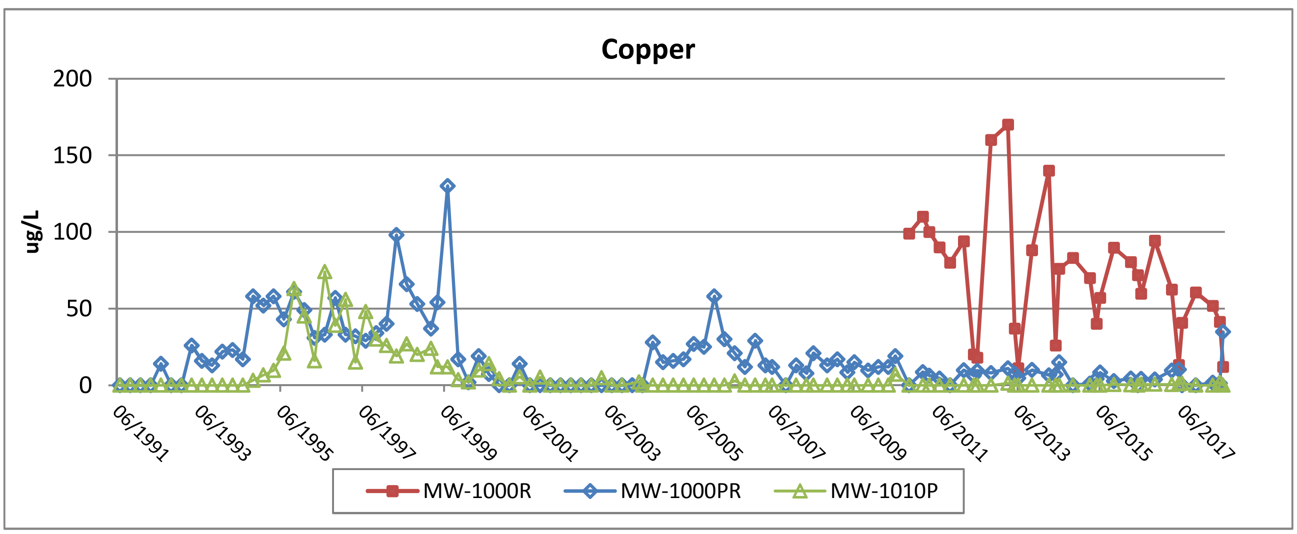


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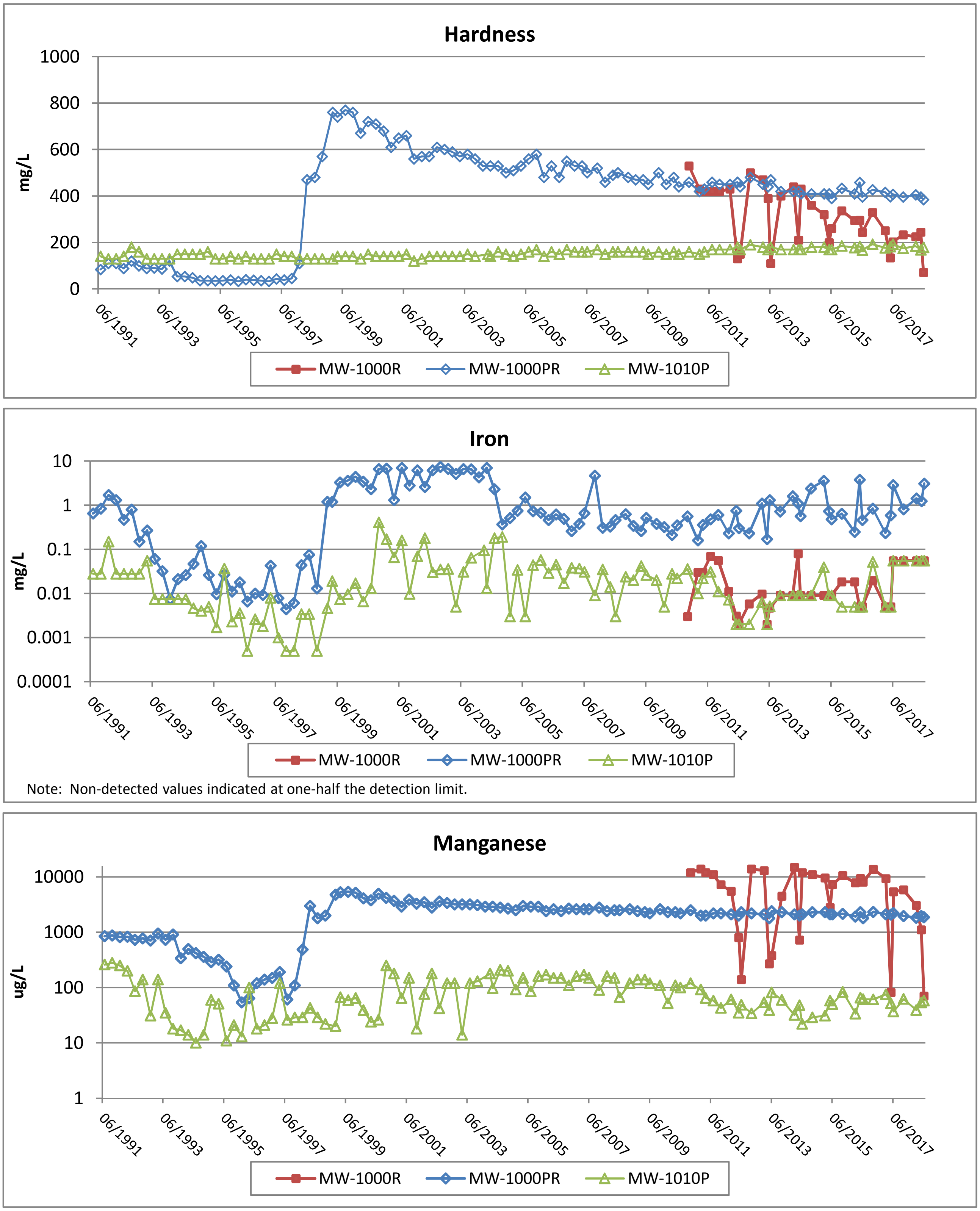
FIGURE 3-1a

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm



Note: Iron trend graphs are displayed on a logarithmic scale so the trend patterns of MW-1000R, MW-1000PR and MW-1010P are visible at different concentration scales.

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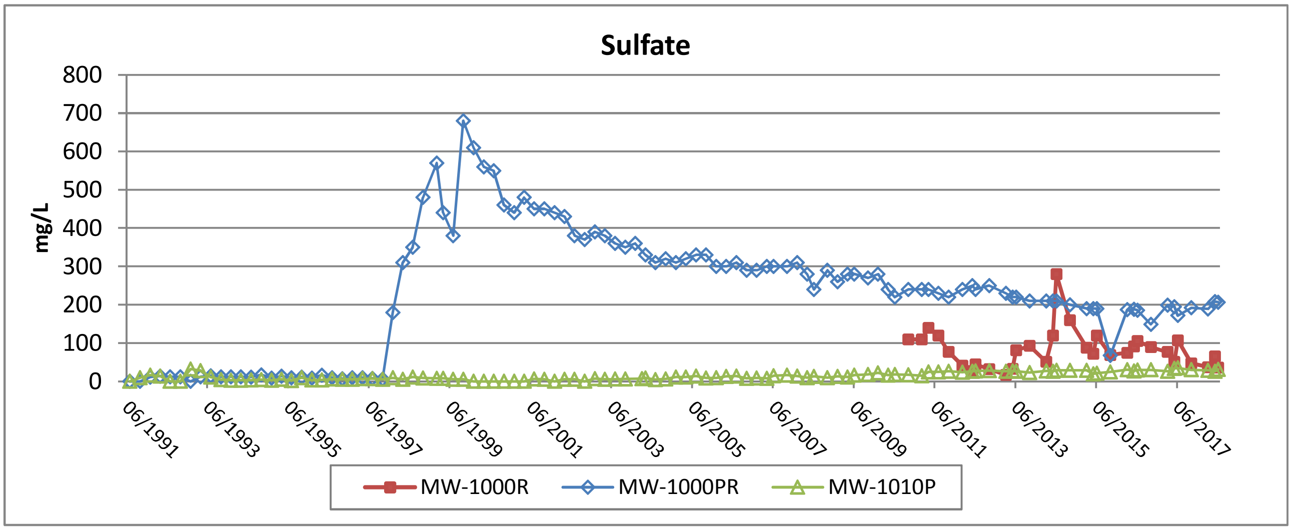
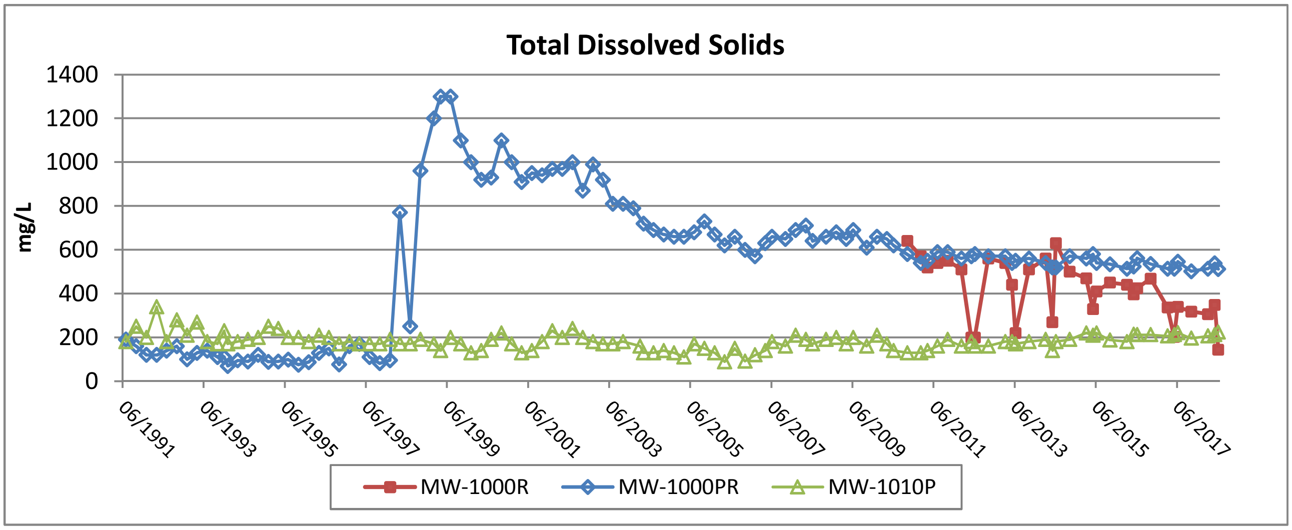
FIGURE 3-1b

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





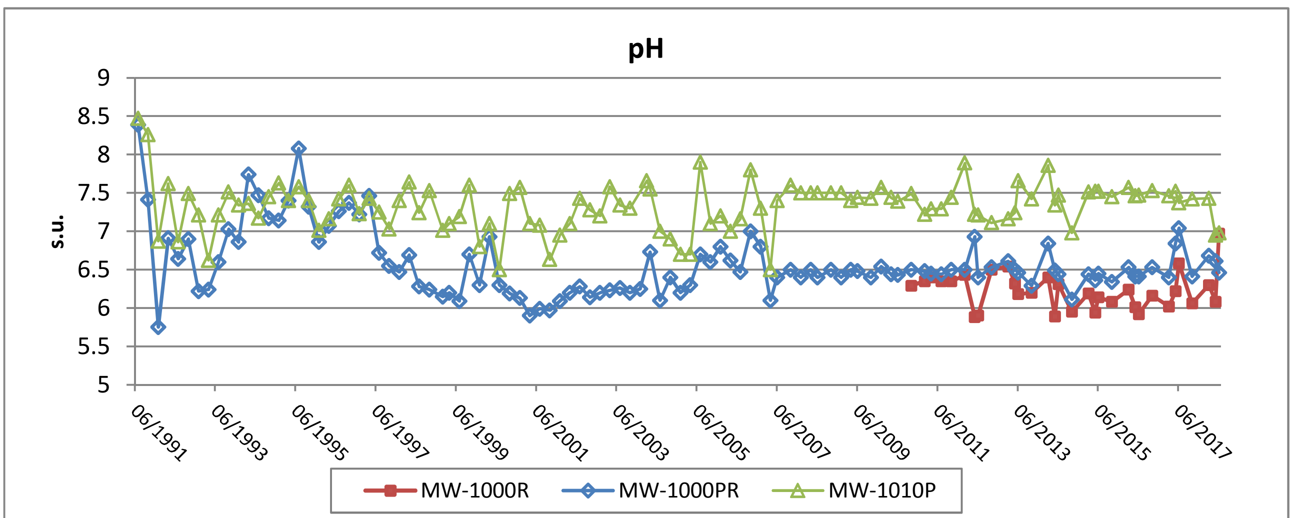


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FIGURE 3-1c

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm

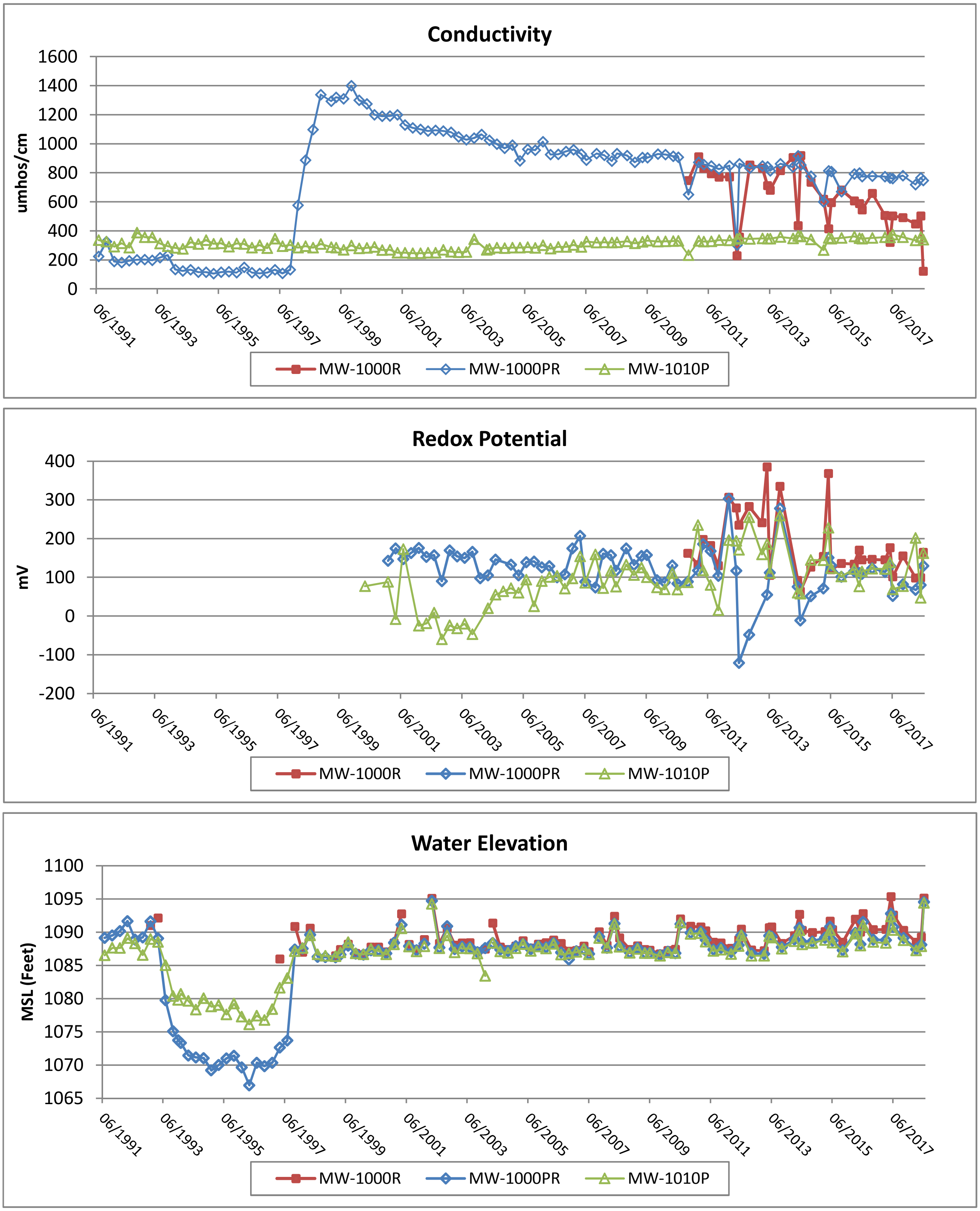

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FIGURE 3-1d

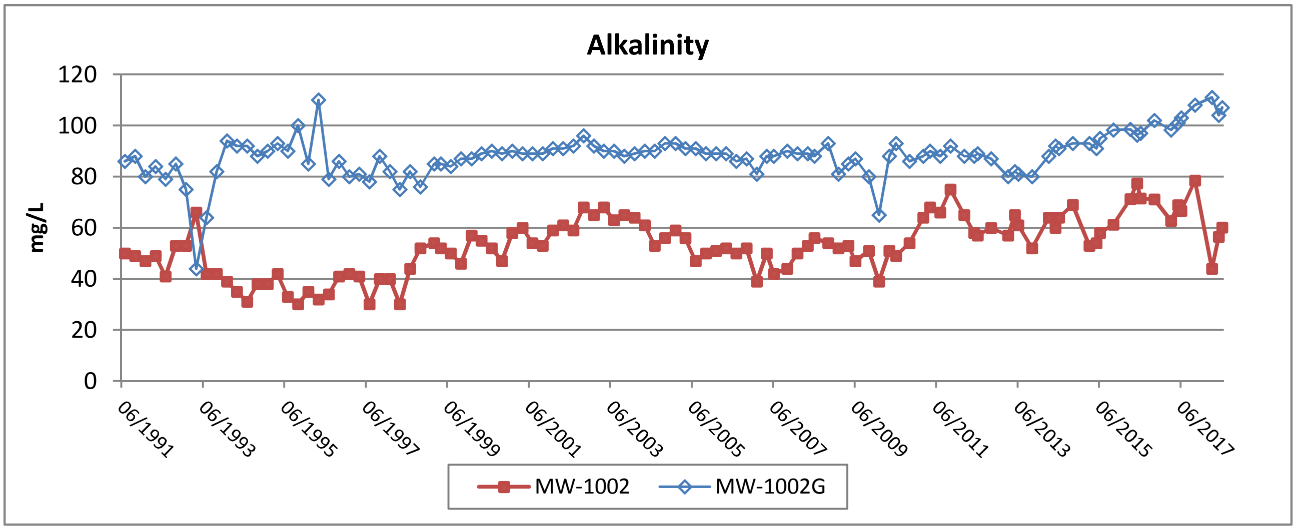
GROUNDWATER TREND GRAPHS - QUARTERLY

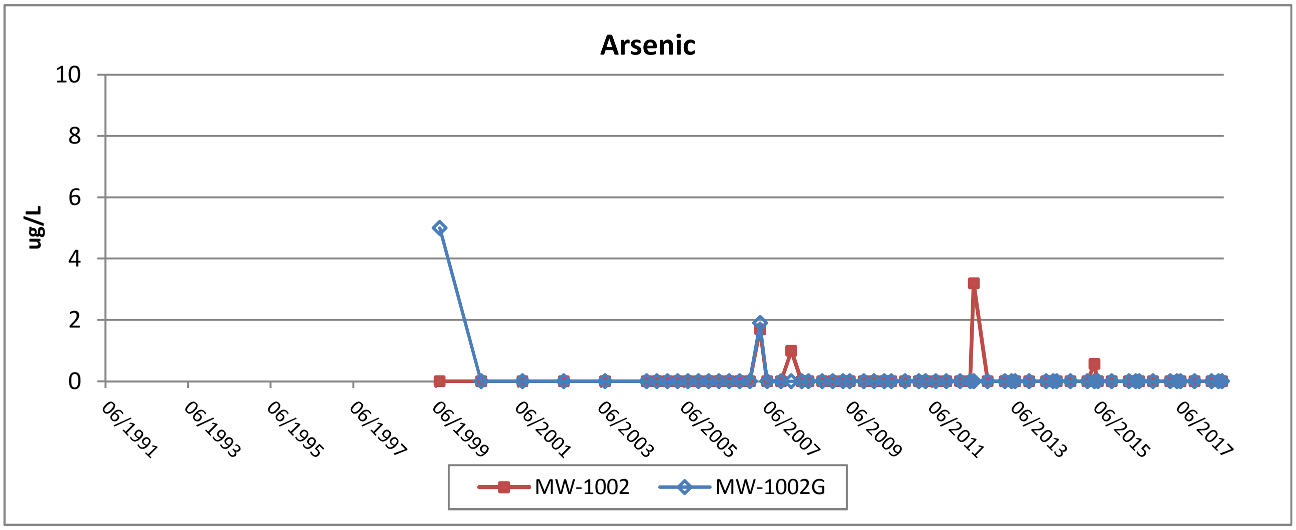
MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





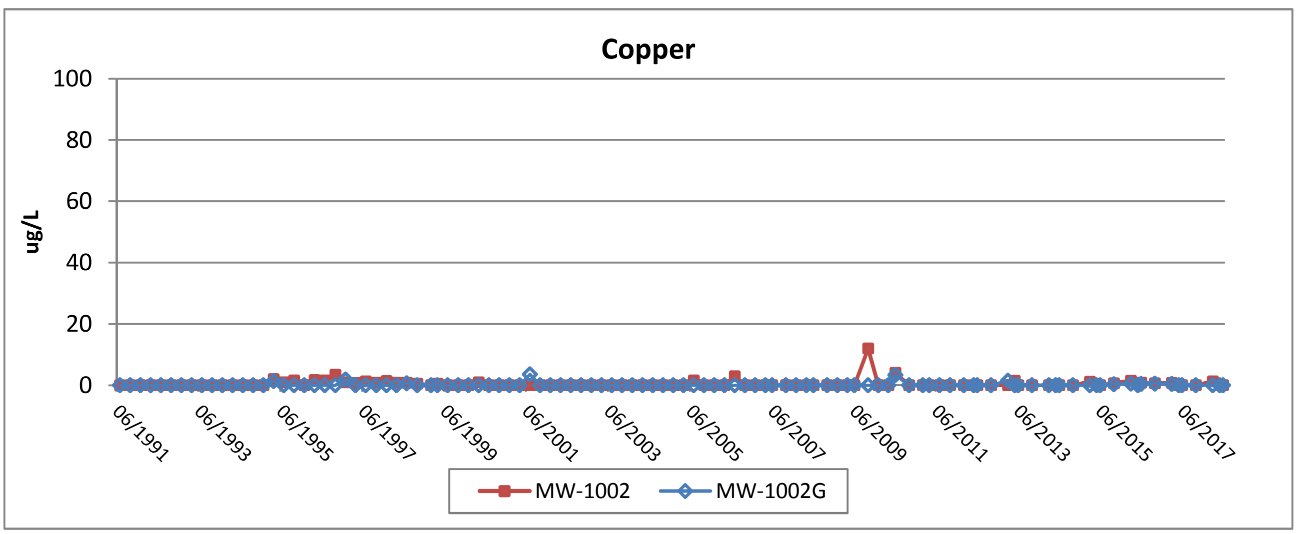


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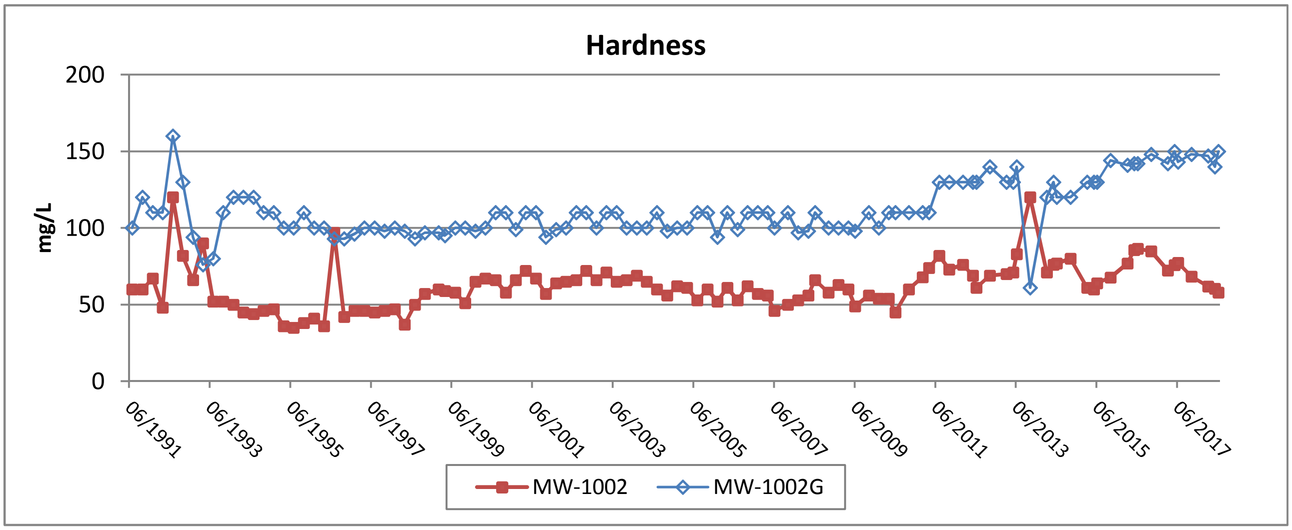
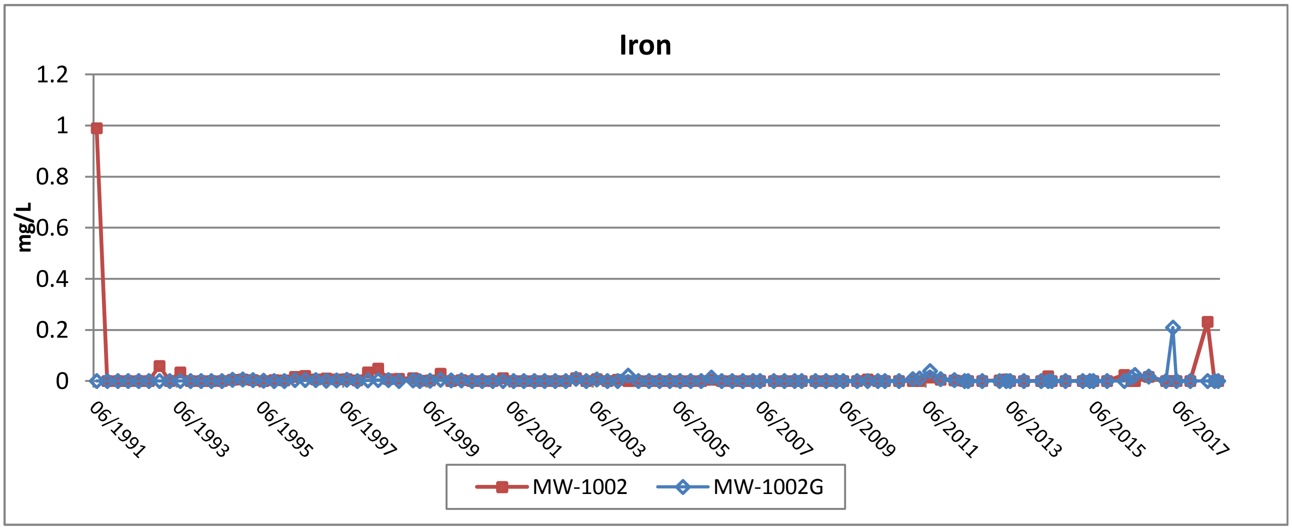
FIGURE 3-2a

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1002/MW-1002G

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





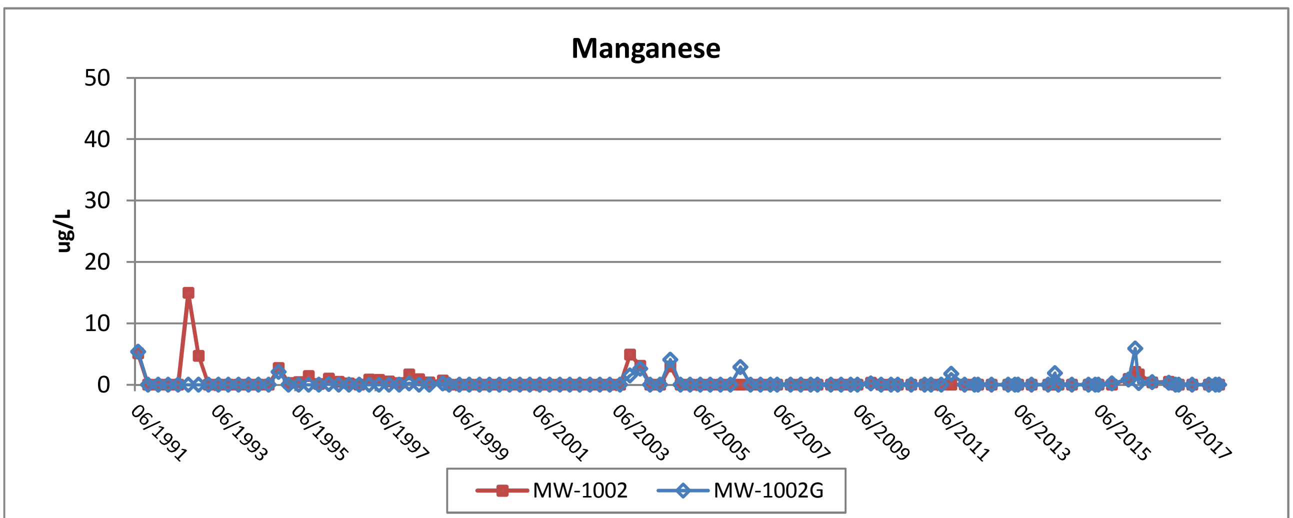


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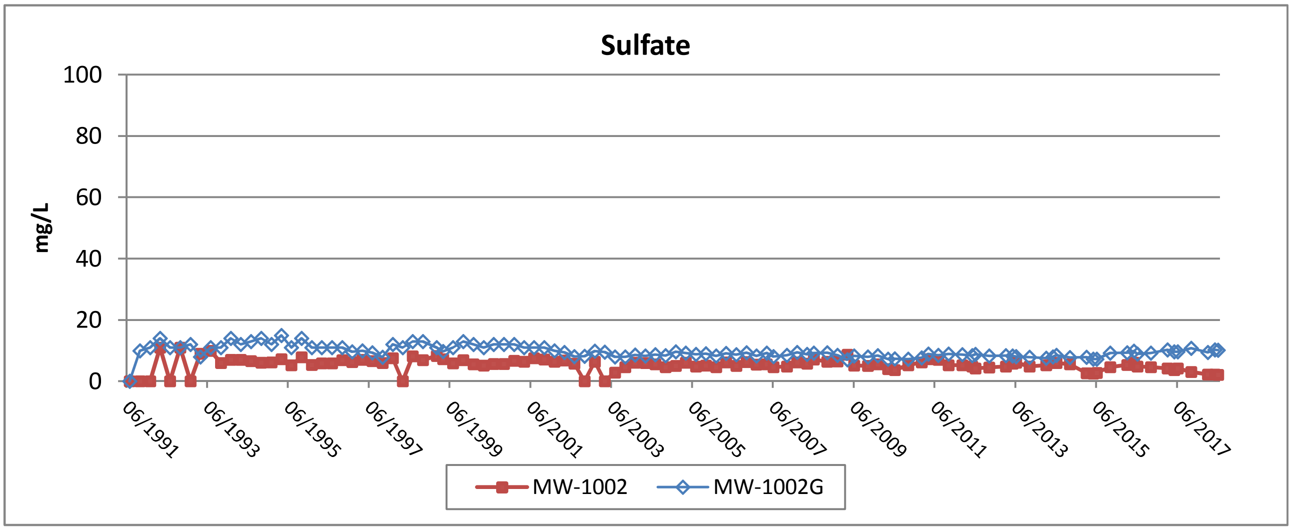
FIGURE 3-2b

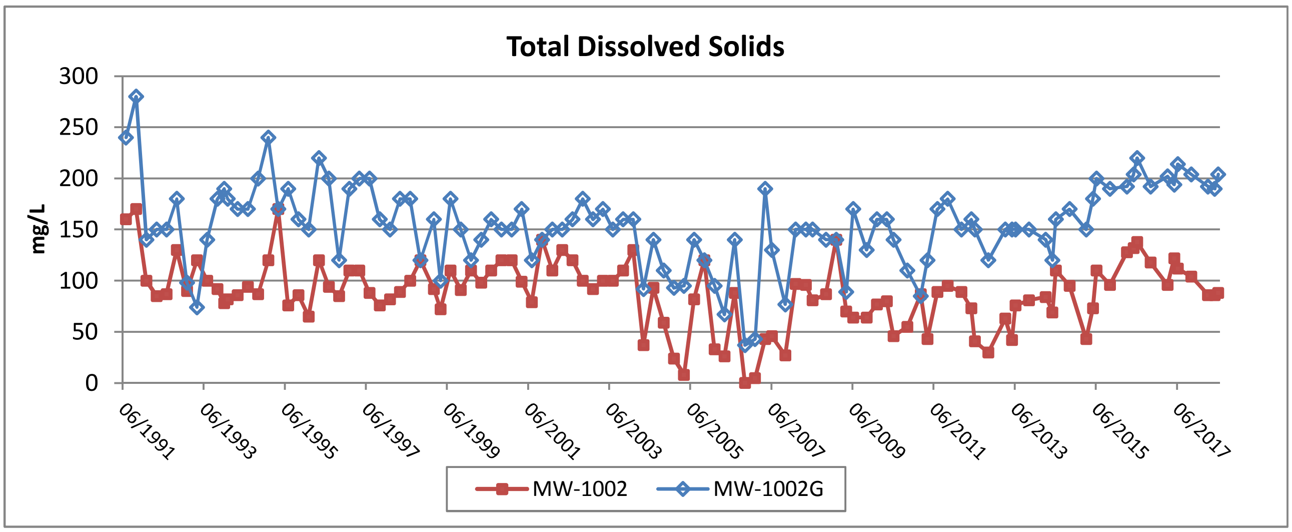
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1002/MW-1002G

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





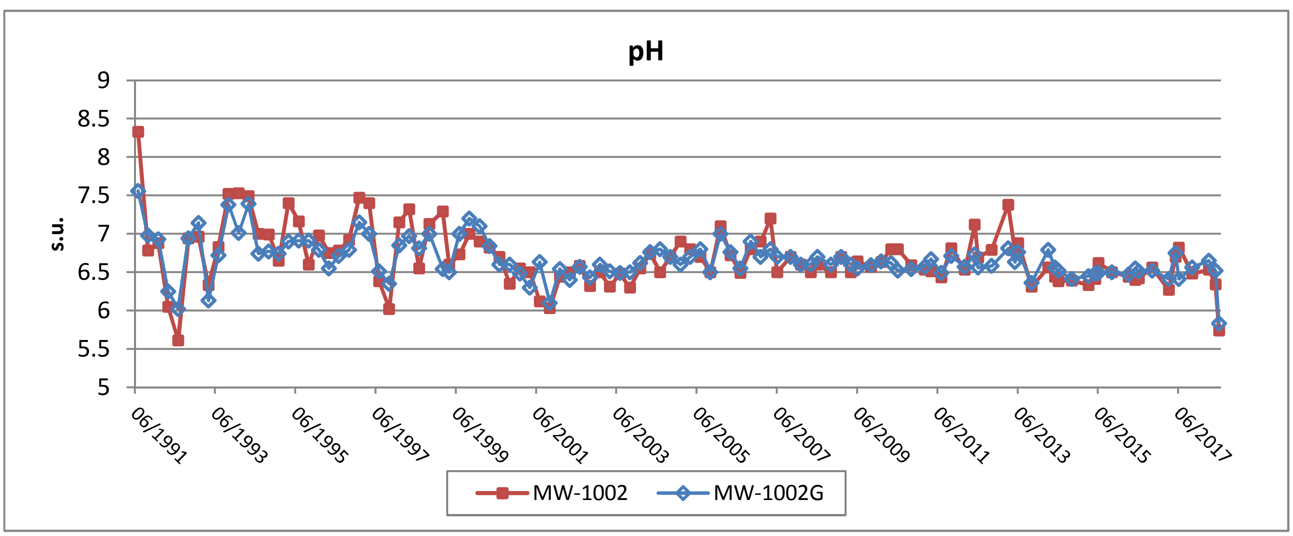


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FIGURE 3-2c

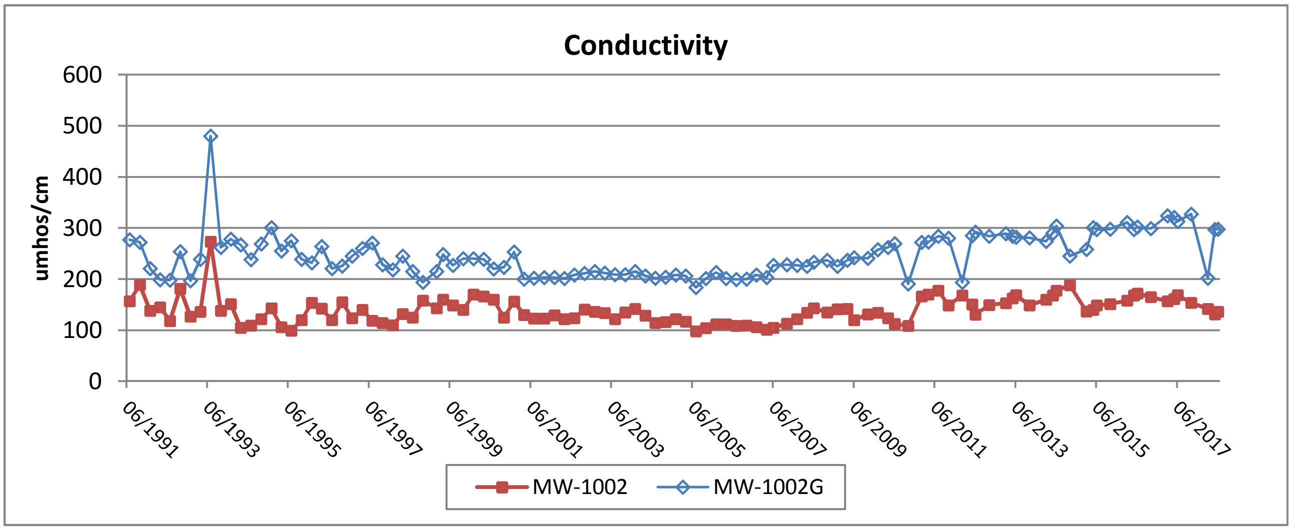
GROUNDWATER TREND GRAPHS - QUARTERLY

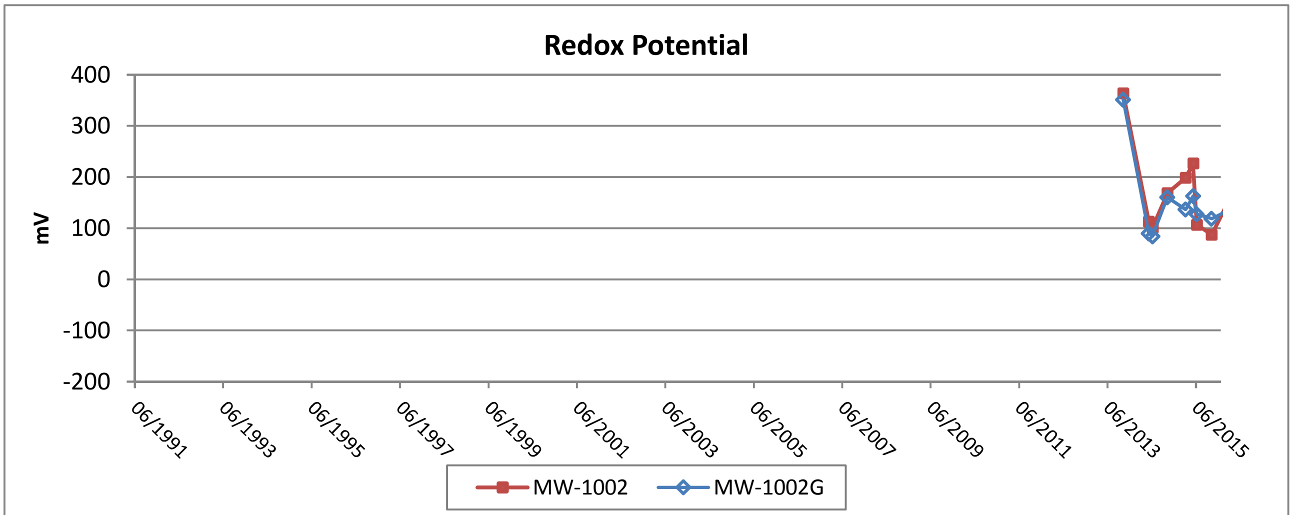
MW-1002/MW-1002G

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





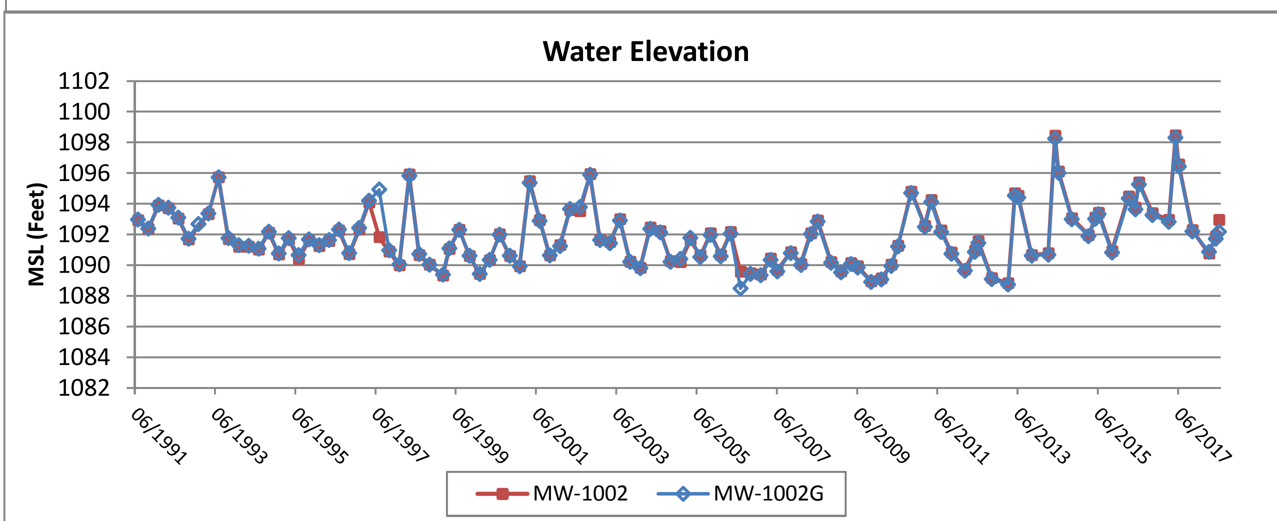


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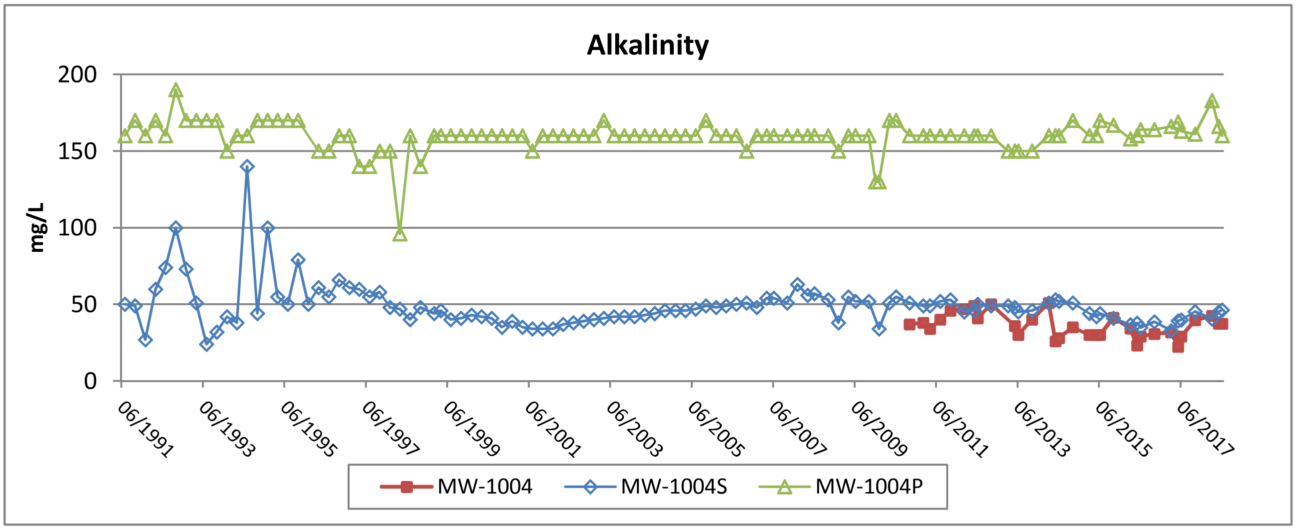
FIGURE 3-2d

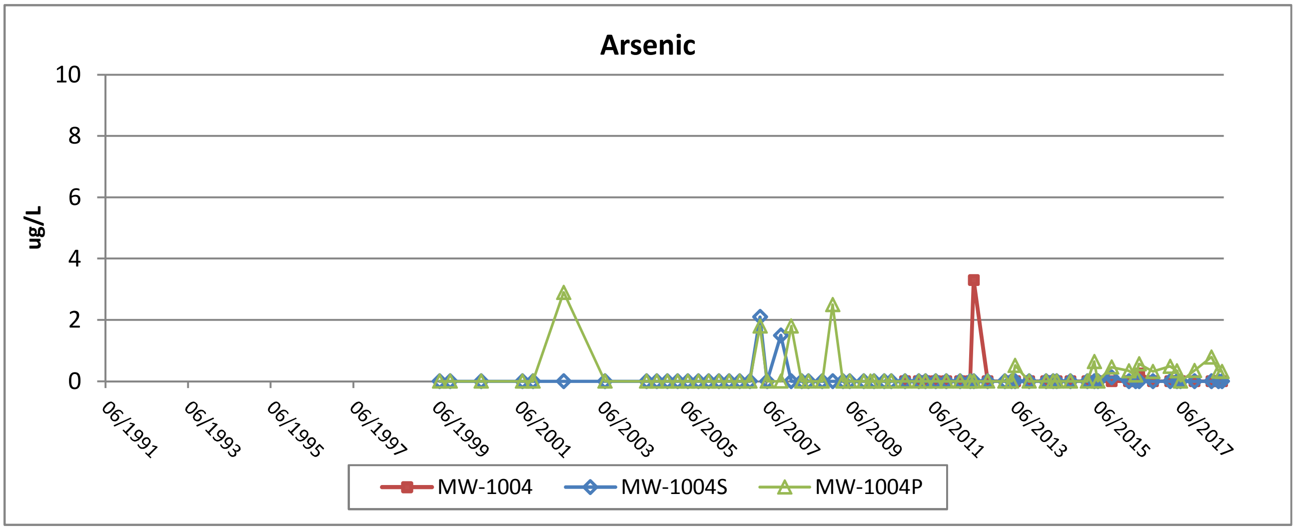
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1002/MW-1002G

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





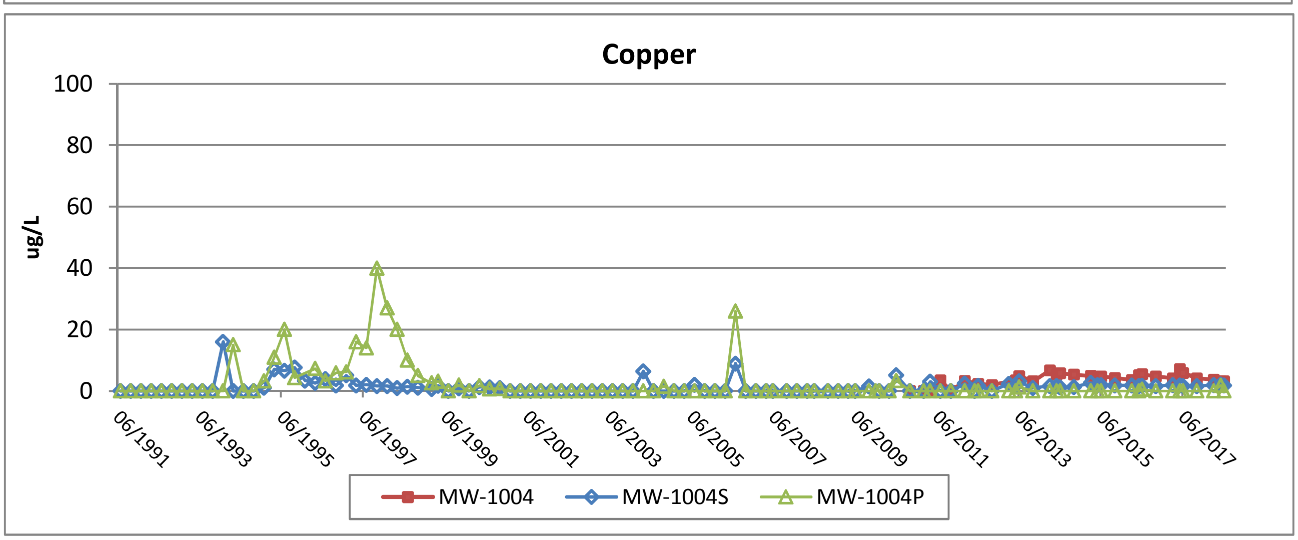


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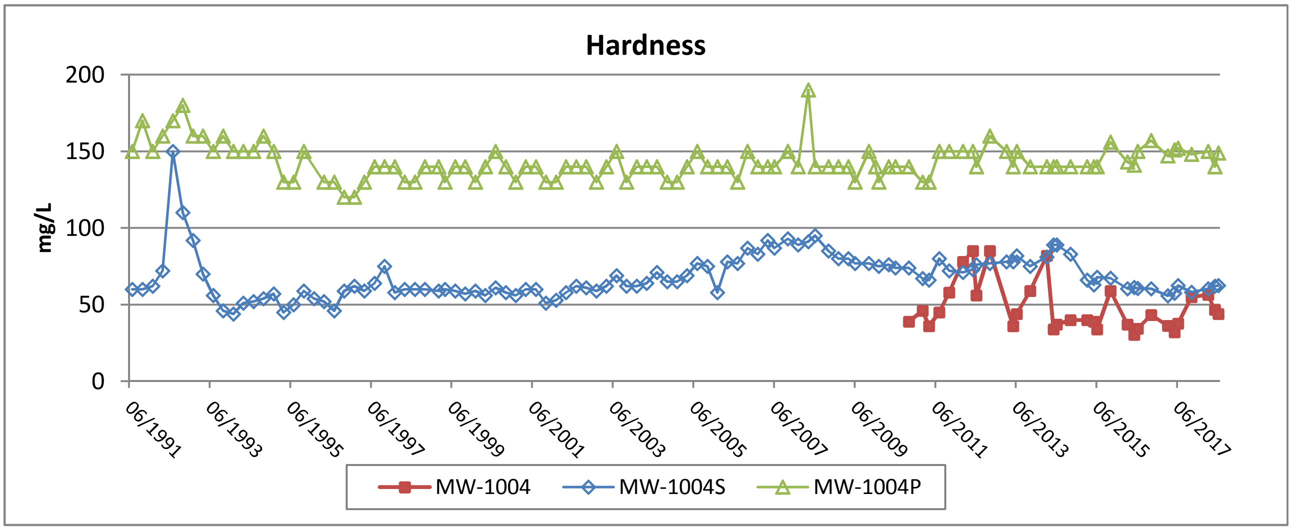
FIGURE 3-3a

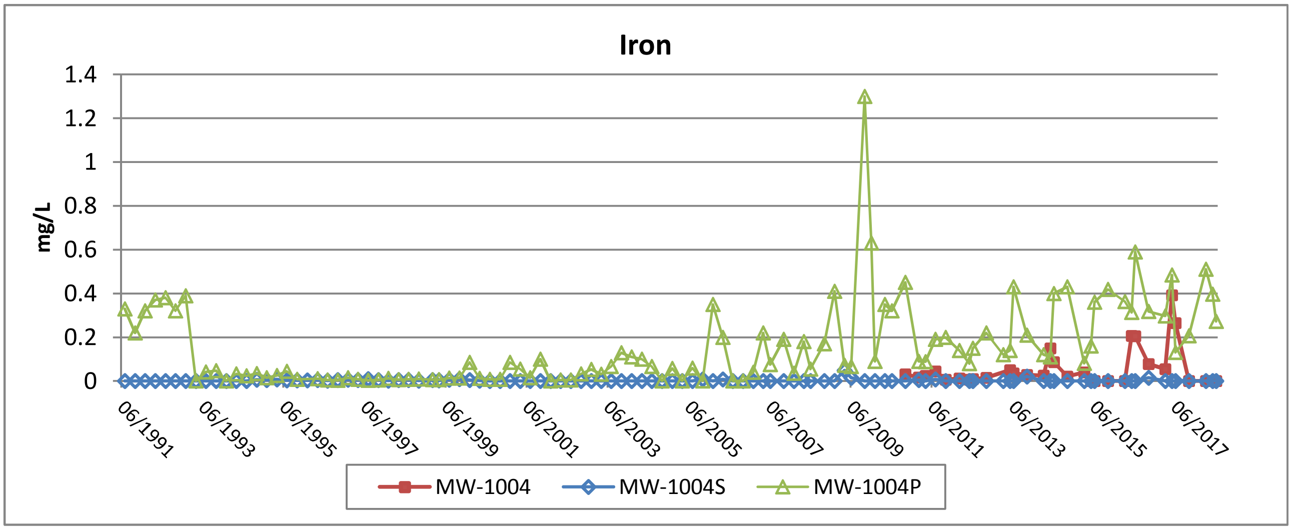
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





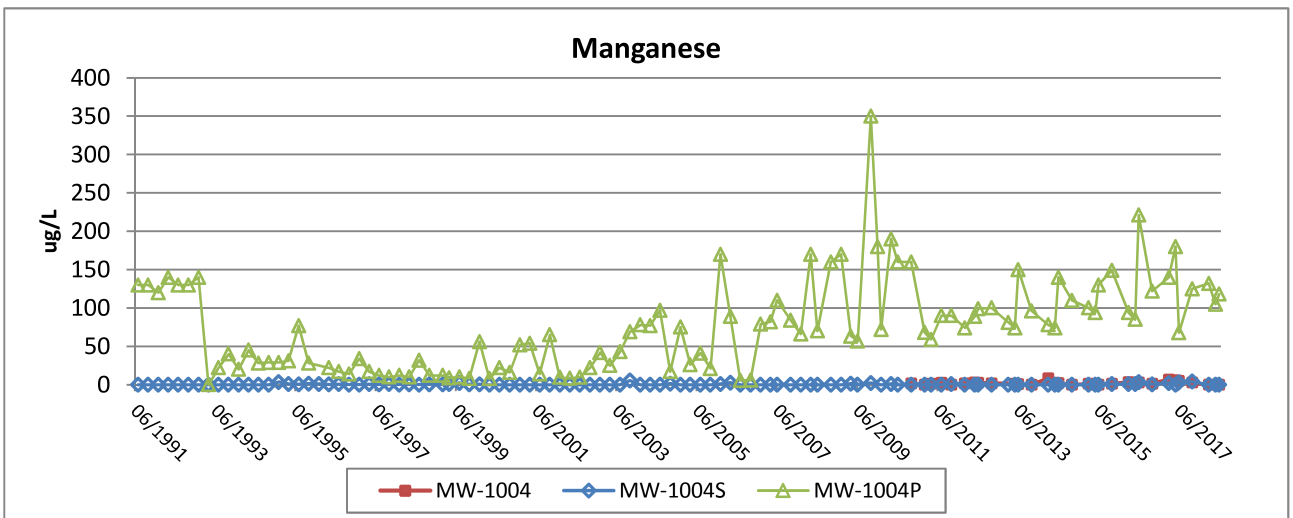


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FIGURE 3-3b

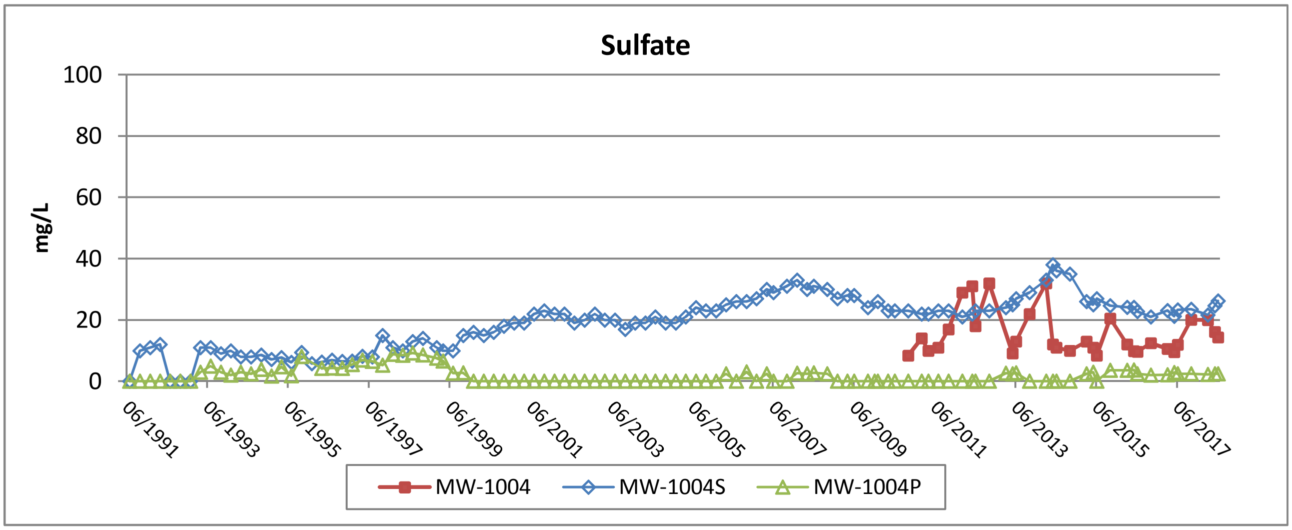
GROUNDWATER TREND GRAPHS - QUARTERLY

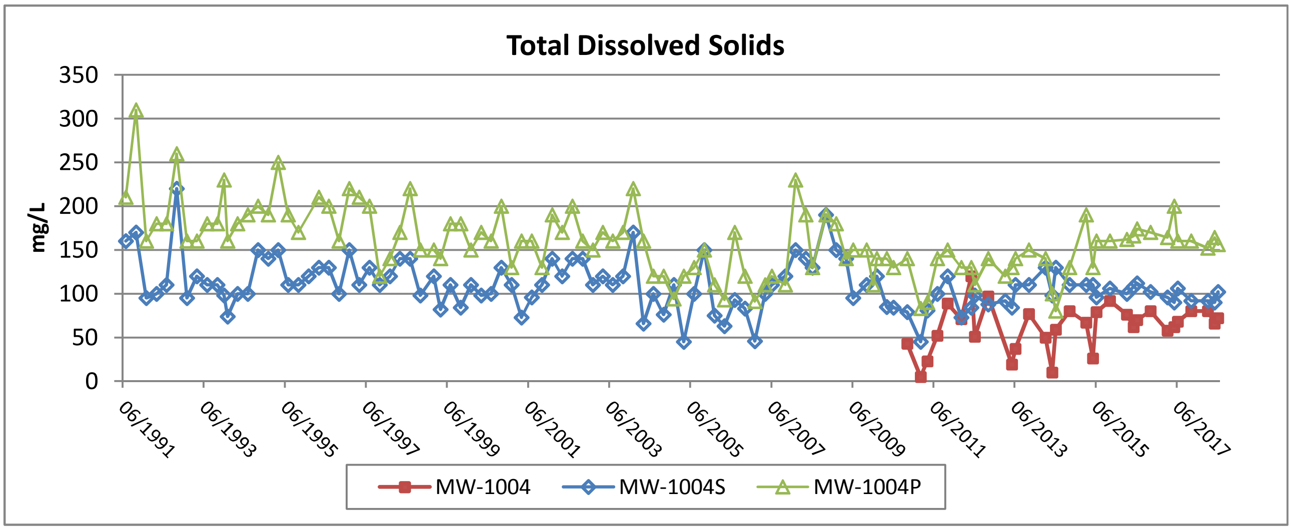
MW-1004/MW-1004S/MW-1004P

Scale: NA | Date: August 2018

Prepared By: SGL | Checked By: SVF | Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





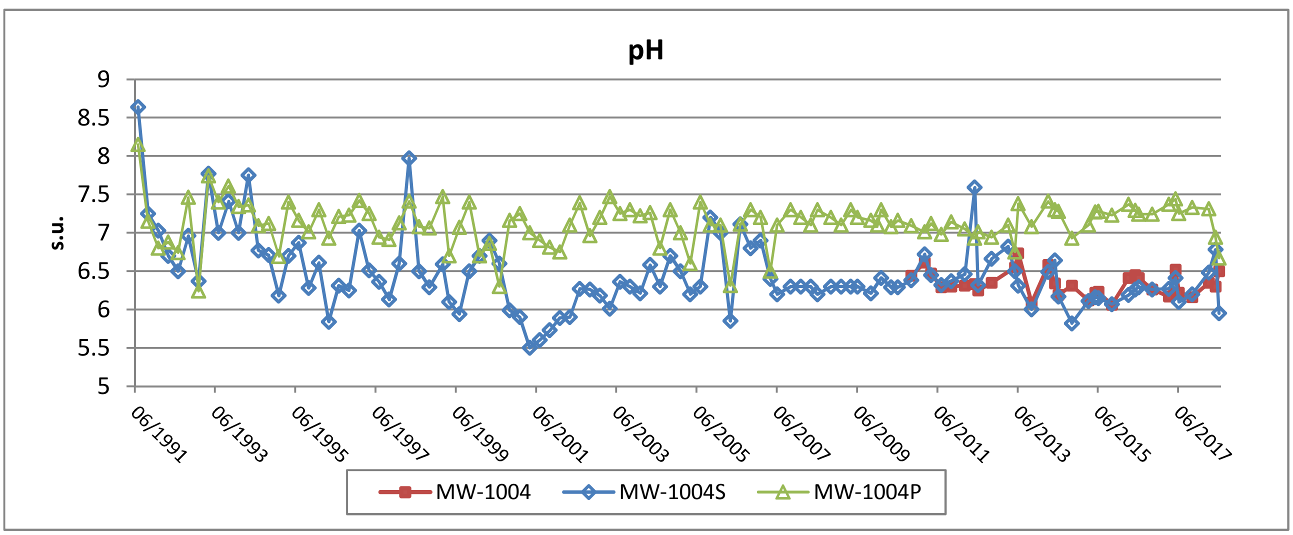


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FIGURE 3-3c

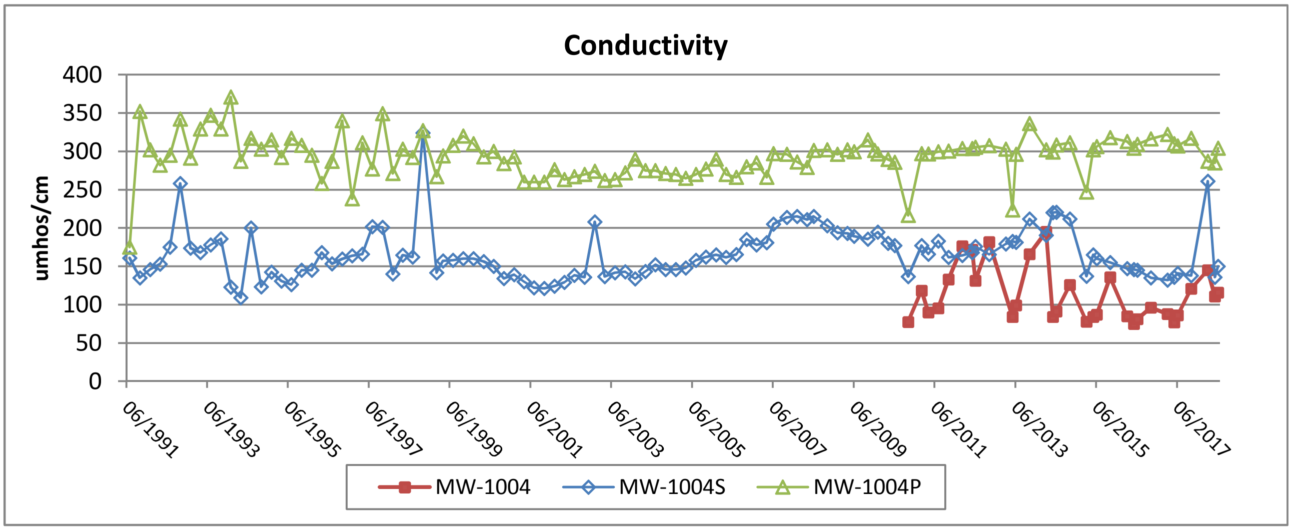
GROUNDWATER TREND GRAPHS - QUARTERLY

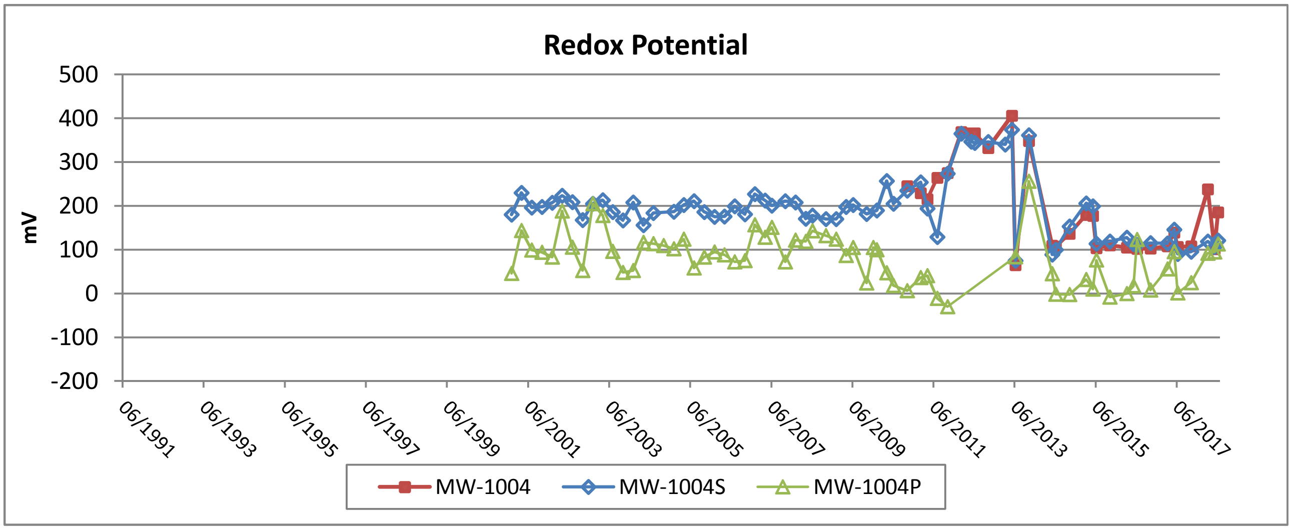
MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





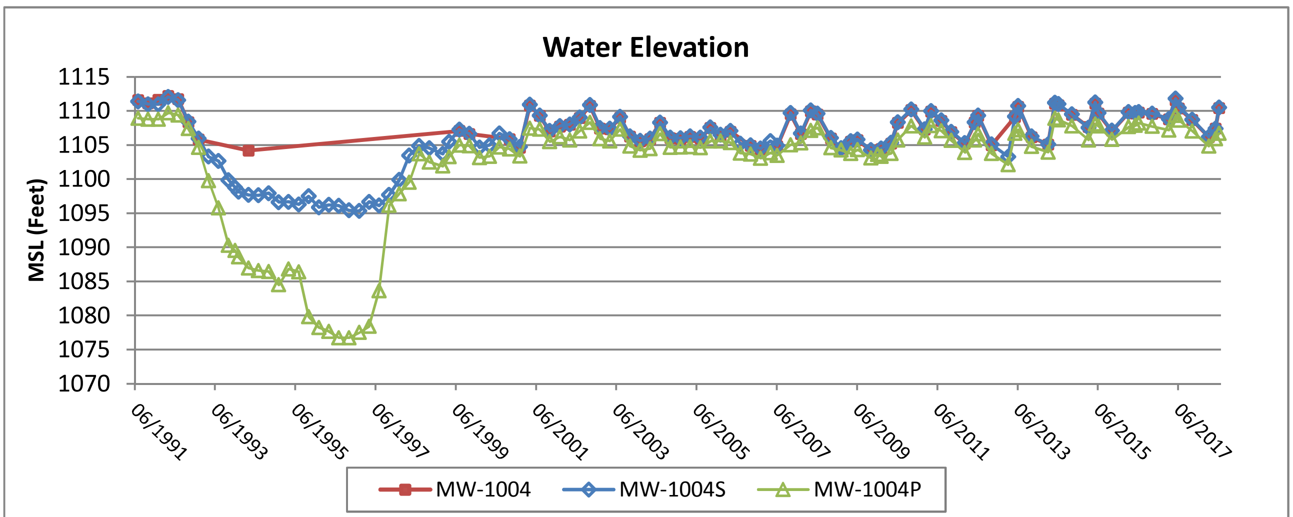


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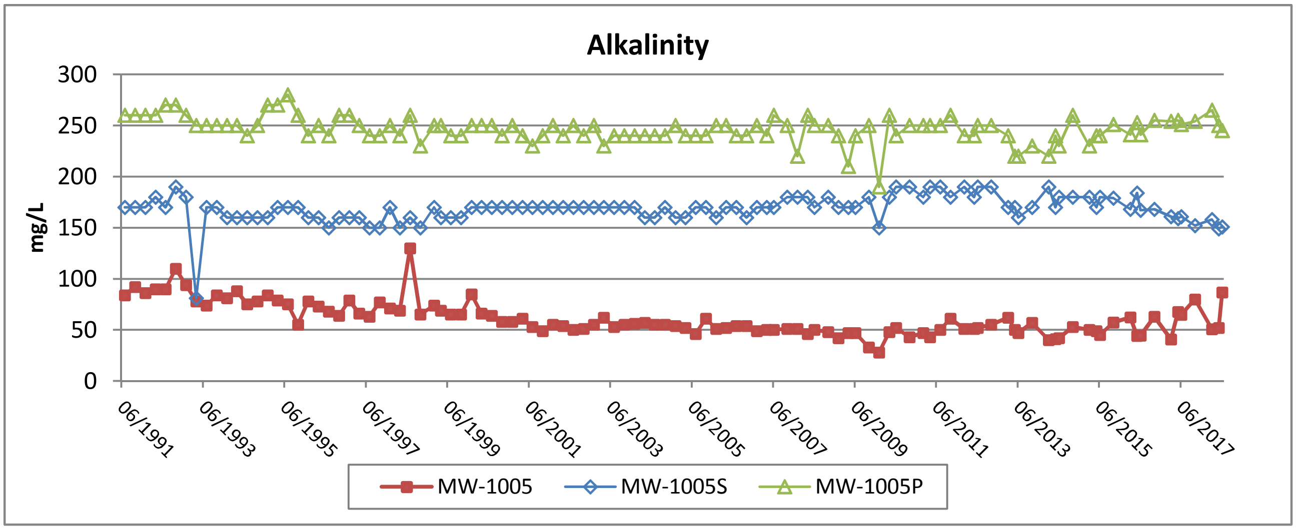
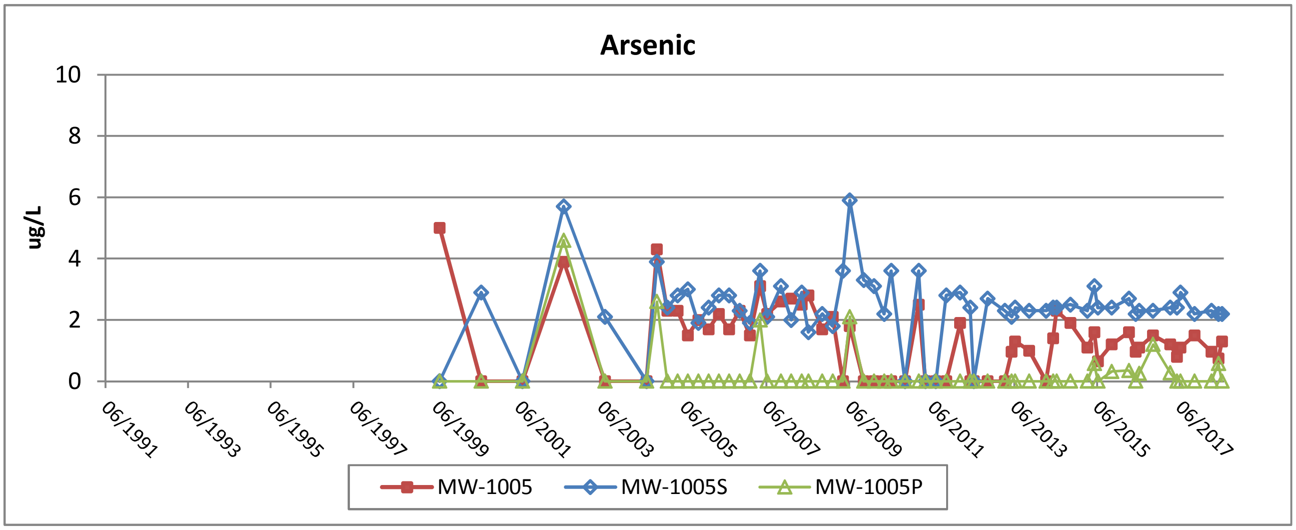
FIGURE 3-3d

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





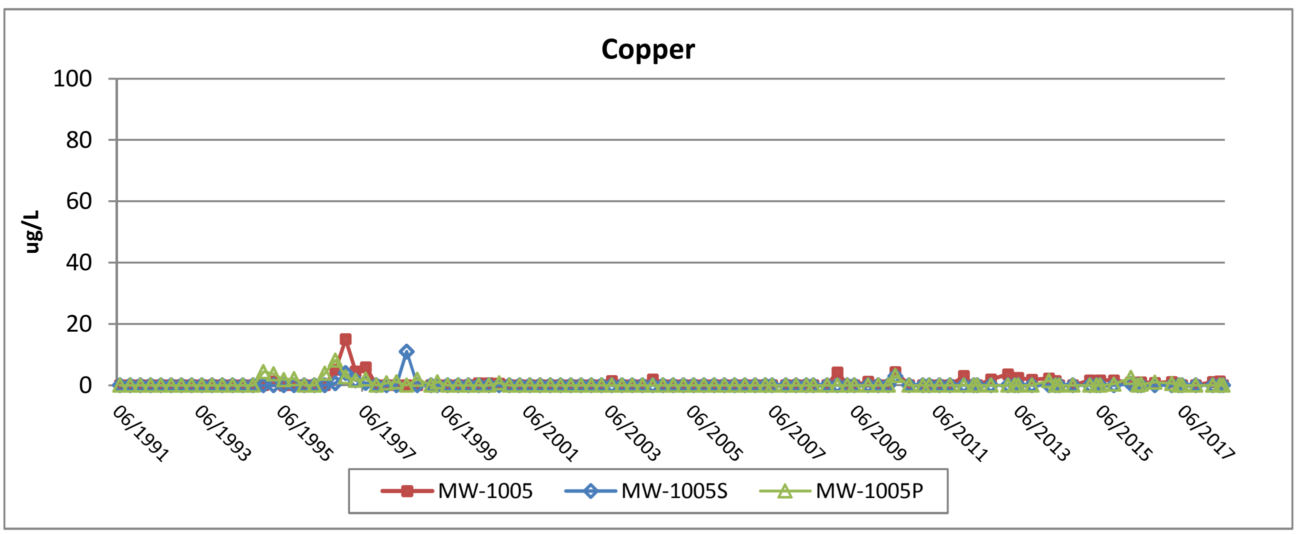


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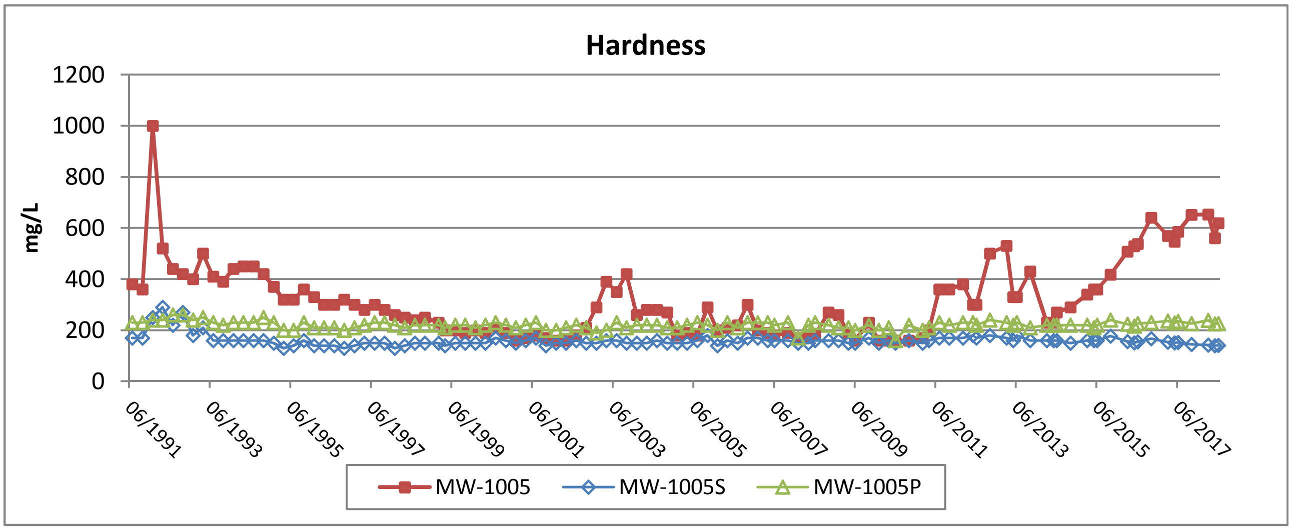
FIGURE 3-4a

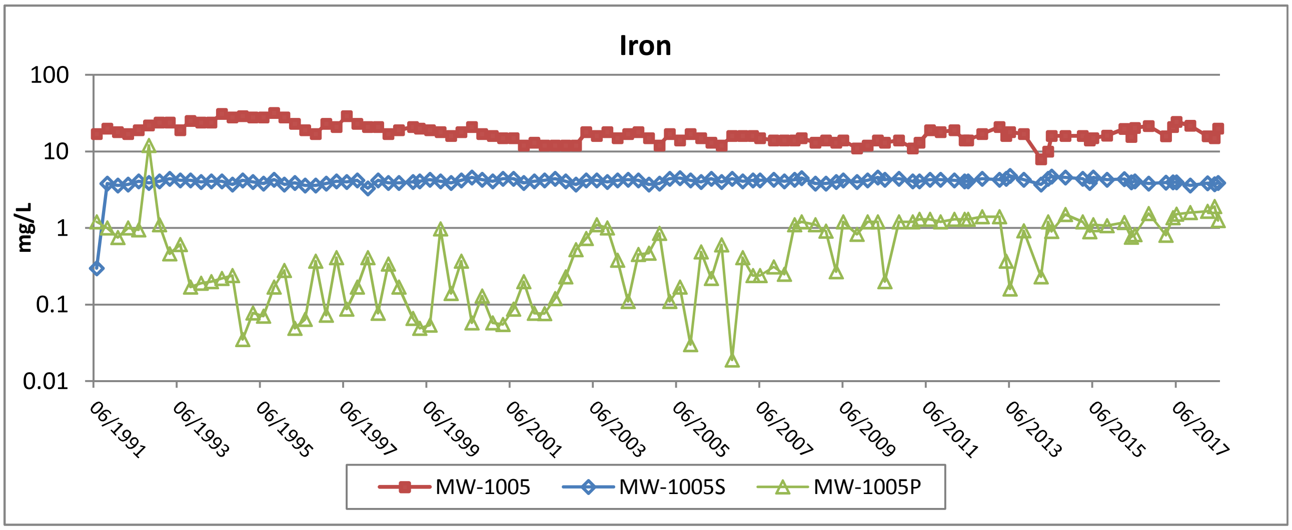
GROUNDWATER TREND GRAPHS - QUARTERLY

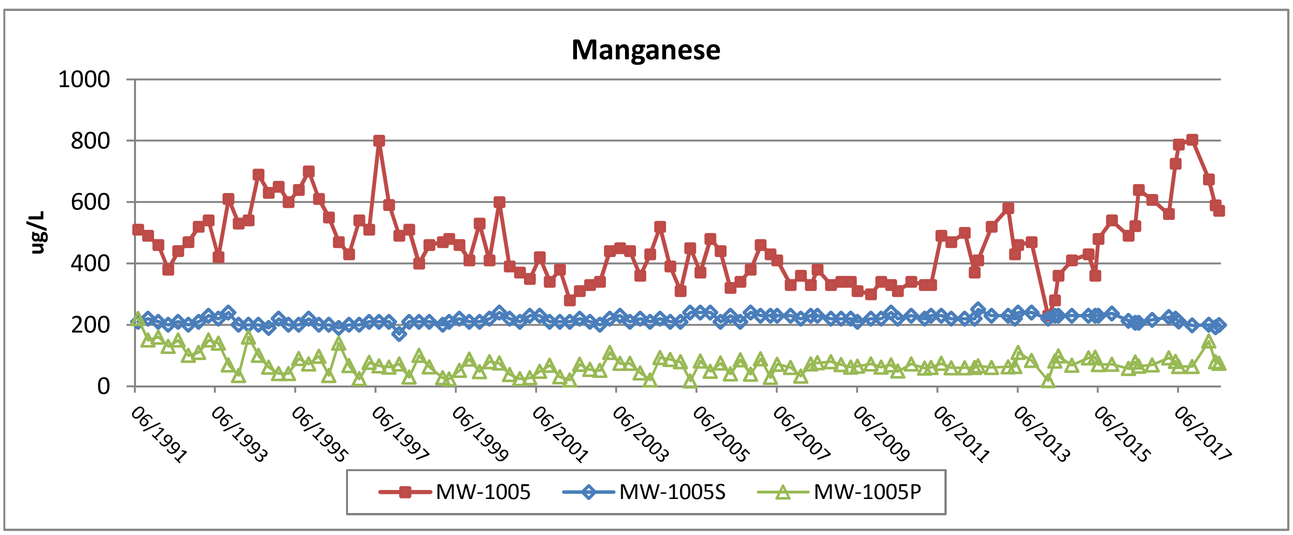
MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm







Note: Iron trend graphs are displayed on a logarithmic scale so the trend patterns of MW-1005, MW-1005S and MW-1005P are visible at different concentration scales.

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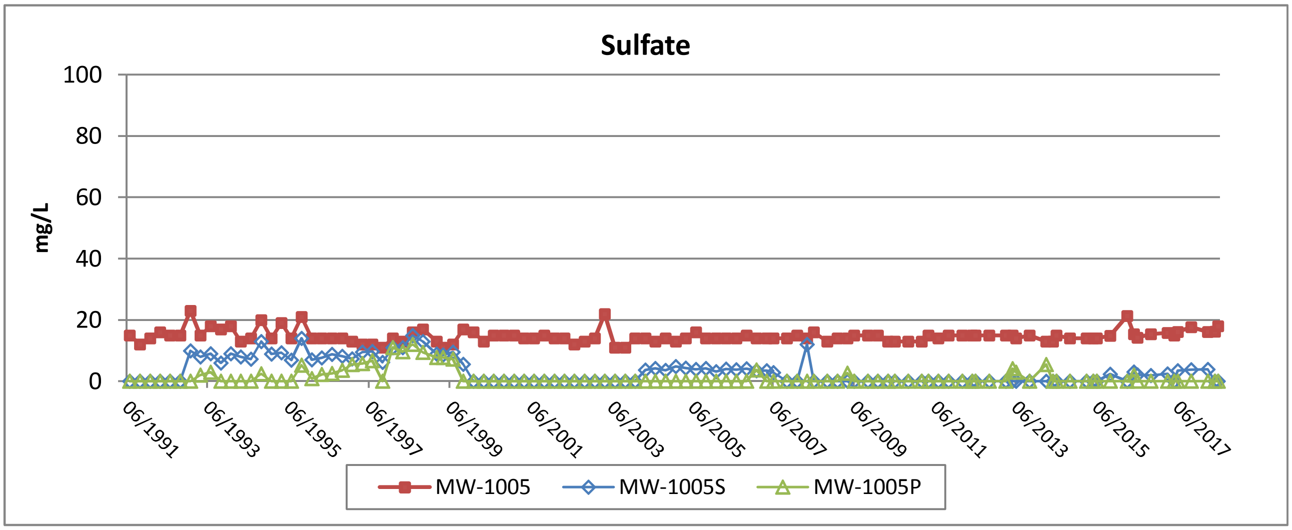
FIGURE 3-4b

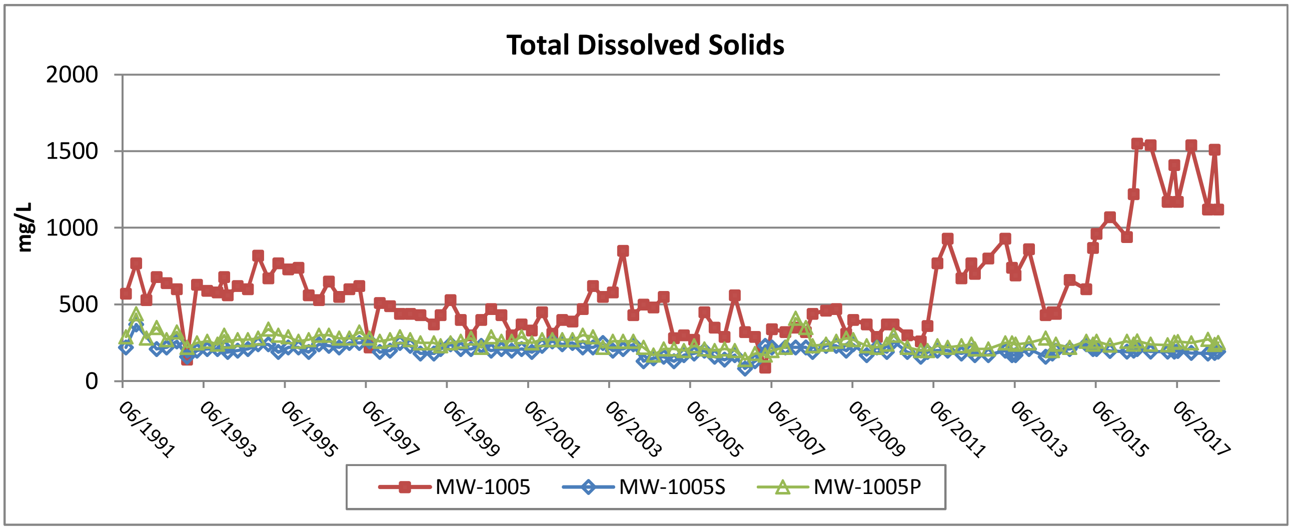
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





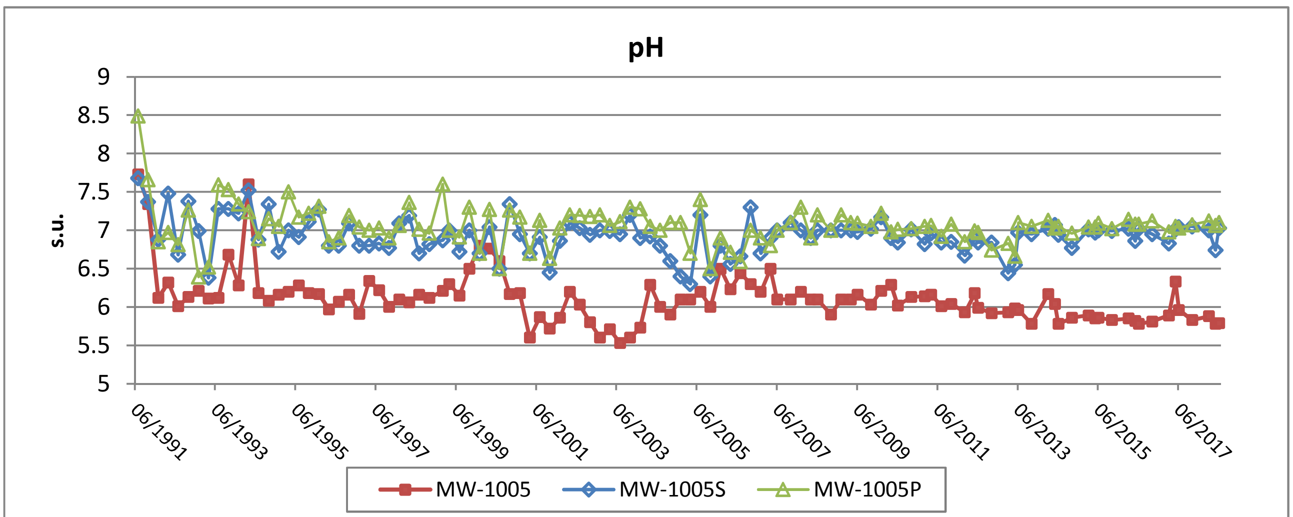


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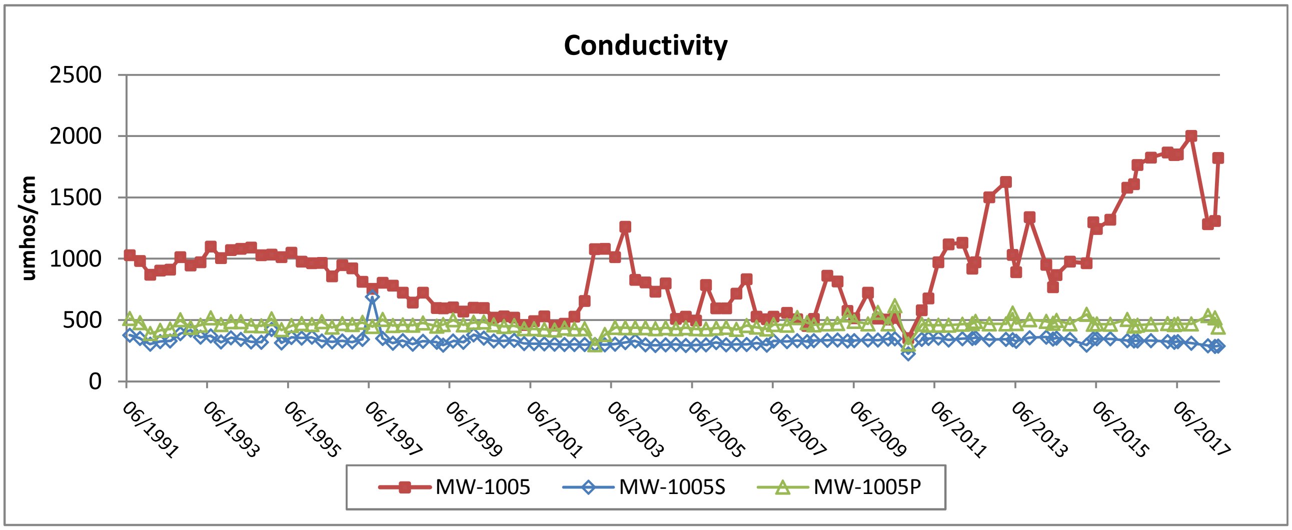
FIGURE 3-4c

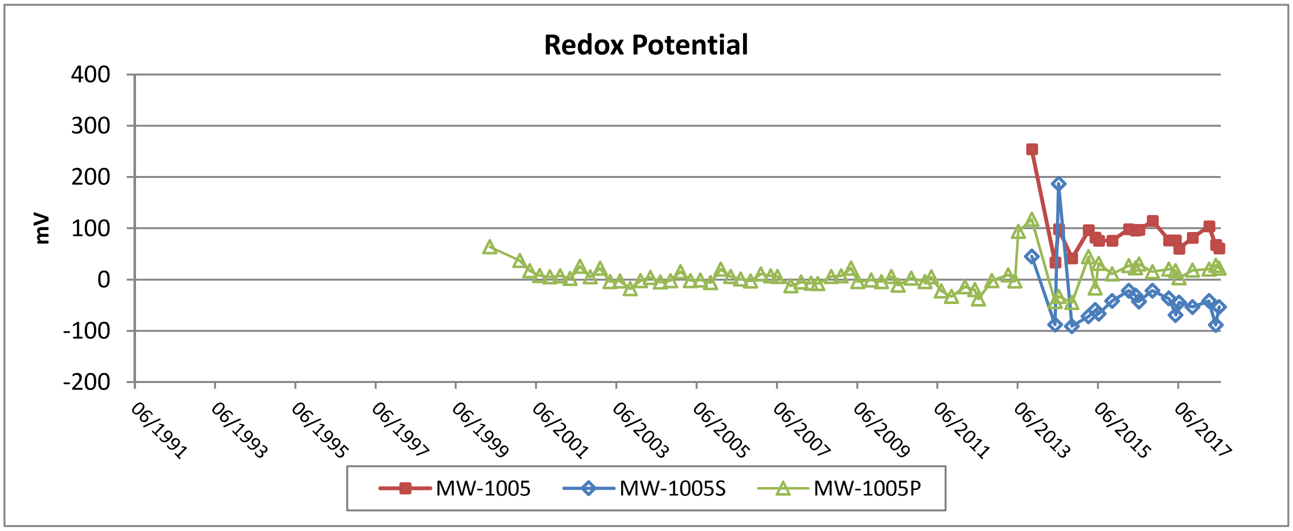
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





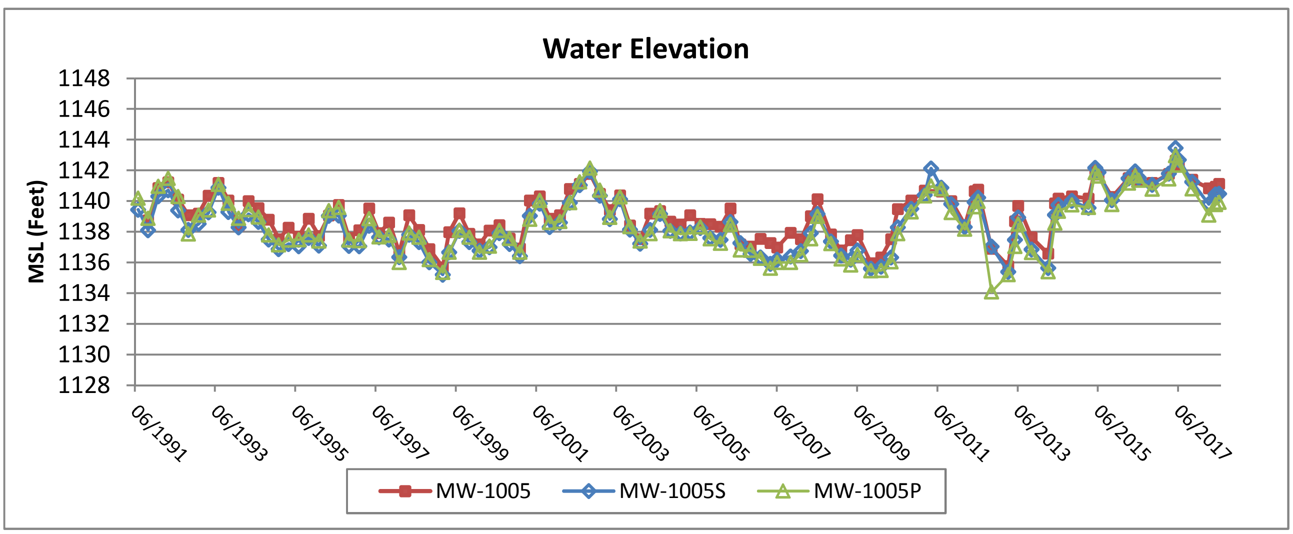


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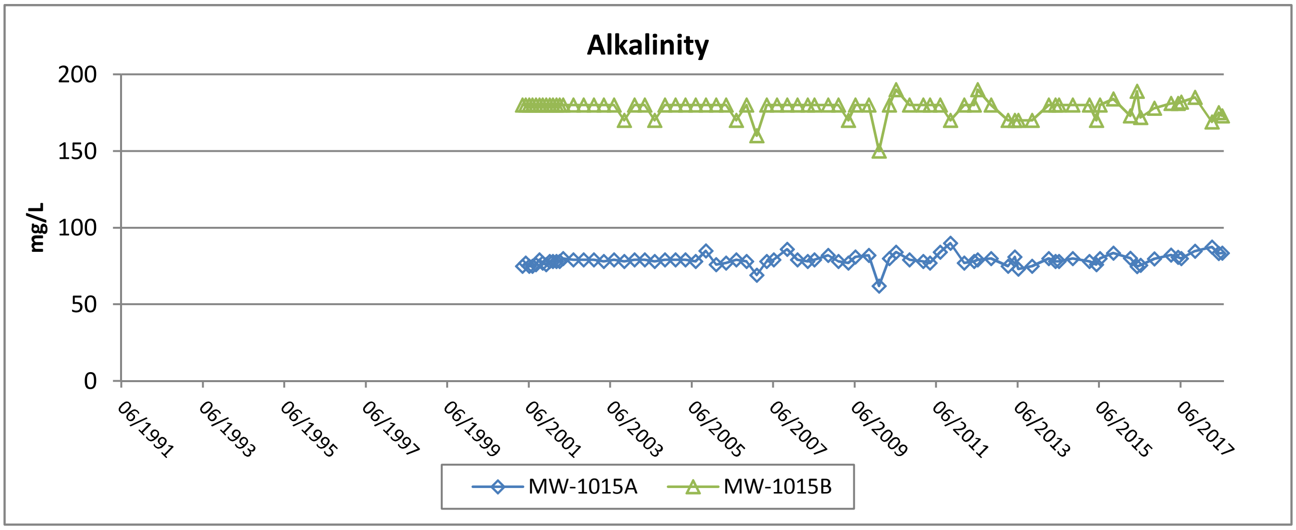
FIGURE 3-4d

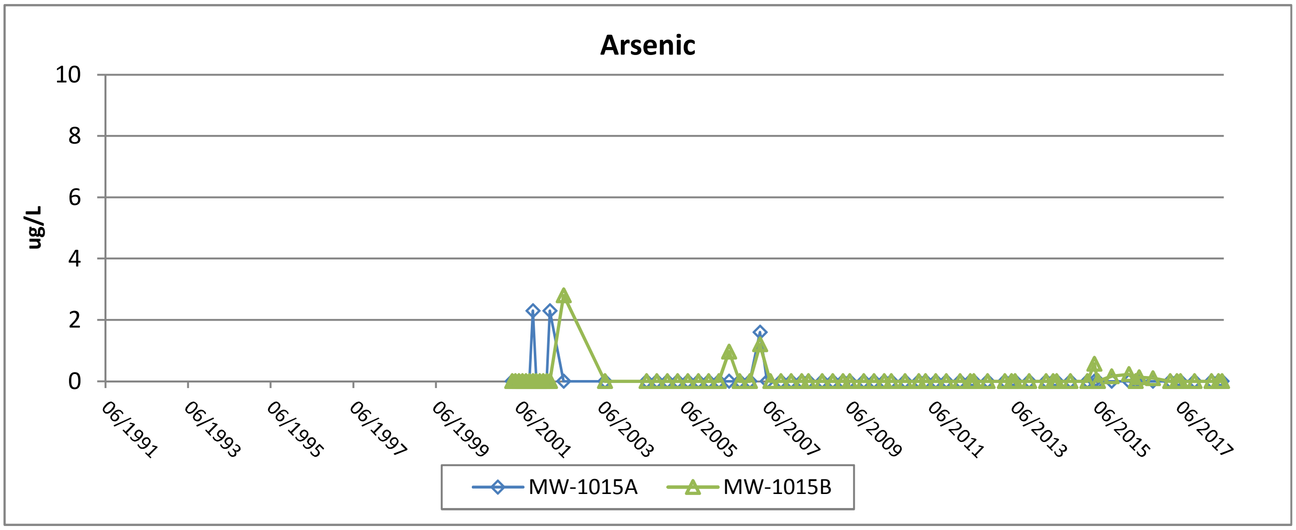
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





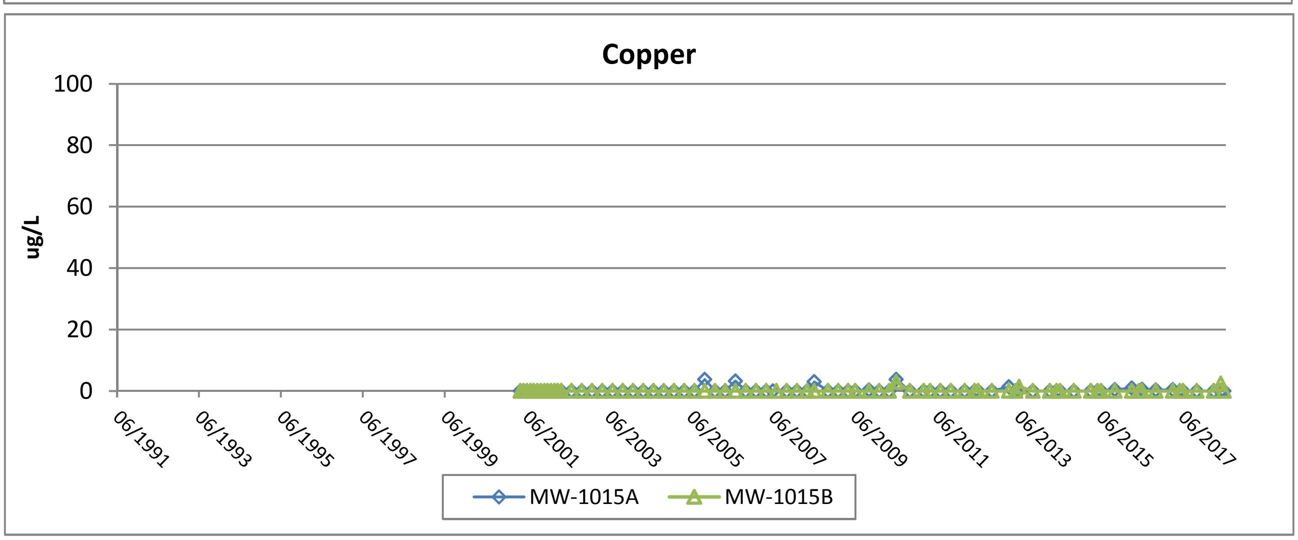


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FIGURE 3-5a

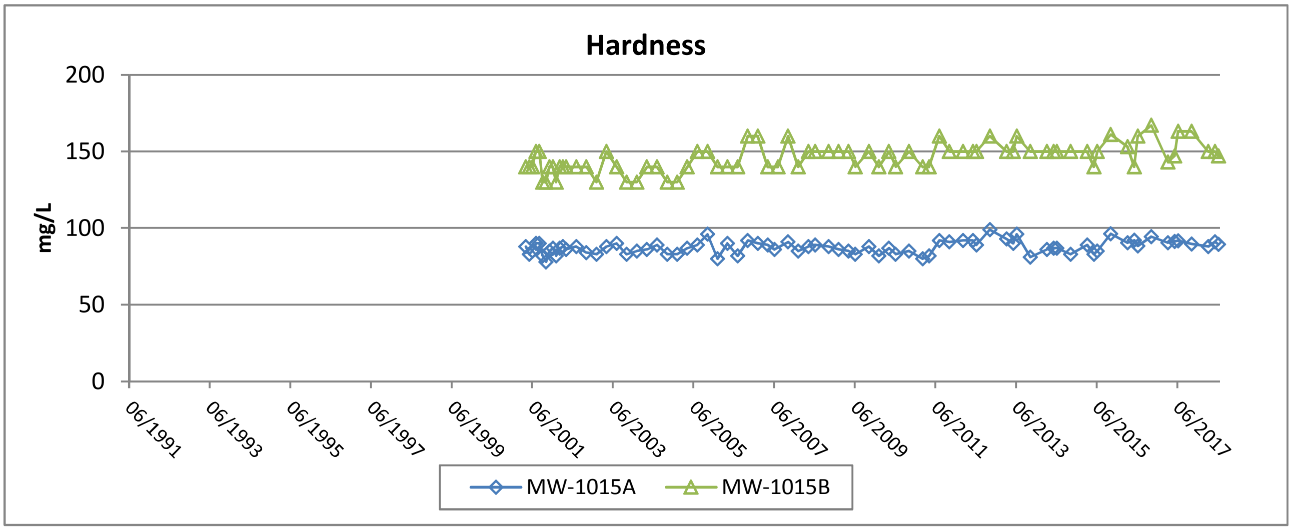
GROUNDWATER TREND GRAPHS - QUARTERLY

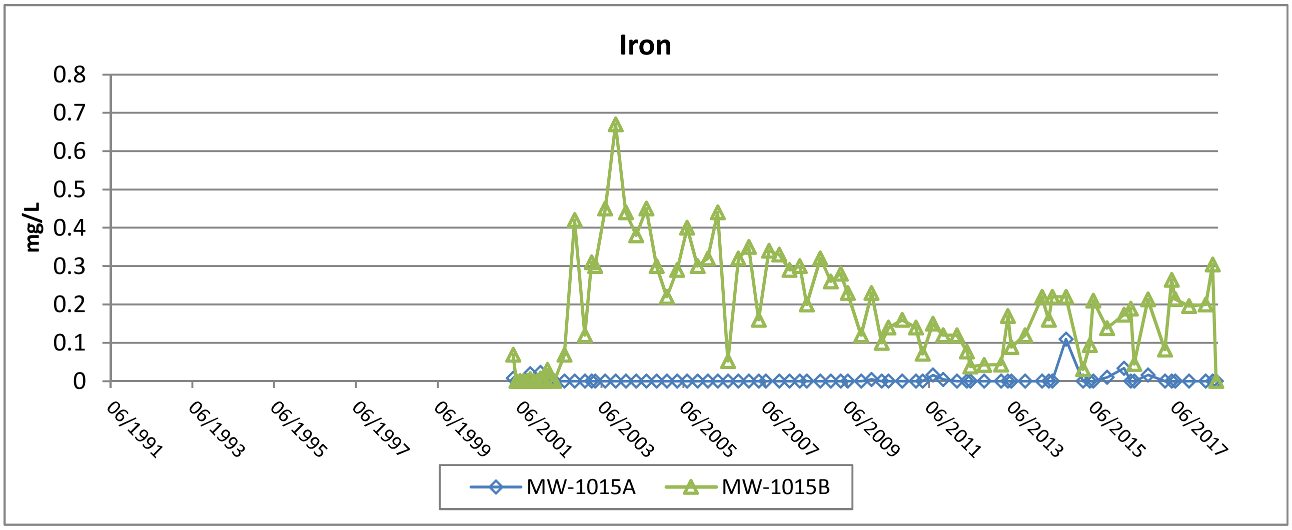
MW-1015A/MW-1015B

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





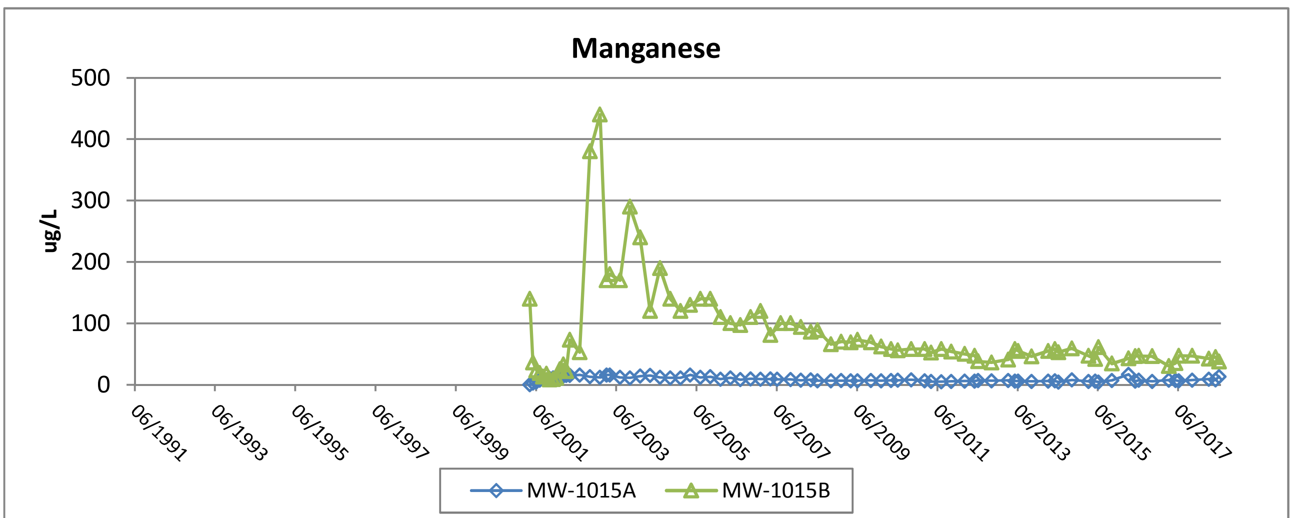


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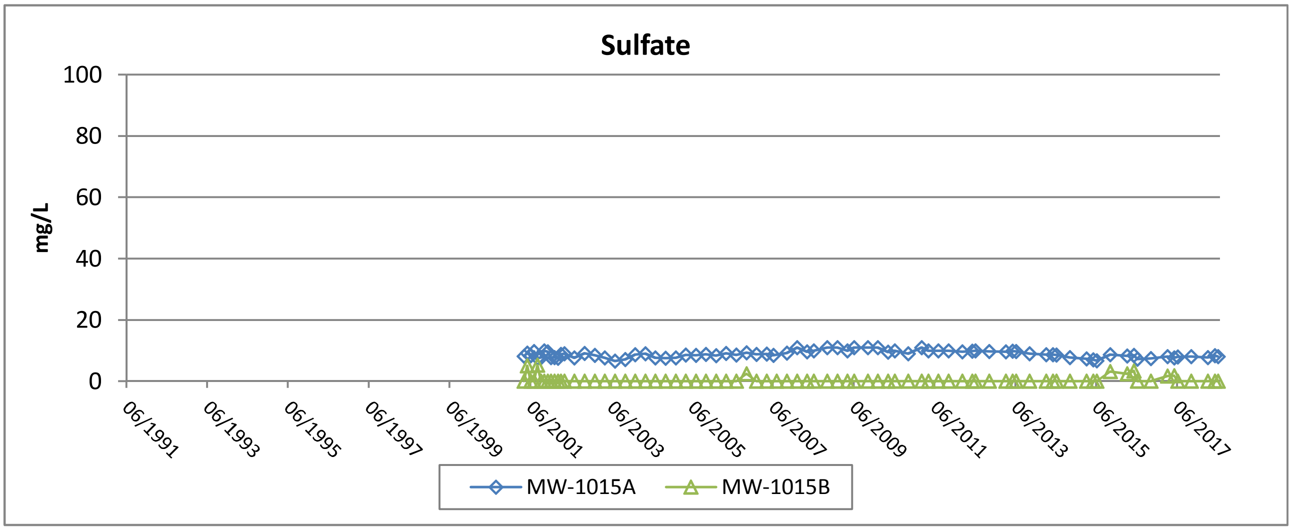
FIGURE 3-5b

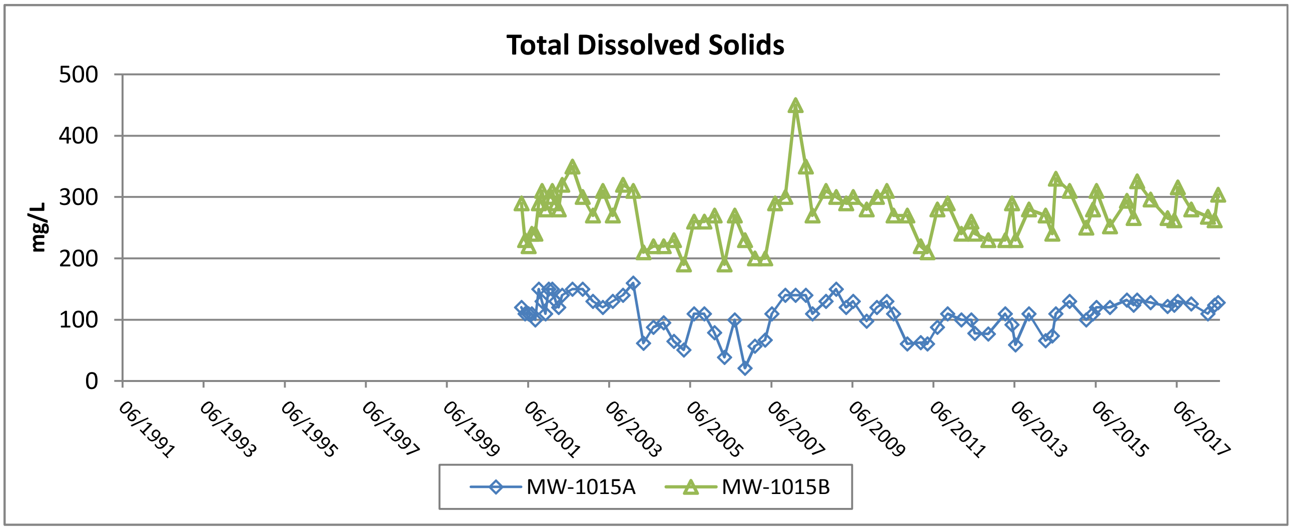
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





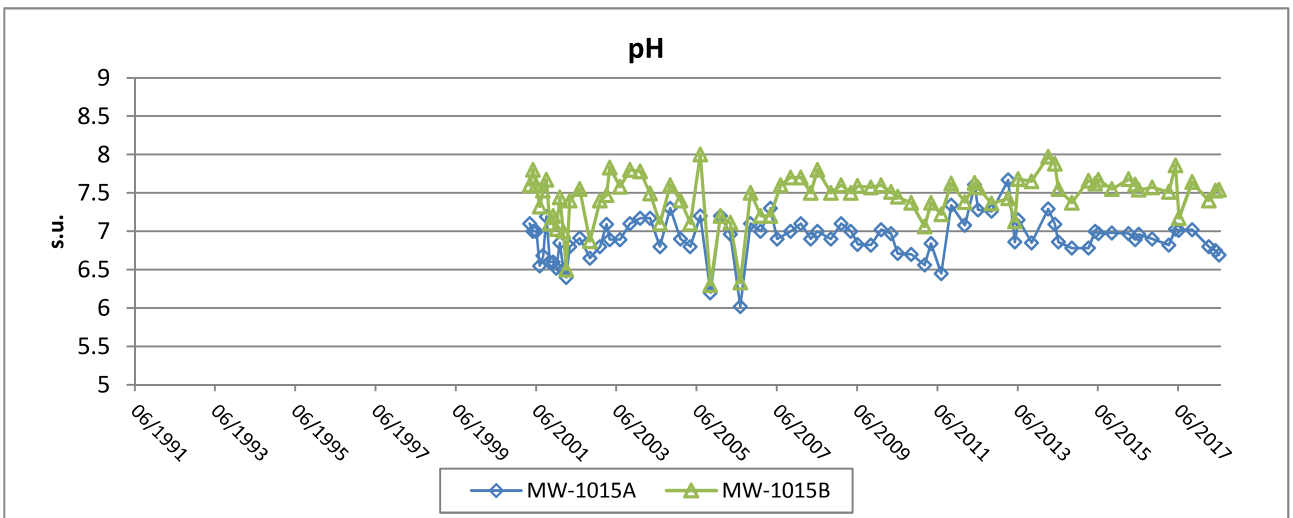


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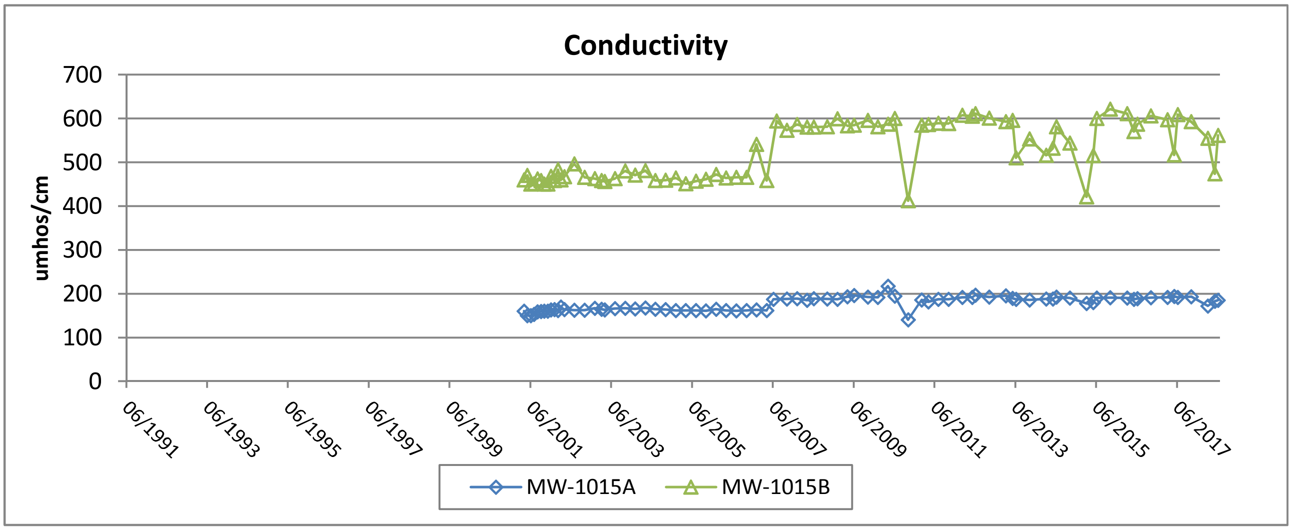
FIGURE 3-5c

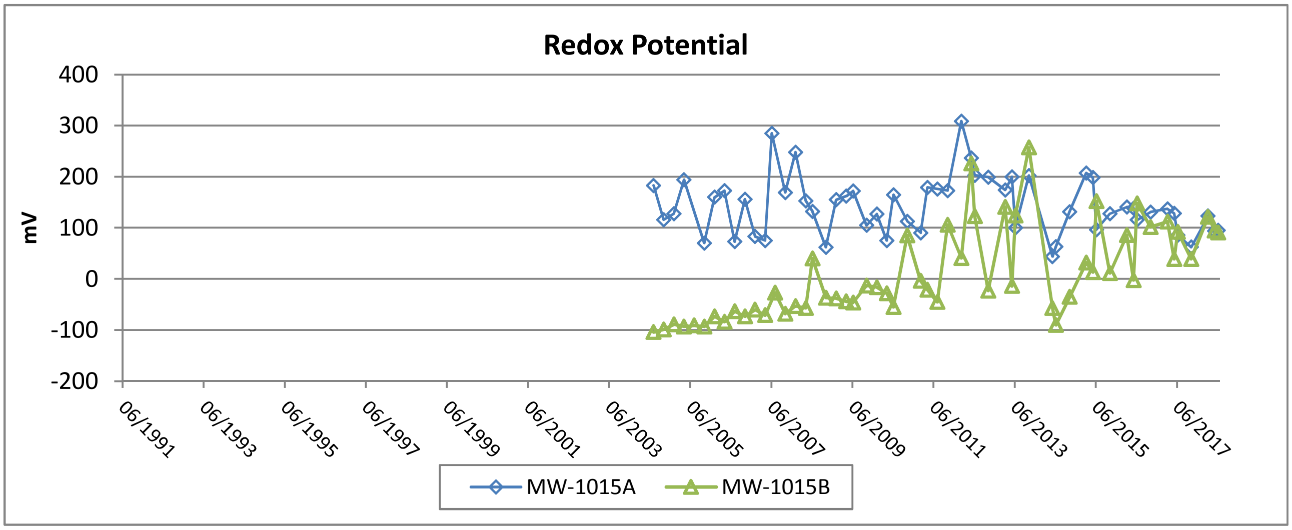
GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm





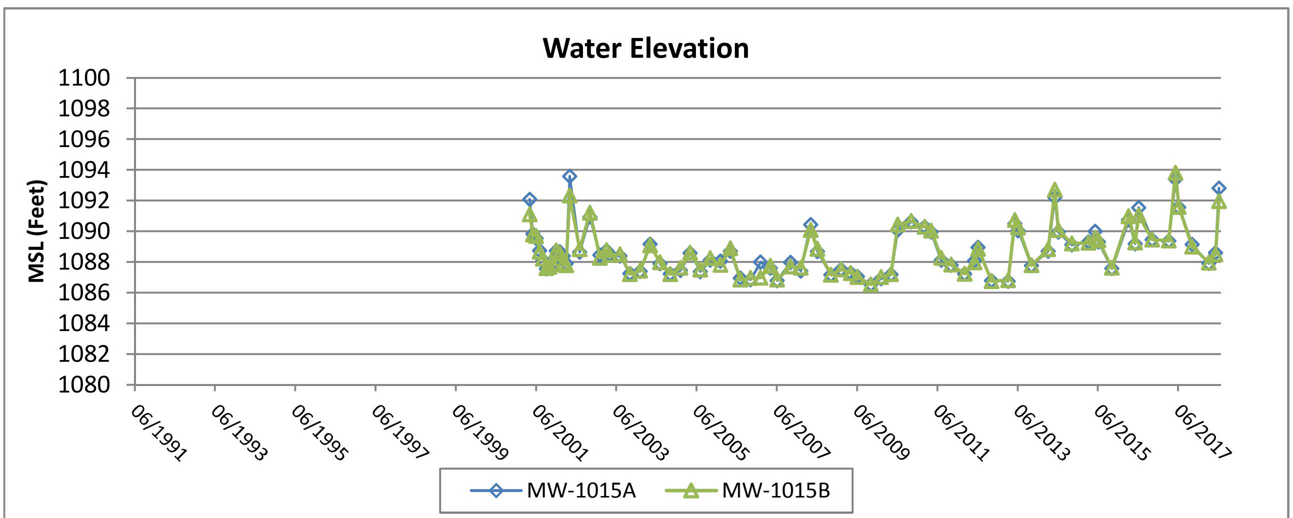


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FIGURE 3-5d

GROUNDWATER TREND GRAPHS - QUARTERLY

MW-1015A/MW-1015B

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Qtrly thru 2018 Q3.xlsm

Attachment 4

Groundwater Chemistry Temporal Optimization Results and Concentration Trend Charts

Annual Parameters

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1000PR	Cadmium ug/l MW-1000PR	Calcium mg/l MW-1000PR	Chloride mg/l MW-1000PR	Chromium ug/l MW-1000PR	Lead ug/l MW-1000PR	Magnesium mg/l MW-1000PR	Mercury ug/l MW-1000PR	Potassium mg/l MW-1000PR	Selenium ug/l MW-1000PR	Silver ug/l MW-1000PR	Sodium mg/l MW-1000PR	Zinc ug/l MW-1000PR
Avg of All Data (With ND = 1/2 MDL)	38	1.5	150	18	1	2	38	0.038	3.5	1.3	0.91	8.5	570
2014-06	37	0.33	120	20	0.57	0	30	0	3.2	0	0	8.6	350
2015-06	35	0	110	16	0.66	0	28	0.064	3.1	0	0	8.2	280
2016-06	32.4	0.17	111	14.2	0.61	0.072	28.6	0	3.15	0.41	0	7.6	297
2017-06	36	0	115	14.7	0	0	29.2	0	3.21	0.98	0	7.64	293
2018-06	94.5	0.71	107	14.2	5.7	0.89	28.2	0	3.05	1.5	0.59	7.29	416
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	2	1	-4	-7	2	5	-2	-2	-2	9	4	-8	2
p-Level	0.408	0.5	0.242	0.0795	0.408	0.1795	0.408	0.408	0.408	0.025	0.242	0.042	0.408
MK Conclusion	NT	NT	S	PD	NT	NT	S	NT	S	I	NT	D	NT
Percent Detects	100%	60%	100%	100%	80%	40%	100%	20%	100%	60%	20%	100%	100%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1000R	Cadmium ug/l MW-1000R	Calcium mg/l MW-1000R	Chloride mg/l MW-1000R	Chromium ug/l MW-1000R	Lead ug/l MW-1000R	Magnesium mg/l MW-1000R	Mercury ug/l MW-1000R	Potassium mg/l MW-1000R	Selenium ug/l MW-1000R	Silver ug/l MW-1000R	Sodium mg/l MW-1000R	Zinc ug/l MW-1000R
Avg of All Data (With ND = 1/2 MDL)	26	0.15	70	12	0.63	0.67	21	0.074	1	0.84	0.33	7.2	4.2
2014-06	28	0.11	120	5.3	0.71	0	34	0	1.2	0	0	10	5
2015-06	25	0	69	25	0.59	0	21	0	1	0	0	8.1	0
2016-06	26.1	0	64.7	22.4	0.52	0	20.2	0	1.09	0	0	7.89	0
2017-06	36.6	0.17	56	16.3	0	0	15.3	0	0.964	0.56	0	7.57	0
2018-06	25	0.17	19.8	7.7	0	0	5.25	0	0.536	0.37	0	4.46	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	-1	4	-10	-2	-9	0	-10	0	-8	5	0	-10	-4
p-Level	0.5	0.242	0.008	0.408	0.025	0.5	0.008	0.5	0.042	0.1795	0.5	0.008	0.242
MK Conclusion	S	NT	D	S	D	S	D	S	D	NT	S	D	NT
Percent Detects	100%	60%	100%	100%	60%	0%	100%	0%	100%	40%	0%	100%	20%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1002	Cadmium ug/l MW-1002	Calcium mg/l MW-1002	Chloride mg/l MW-1002	Chromium ug/l MW-1002	Lead ug/l MW-1002	Magnesium mg/l MW-1002	Mercury ug/l MW-1002	Potassium mg/l MW-1002	Selenium ug/l MW-1002	Silver ug/l MW-1002	Sodium mg/l MW-1002	Zinc ug/l MW-1002
Avg of All Data (With ND = 1/2 MDL)	7.3	0.26	17	6.1	0.89	0.63	5.5	0.037	0.7	0.95	0.39	3.2	4.4
2014-06	8.8	0	20	9	1.1	0	6.6	0	0.74	0	0	3.9	0
2015-06	7.6	0	17	7.7	0.67	0	5.5	0	0.69	0	0	3.4	0
2016-06	9.1	0	22	10.4	1.2	0	7.66	0	0.825	0	0	3.82	0
2017-06	8.3	0	19.8	8.9	1	0	6.79	0	0.744	0	0	3.87	0
2018-06	6.5	0	14.9	7.4	0	0	5.01	0	0.607	0	0	3.03	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	-4	0	-4	-4	-4	0	-2	0	-2	0	0	-4	0
p-Level	0.242	0.5	0.242	0.242	0.242	0.5	0.408	0.5	0.408	0.5	0.5	0.242	0.5
MK Conclusion	S	S	S	S	S	S	S	S	S	S	S	S	S
Percent Detects	100%	0%	100%	100%	80%	0%	100%	0%	100%	0%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1002G	Cadmium ug/l MW-1002G	Calcium mg/l MW-1002G	Chloride mg/l MW-1002G	Chromium ug/l MW-1002G	Lead ug/l MW-1002G	Magnesium mg/l MW-1002G	Mercury ug/l MW-1002G	Potassium mg/l MW-1002G	Selenium ug/l MW-1002G	Silver ug/l MW-1002G	Sodium mg/l MW-1002G	Zinc ug/l MW-1002G
Avg of All Data (With ND = 1/2 MDL)	29	0.31	28	21	0.5	0.54	11	0.037	0.86	1	0.29	5.4	4.8
2014-06	34	0	31	28	0	0	12	0	0.84	0	0	5.8	0
2015-06	34	0	32	29	0	0	12	0	0.85	0	0	6	0
2016-06	34	0	34.5	29.6	0.78	0	13.7	0	0.91	0	0	5.9	0
2017-06	35	0	34.4	31	0	0	13.9	0	0.909	0	0	6.05	0
2018-06	37.8	0	36.7	29.7	0	0	14.2	0	0.864	0	0	6.09	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	7	0	8	8	0	0	9	0	4	0	0	8	0
p-Level	0.0795	0.5	0.042	0.042	0.5	0.5	0.025	0.5	0.242	0.5	0.5	0.042	0.5
MK Conclusion	PI	S	I	I	NT	S	I	S	NT	S	S	I	S
Percent Detects	100%	0%	100%	100%	20%	0%	100%	0%	100%	0%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1004	Cadmium ug/l MW-1004	Calcium mg/l MW-1004	Chloride mg/l MW-1004	Chromium ug/l MW-1004	Lead ug/l MW-1004	Magnesium mg/l MW-1004	Mercury ug/l MW-1004	Potassium mg/l MW-1004	Selenium ug/l MW-1004	Silver ug/l MW-1004	Sodium mg/l MW-1004	Zinc ug/l MW-1004
Avg of All Data (With ND = 1/2 MDL)	4	0.19	11	1.3	0.86	0.4	3.5	0.069	0.74	0.8	0.23	2.6	4
2014-06	4.5	0	9.9	0	0	0	3	0	0.69	0	0	2.6	0
2015-06	2.7	0	8.9	0	0	0	2.9	0	0.69	0	0	2.4	0
2016-06	4.1	0	8.96	2	0.89	0.077	2.89	0	0.752	0.22	0	2.26	5.9
2017-06	4.9	0	9.84	0.9	1.1	0	3.19	0	0.801	0	0	2.38	0
2018-06	3.4	0	11.6	1.2	0	0	3.62	0	0.67	0	0	2.42	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	0	0	4	5	3	0	4	0	1	0	0	-2	0
p-Level	0.5	0.5	0.242	0.1795	0.325	0.5	0.242	0.5	0.5	0.5	0.5	0.408	0.5
MK Conclusion	S	S	NT	NT	NT	NT	NT	S	NT	NT	S	S	NT
Percent Detects	100%	0%	100%	60%	40%	20%	100%	0%	100%	20%	0%	100%	20%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1004P	Cadmium ug/l MW-1004P	Calcium mg/l MW-1004P	Chloride mg/l MW-1004P	Chromium ug/l MW-1004P	Lead ug/l MW-1004P	Magnesium mg/l MW-1004P	Mercury ug/l MW-1004P	Potassium mg/l MW-1004P	Selenium ug/l MW-1004P	Silver ug/l MW-1004P	Sodium mg/l MW-1004P	Zinc ug/l MW-1004P
Avg of All Data (With ND = 1/2 MDL)	42	0.19	34	1.4	0.4	0.55	14	0.037	5.6	1	0.28	6.4	5
2014-06	44	0	33	0	0	0	13	0	5.4	0	0	6.3	0
2015-06	43	0	34	0	0	0	14	0	5.7	0	0	6.5	0
2016-06	43.8	0	35.8	2.2	0	0	14.7	0	5.9	0	0	6.28	0
2017-06	41.8	0	36.4	1.1	0	0	14.7	0	5.84	0	0	6.2	0
2018-06	44.8	0	36	1.1	0	0	14.5	0	5.6	0	0	6.17	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	0	0	8	4	0	0	5	0	2	0	0	-8	0
p-Level	0.5	0.5	0.042	0.242	0.5	0.5	0.1795	0.5	0.408	0.5	0.5	0.042	0.5
MK Conclusion	S	S	I	NT	S	S	NT	S	NT	S	S	D	S
Percent Detects	100%	0%	100%	60%	0%	0%	100%	0%	100%	0%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1004S	Cadmium ug/l MW-1004S	Calcium mg/l MW-1004S	Chloride mg/l MW-1004S	Chromium ug/l MW-1004S	Lead ug/l MW-1004S	Magnesium mg/l MW-1004S	Mercury ug/l MW-1004S	Potassium mg/l MW-1004S	Selenium ug/l MW-1004S	Silver ug/l MW-1004S	Sodium mg/l MW-1004S	Zinc ug/l MW-1004S
Avg of All Data (With ND = 1/2 MDL)	4.3	0.19	18	4.8	0.73	0.76	6.2	0.037	0.84	1	0.28	4.6	4.4
2014-06	5.7	0	23	5.1	0.99	0	7.6	0	0.93	0	0	5.2	0
2015-06	3.9	0	17	3	0.7	0	5.9	0	0.77	0	0	4	0
2016-06	3.4	0	15.5	2.7	1.1	0	5.28	0	0.804	0.26	0	3.66	0
2017-06	3.6	0	16	2.1	1	0	5.48	0	0.82	0	0	3.59	0
2018-06	3.7	0	16.3	1.5	0	0	5.33	0	0.765	0	0	3.14	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	-4	0	-4	-10	-2	0	-6	0	-4	0	0	-10	0
p-Level	0.242	0.5	0.242	0.008	0.408	0.5	0.117	0.5	0.242	0.5	0.5	0.008	0.5
MK Conclusion	S	S	S	D	S	S	S	S	S	NT	S	D	S
Percent Detects	100%	0%	100%	100%	80%	0%	100%	0%	100%	20%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1005	Cadmium ug/l MW-1005	Calcium mg/l MW-1005	Chloride mg/l MW-1005	Chromium ug/l MW-1005	Lead ug/l MW-1005	Magnesium mg/l MW-1005	Mercury ug/l MW-1005	Potassium mg/l MW-1005	Selenium ug/l MW-1005	Silver ug/l MW-1005	Sodium mg/l MW-1005	Zinc ug/l MW-1005
Avg of All Data (With ND = 1/2 MDL)	150	0.23	67	260	0.78	0.63	32	0.04	0.86	0.86	0.37	35	4.4
2014-06	150	0	60	230	0.61	0	29	0	0.74	0	0	33	0
2015-06	200	0	82	340	0	0	38	0	0.92	0	0	61	0
2016-06	296	0.089	123	457	0.93	0	55.7	0	1.26	0	0	75	3.8
2017-06	356	0	136	547	0	0	59.7	0	1.31	0	0	83.2	0
2018-06	364	0	142	594	0	0	64.6	0	1.17	0	0	77.6	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	10	0	10	10	-3	0	10	0	6	0	0	8	0
p-Level	0.008	0.5	0.008	0.008	0.325	0.5	0.008	0.5	0.117	0.5	0.5	0.042	0.5
MK Conclusion	I	NT	I	I	NT	S	I	S	NT	S	S	I	NT
Percent Detects	100%	20%	100%	100%	40%	0%	100%	0%	100%	0%	0%	100%	20%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1005P	Cadmium ug/l MW-1005P	Calcium mg/l MW-1005P	Chloride mg/l MW-1005P	Chromium ug/l MW-1005P	Lead ug/l MW-1005P	Magnesium mg/l MW-1005P	Mercury ug/l MW-1005P	Potassium mg/l MW-1005P	Selenium ug/l MW-1005P	Silver ug/l MW-1005P	Sodium mg/l MW-1005P	Zinc ug/l MW-1005P
Avg of All Data (With ND = 1/2 MDL)	68	0.21	53	7.5	0.4	0.73	21	0.037	8.8	0.95	0.29	13	4.5
2014-06	72	0	55	17	0	0	22	0	8.8	0	0	13	0
2015-06	69	0	52	6.8	0	0	22	0	9	0	0	9.6	0
2016-06	67.2	0	53.8	4.6	0	0.059	22.3	0	9.04	0	0	8.76	0
2017-06	71.2	0	56	4.1	0	0	23.1	0	9.3	0	0	9.18	0
2018-06	73.8	0	54.3	6.5	0	0	21.9	0	8.63	0	0	9.09	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	2	0	2	-6	0	0	1	0	2	0	0	-6	0
p-Level	0.408	0.5	0.408	0.117	0.5	0.5	0.5	0.5	0.408	0.5	0.5	0.117	0.5
MK Conclusion	NT	S	NT	S	S	NT	NT	S	NT	S	S	S	S
Percent Detects	100%	0%	100%	100%	0%	20%	100%	0%	100%	0%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1005S	Cadmium ug/l MW-1005S	Calcium mg/l MW-1005S	Chloride mg/l MW-1005S	Chromium ug/l MW-1005S	Lead ug/l MW-1005S	Magnesium mg/l MW-1005S	Mercury ug/l MW-1005S	Potassium mg/l MW-1005S	Selenium ug/l MW-1005S	Silver ug/l MW-1005S	Sodium mg/l MW-1005S	Zinc ug/l MW-1005S
Avg of All Data (With ND = 1/2 MDL)	45	0.17	40	1.7	0.44	0.57	14	0.037	3	1	0.31	6.4	4.4
2014-06	48	0	39	0	0	0	14	0	2.7	0	0	6.4	0
2015-06	47	0	40	2.7	0	0	14	0	2.9	0	0	6.3	0
2016-06	42	0	39.2	2.5	0.54	0	14	0	2.93	0	0	5.92	0
2017-06	42.8	0.39	38.5	1.5	0	0.43	13.5	0	2.77	0.39	0.21	5.8	0
2018-06	40	0	35.7	3.1	0	0	12.6	0	2.52	0	0	5.6	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	-8	2	-6	4	0	2	-7	0	-2	2	2	-10	0
p-Level	0.042	0.408	0.117	0.242	0.5	0.408	0.0795	0.5	0.408	0.408	0.408	0.008	0.5
MK Conclusion	D	NT	S	NT	NT	NT	PD	S	S	NT	NT	D	S
Percent Detects	100%	20%	100%	80%	20%	20%	100%	0%	100%	20%	20%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1010P	Cadmium ug/l MW-1010P	Calcium mg/l MW-1010P	Chloride mg/l MW-1010P	Chromium ug/l MW-1010P	Lead ug/l MW-1010P	Magnesium mg/l MW-1010P	Mercury ug/l MW-1010P	Potassium mg/l MW-1010P	Selenium ug/l MW-1010P	Silver ug/l MW-1010P	Sodium mg/l MW-1010P	Zinc ug/l MW-1010P
Avg of All Data (With ND = 1/2 MDL)	42	0.21	44	4.6	0.45	0.8	11	0.035	2.6	1	0.36	4.6	6
2014-06	45	0	48	5.4	0	0	12	0	2.4	0	0	4.4	0
2015-06	44	0	48	4.9	0	0	13	0	2.6	0	0	4.5	5.4
2016-06	40.2	0	45.5	6.1	0	0	12.9	0	2.64	0	0	4.29	8.6
2017-06	46.1	0	53.6	5.4	0	0	14	0	2.64	0	0	4.27	0
2018-06	45.9	0	49.4	5.1	0	0	13.4	0	2.6	0	0	4.24	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	2	0	3	-1	0	0	6	0	4	0	0	-8	-1
p-Level	0.408	0.5	0.325	0.5	0.5	0.5	0.117	0.5	0.242	0.5	0.5	0.042	0.5
MK Conclusion	NT	S	NT	S	S	S	NT	S	NT	S	S	D	NT
Percent Detects	100%	0%	100%	100%	0%	0%	100%	0%	100%	0%	0%	100%	40%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1015A	Cadmium ug/l MW-1015A	Calcium mg/l MW-1015A	Chloride mg/l MW-1015A	Chromium ug/l MW-1015A	Lead ug/l MW-1015A	Magnesium mg/l MW-1015A	Mercury ug/l MW-1015A	Potassium mg/l MW-1015A	Selenium ug/l MW-1015A	Silver ug/l MW-1015A	Sodium mg/l MW-1015A	Zinc ug/l MW-1015A
Avg of All Data (With ND = 1/2 MDL)	12	0.14	21	6.4	0.36	0.63	8.6	0.035	0.76	0.96	0.31	3.4	4.6
2014-06	8.5	0	21	6.4	0	0	8.5	0	0.74	0	0	3.7	0
2015-06	7.9	0	20	6.4	0	0	8.4	0	0.71	0	0	3.5	0
2016-06	7.4	0	20.8	6	0.52	0	8.82	0	0.691	0	0	3.38	0
2017-06	7.9	0	21.8	6.3	0	0	9.07	0	0.647	0	0	3.38	0
2018-06	8	0	21.3	7	0	0	8.81	0	0.71	0	0	3.26	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	-1	0	4	1	0	0	4	0	-5	0	0	-9	0
p-Level	0.5	0.5	0.242	0.5	0.5	0.5	0.242	0.5	0.1795	0.5	0.5	0.025	0.5
MK Conclusion	S	S	NT	NT	NT	S	NT	S	S	S	S	D	S
Percent Detects	100%	0%	100%	100%	20%	0%	100%	0%	100%	0%	0%	100%	0%

Rate of Change Analysis for Trend Results - Annual Parameters

Analyte Units Location	Barium ug/l MW-1015B	Cadmium ug/l MW-1015B	Calcium mg/l MW-1015B	Chloride mg/l MW-1015B	Chromium ug/l MW-1015B	Lead ug/l MW-1015B	Magnesium mg/l MW-1015B	Mercury ug/l MW-1015B	Potassium mg/l MW-1015B	Selenium ug/l MW-1015B	Silver ug/l MW-1015B	Sodium mg/l MW-1015B	Zinc ug/l MW-1015B
Avg of All Data (With ND = 1/2 MDL)	45	0.13	34	72	0.39	0.7	15	0.037	6.7	0.94	0.29	54	4.6
2014-06	44	0	35	67	0	0	15	0	6.4	0	0	57	0
2015-06	46	0	36	79	0	0	16	0	6.7	0	0	64	0
2016-06	43	0	37.3	74.6	0.53	0	16.2	0	6.79	0	0	59.1	0
2017-06	46.5	0	38	90.1	0	0	16.5	0	6.81	0	0	63.4	0
2018-06	46.4	0.089	34.3	89.5	0	0	14.9	0	6.23	0	0	62.8	0
2014 - 2018 Analysis													
(Previous 5-Years)													
	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results	MK Results
Sample Size	5	5	5	5	5	5	5	5	5	5	5	5	5
Mann-Kendall S	4	4	2	6	0	0	2	0	2	0	0	2	0
p-Level	0.242	0.242	0.408	0.117	0.5	0.5	0.408	0.5	0.408	0.5	0.5	0.408	0.5
MK Conclusion	NT	NT	NT	NT	NT	S	NT	S	NT	S	S	NT	S
Percent Detects	100%	20%	100%	100%	20%	0%	100%	0%	100%	0%	0%	100%	0%

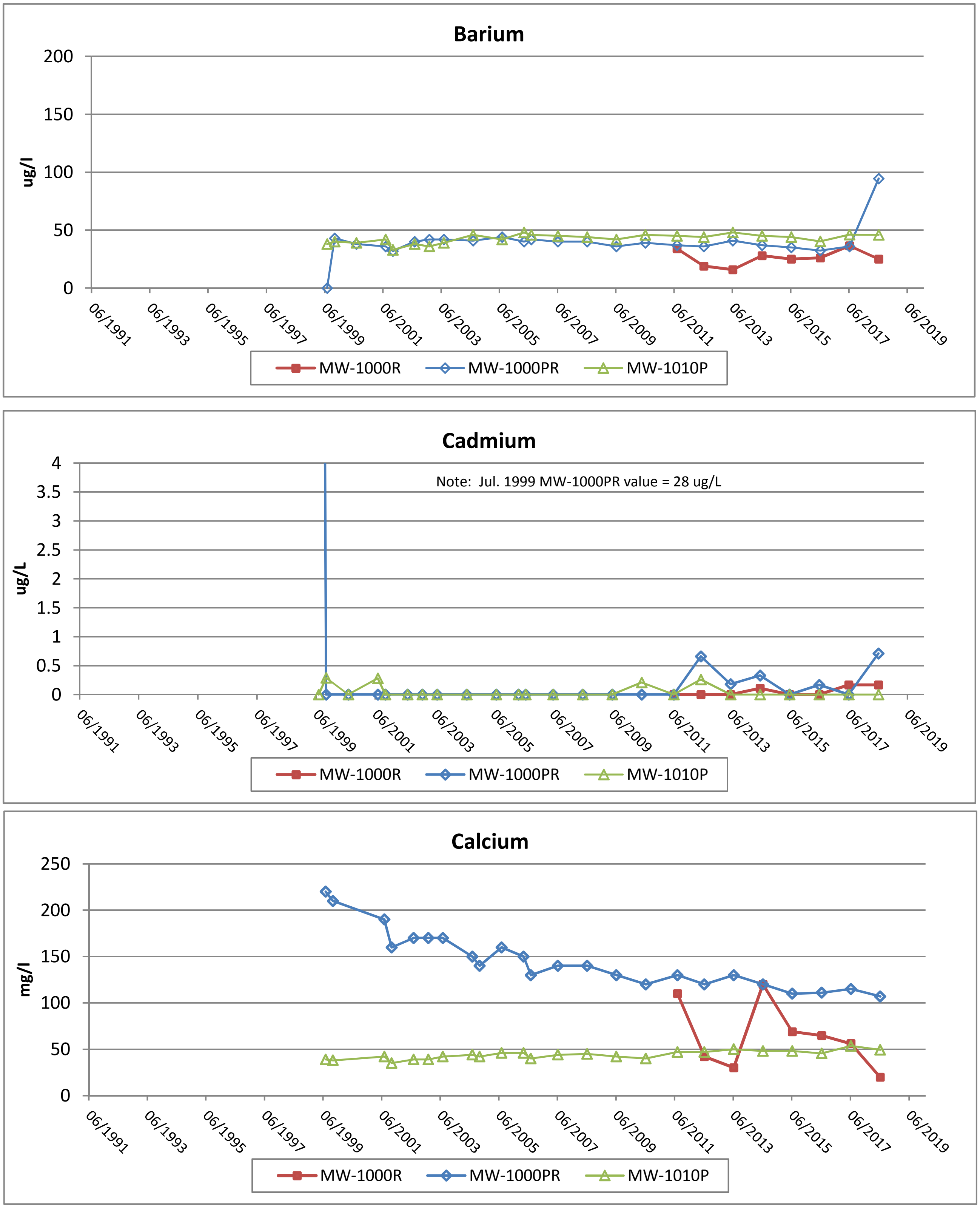

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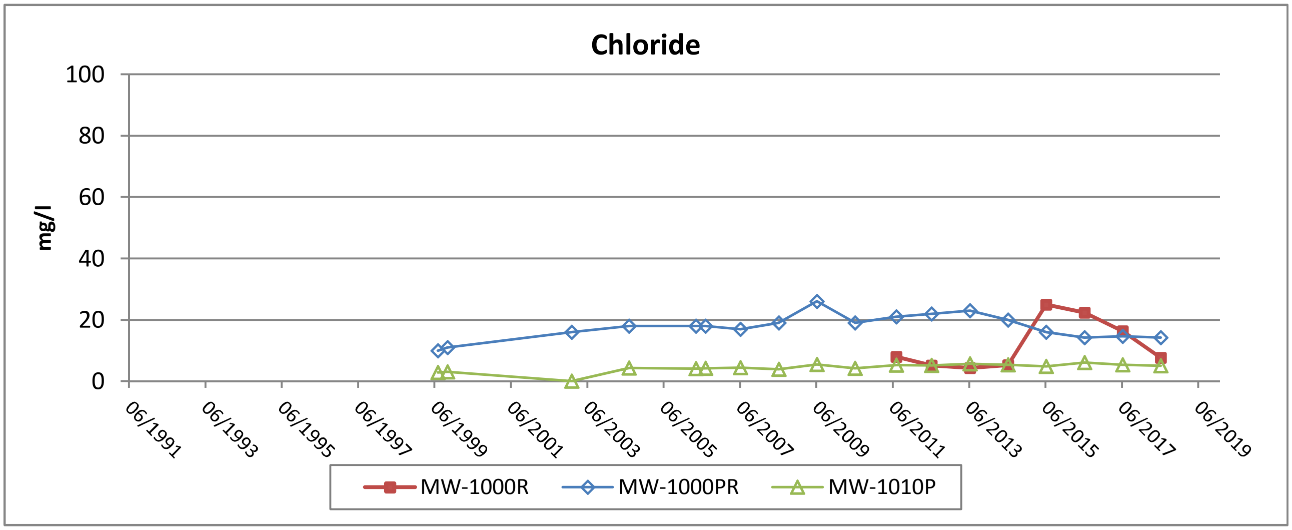
FIGURE 4-1a

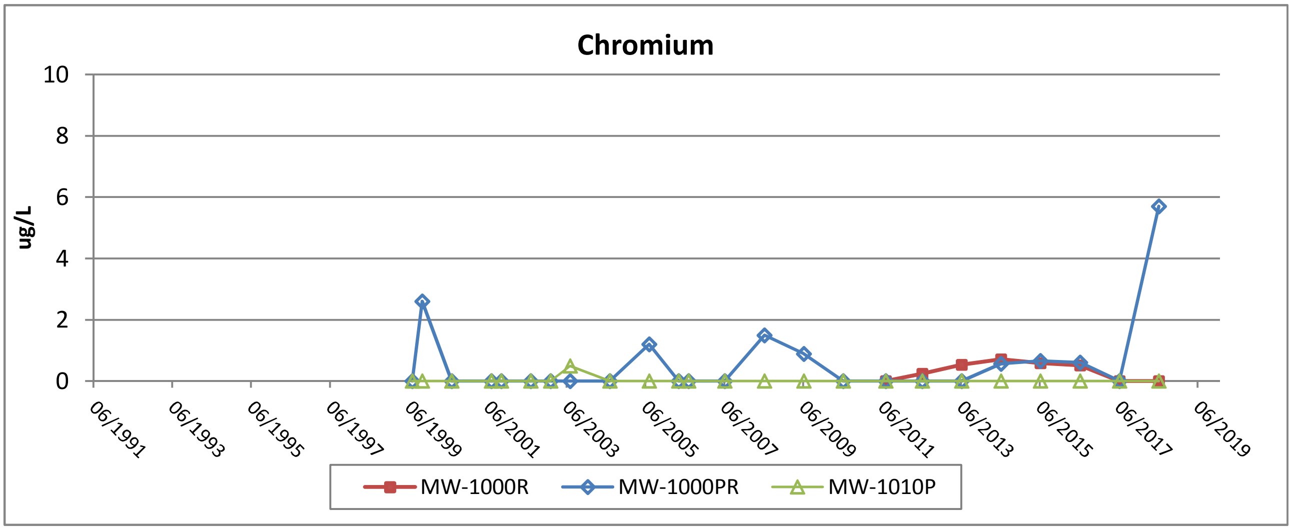
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





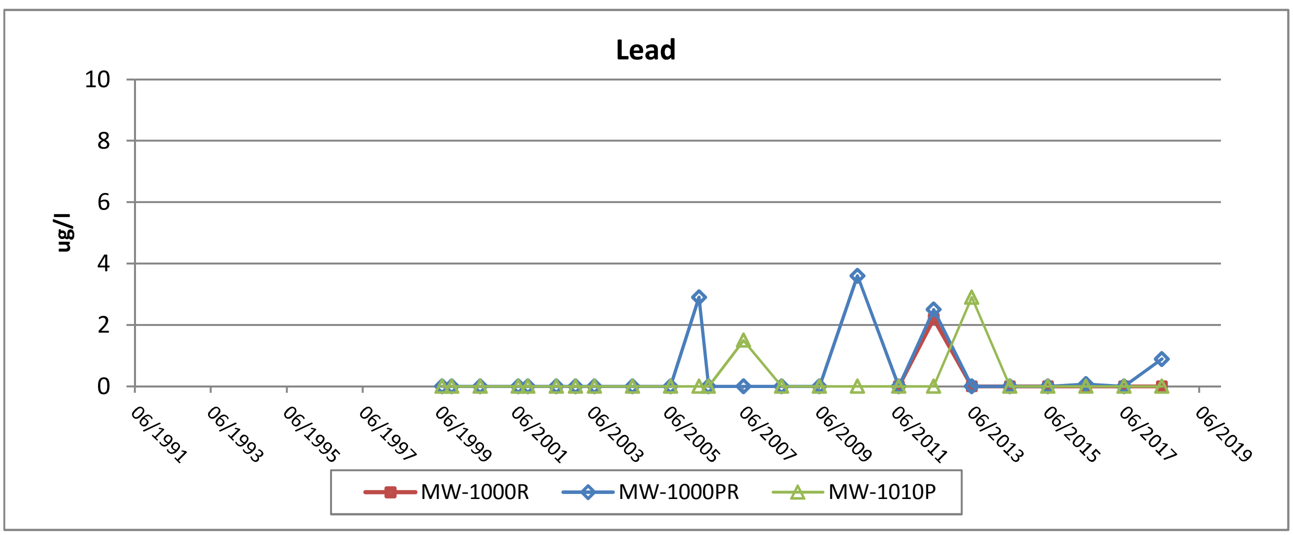


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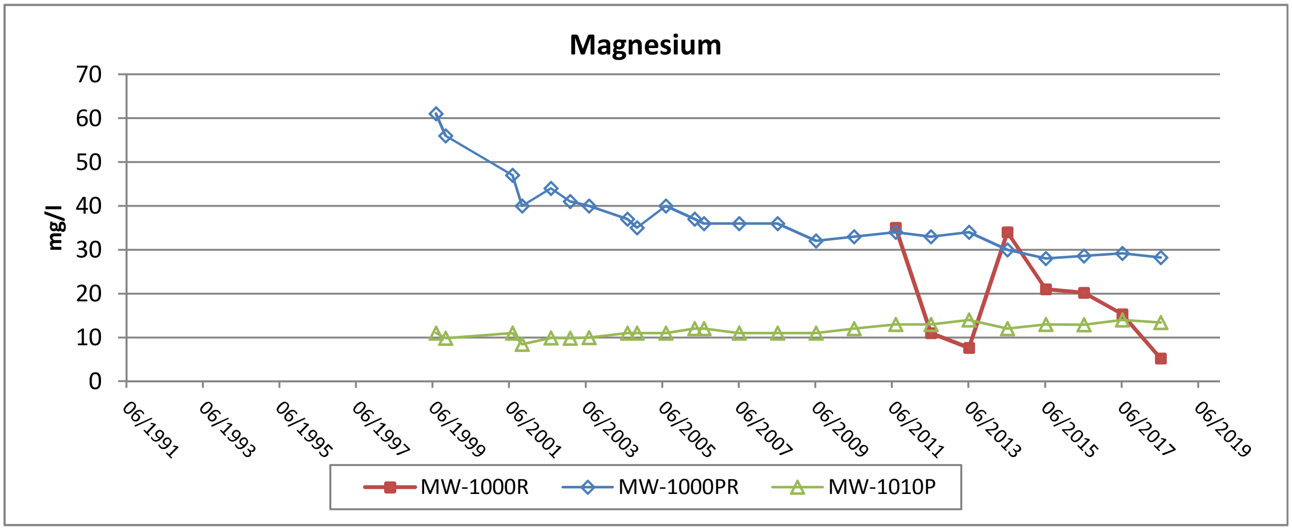
FIGURE 4-1b

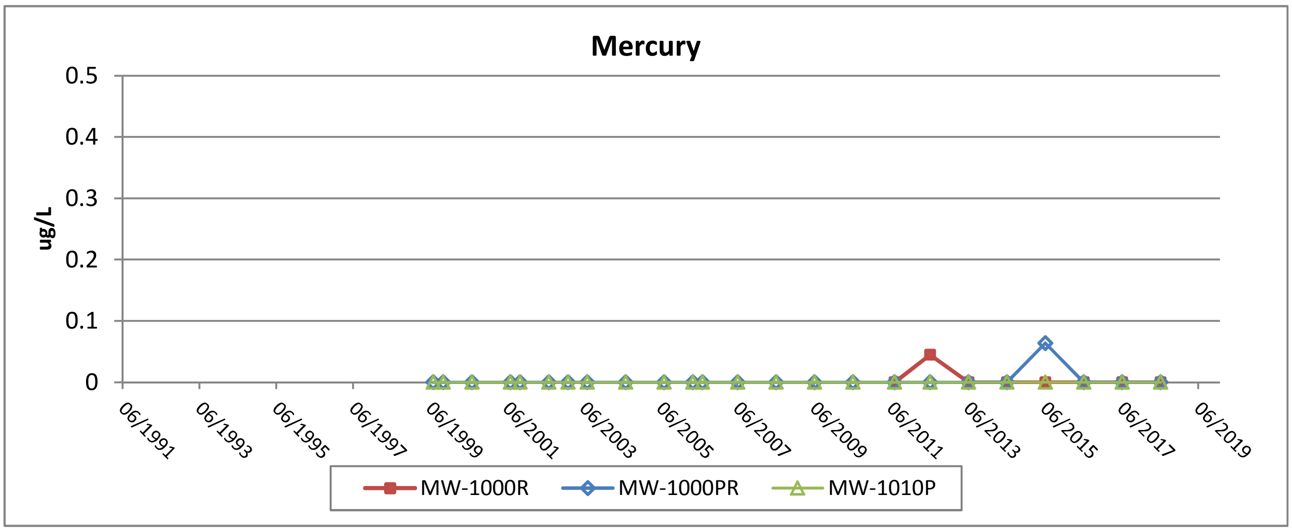
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





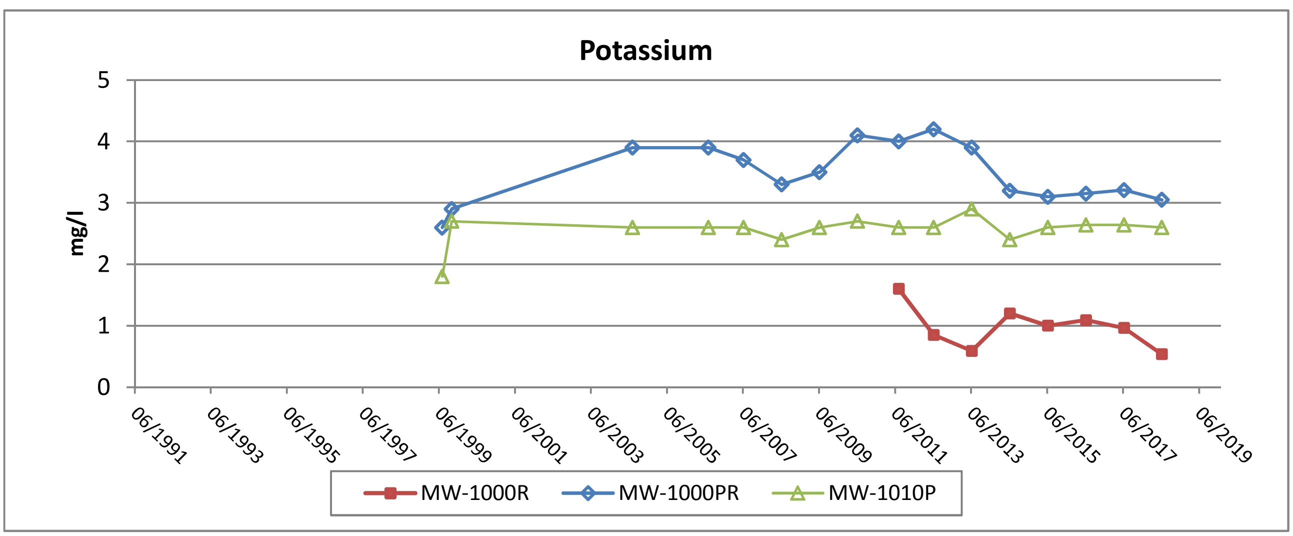


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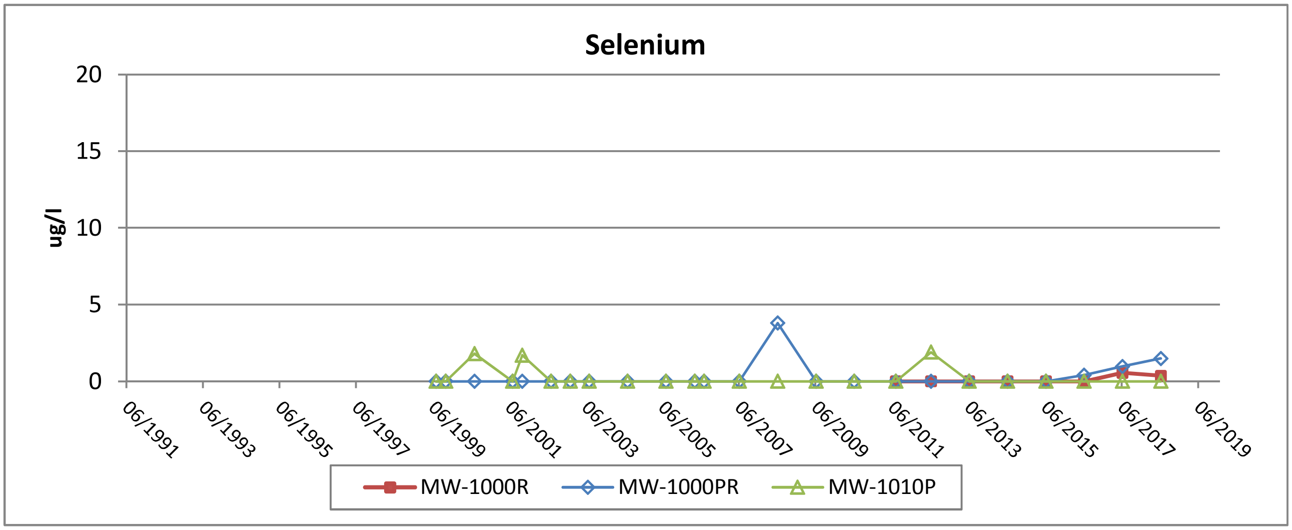
FIGURE 4-1c

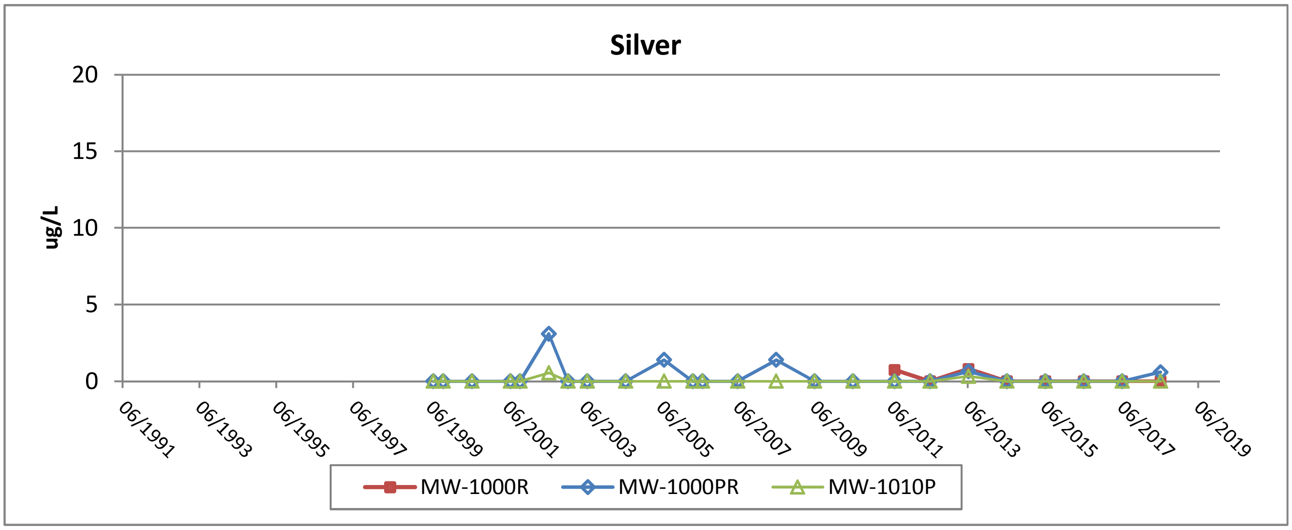
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





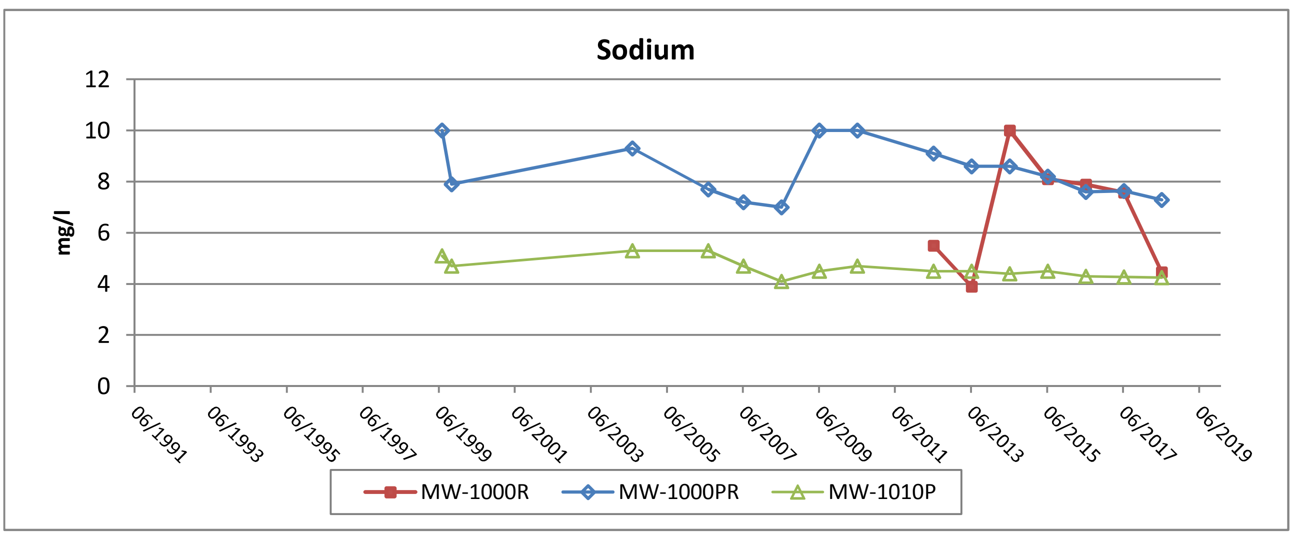


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FIGURE 4-1d

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm

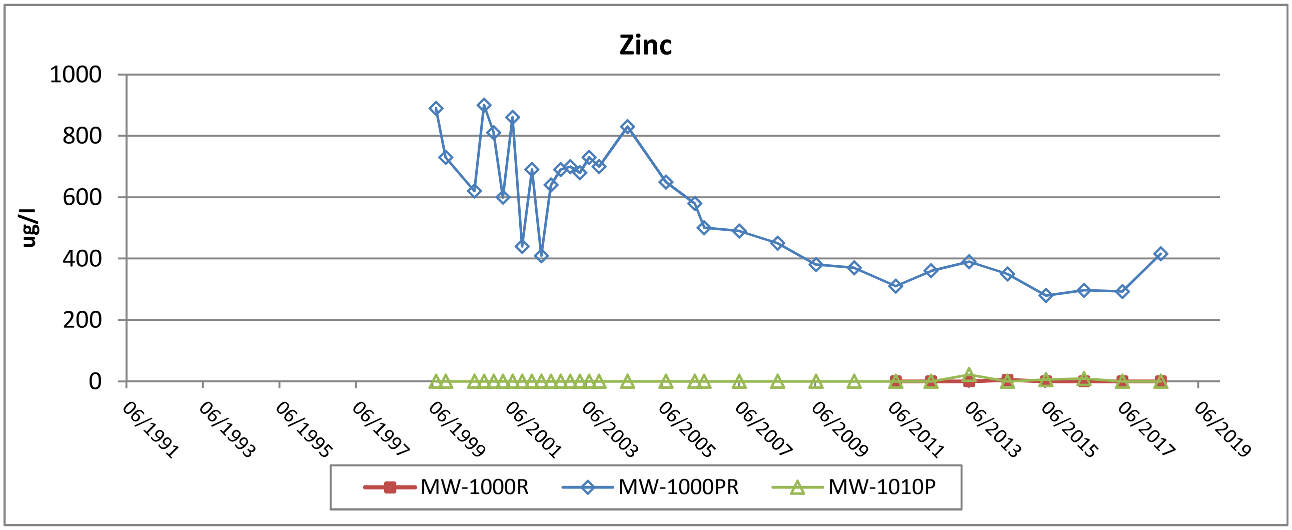

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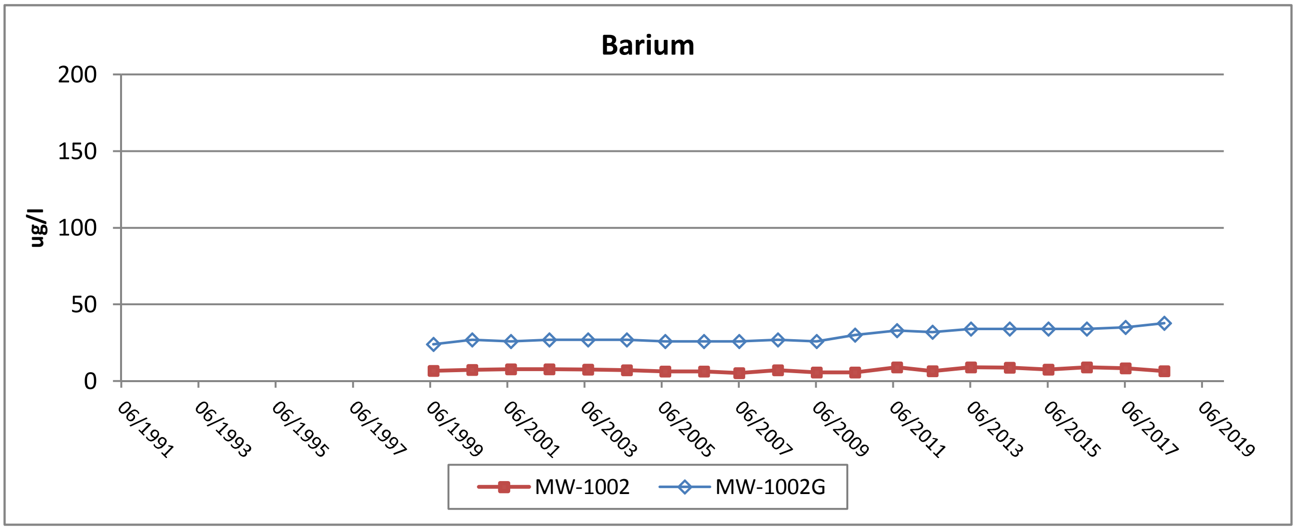
FIGURE 4-1e

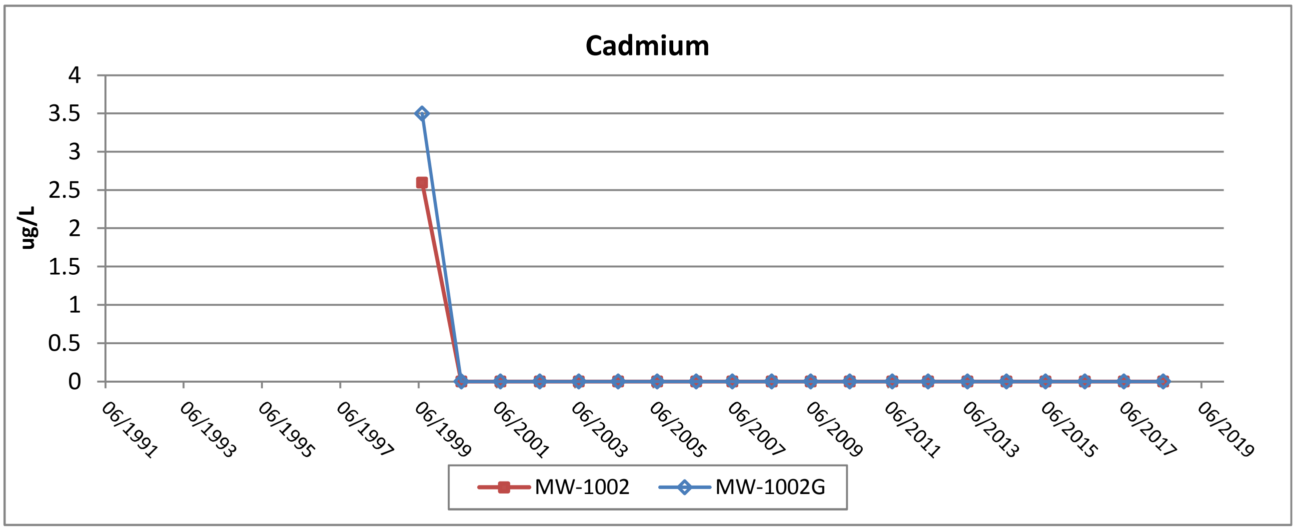
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1000R/MW-1000PR/MW-1010P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





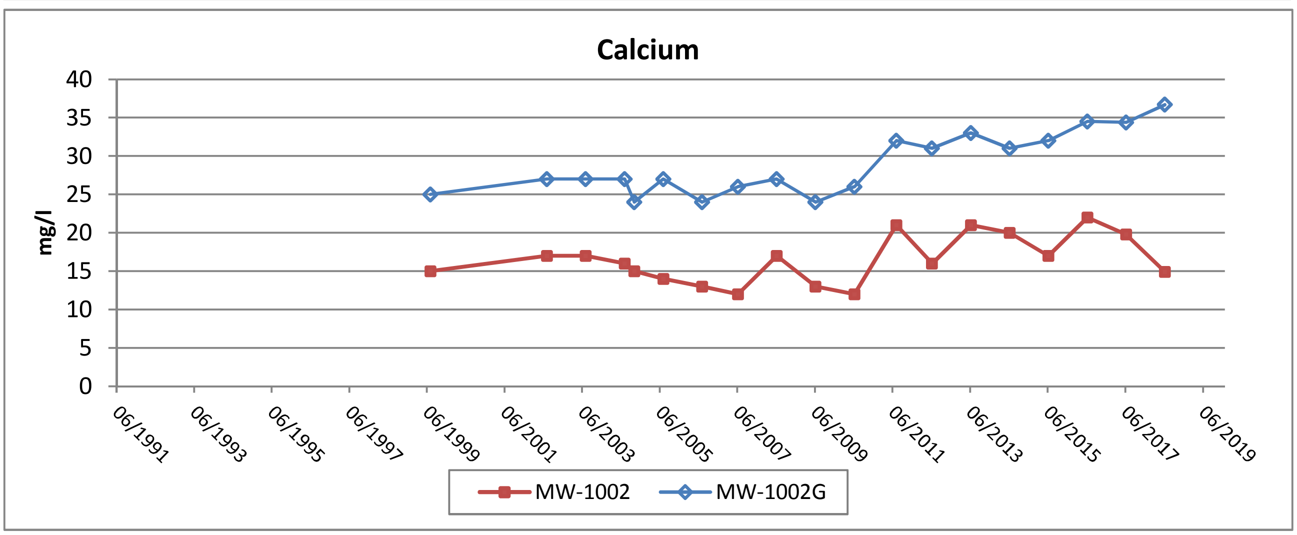


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FIGURE 4-2a

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1002/MW-1002G

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

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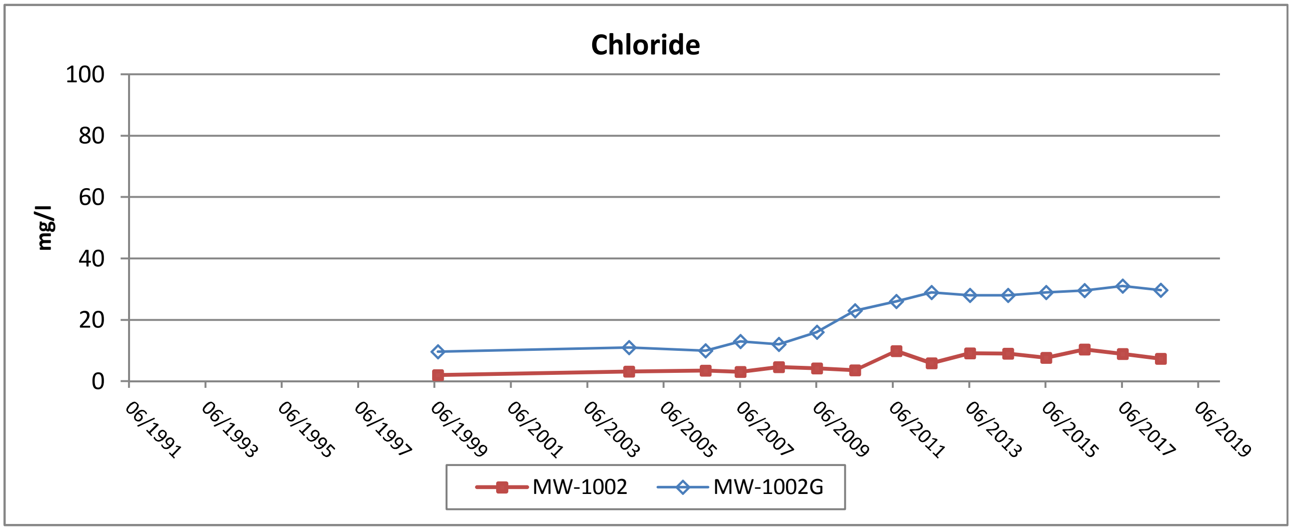

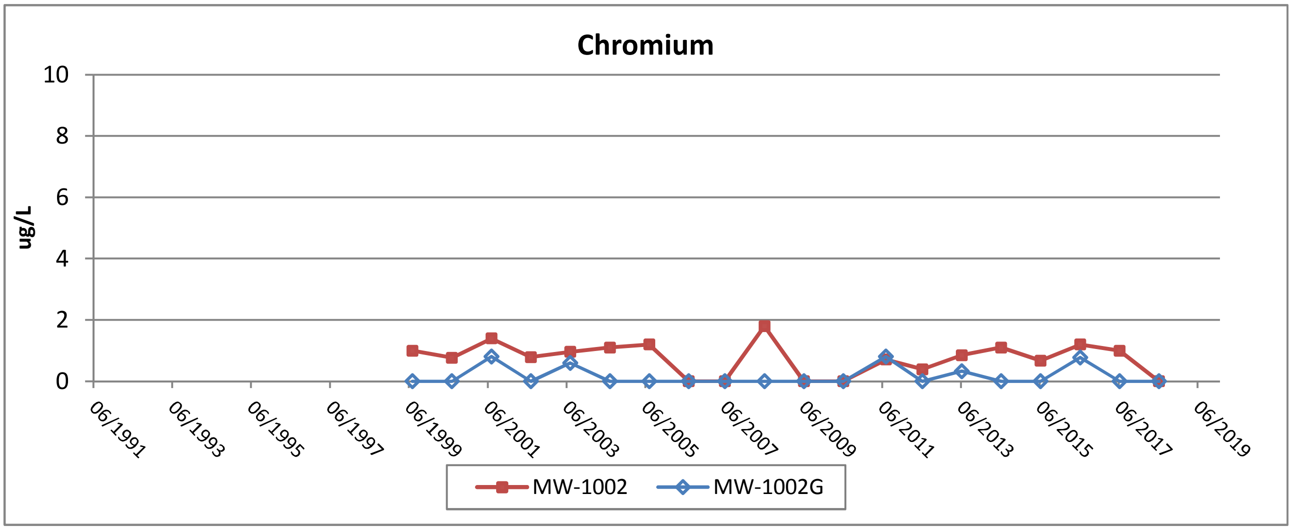

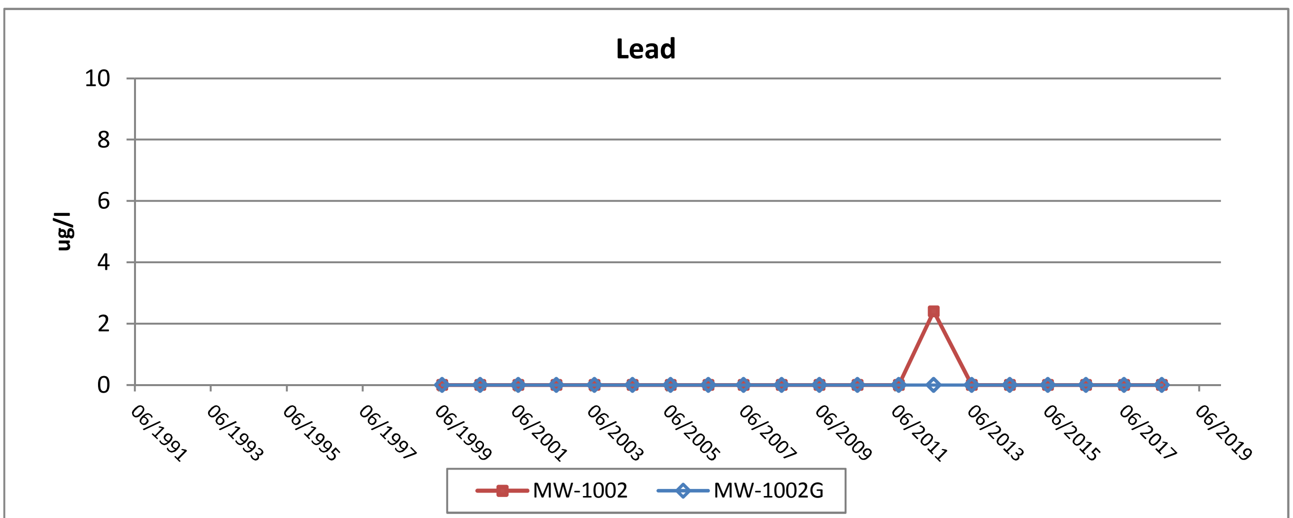

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FIGURE 4-2b

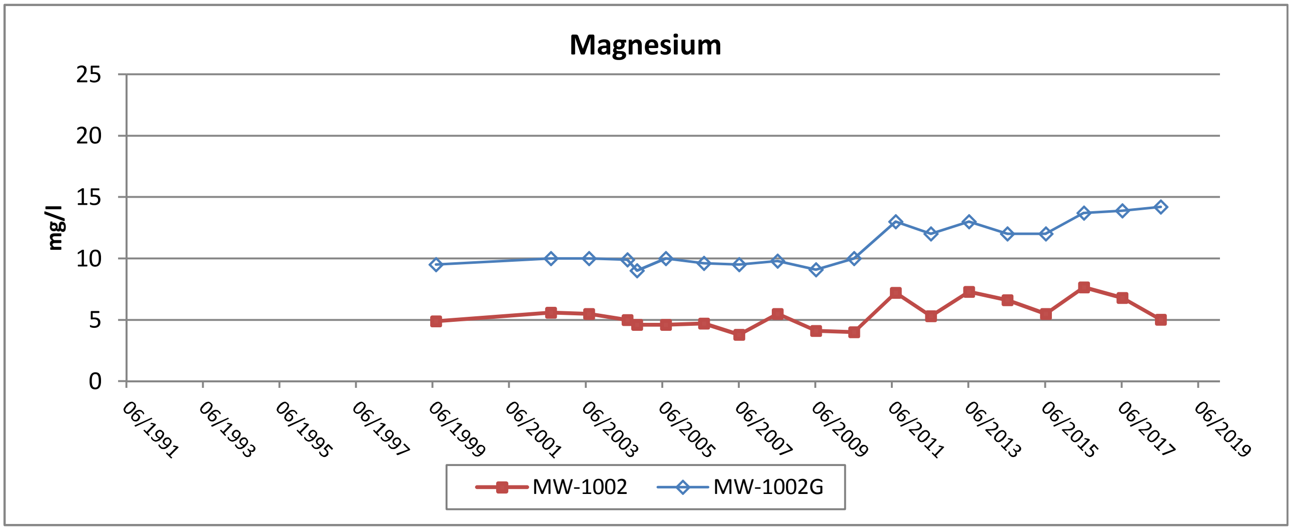
GROUNDWATER TREND GRAPHS - ANNUAL

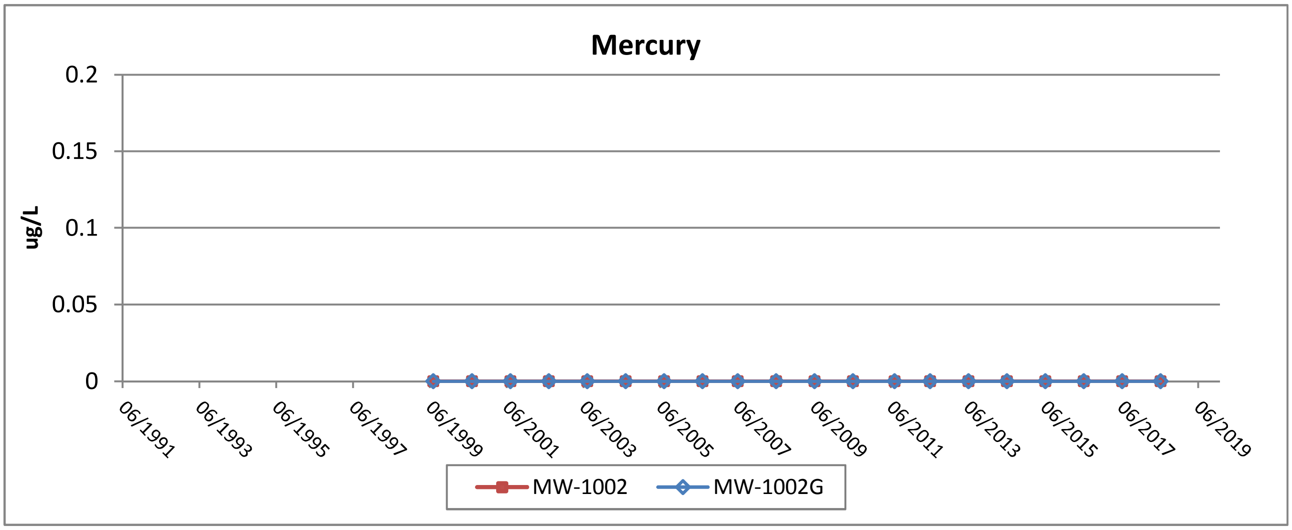
MW-1002/MW-1002G

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





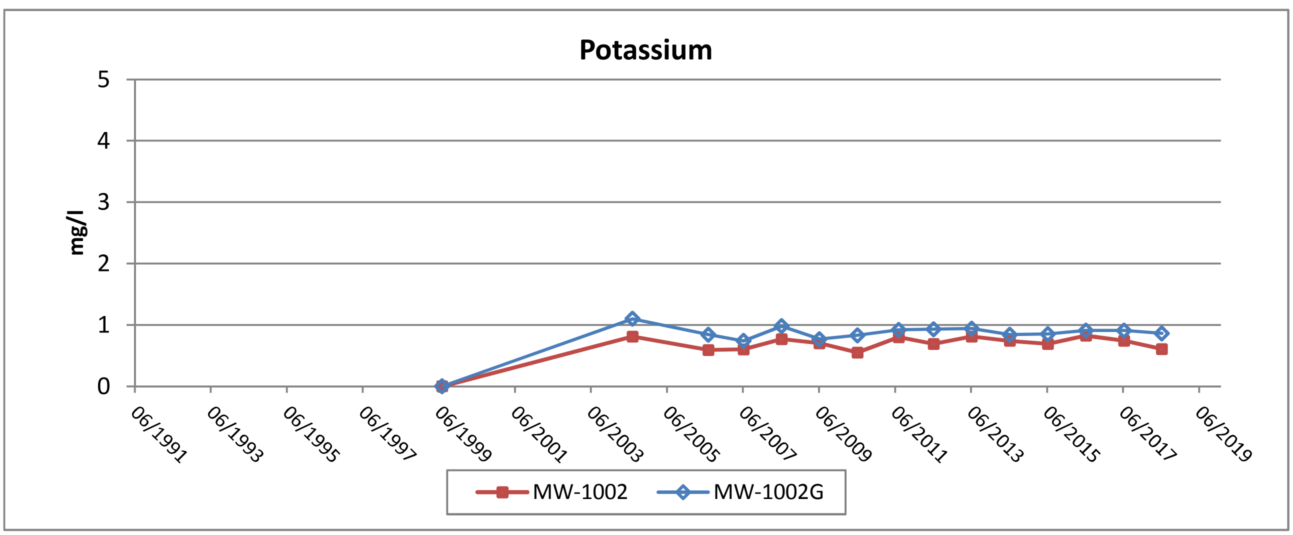


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FIGURE 4-2c

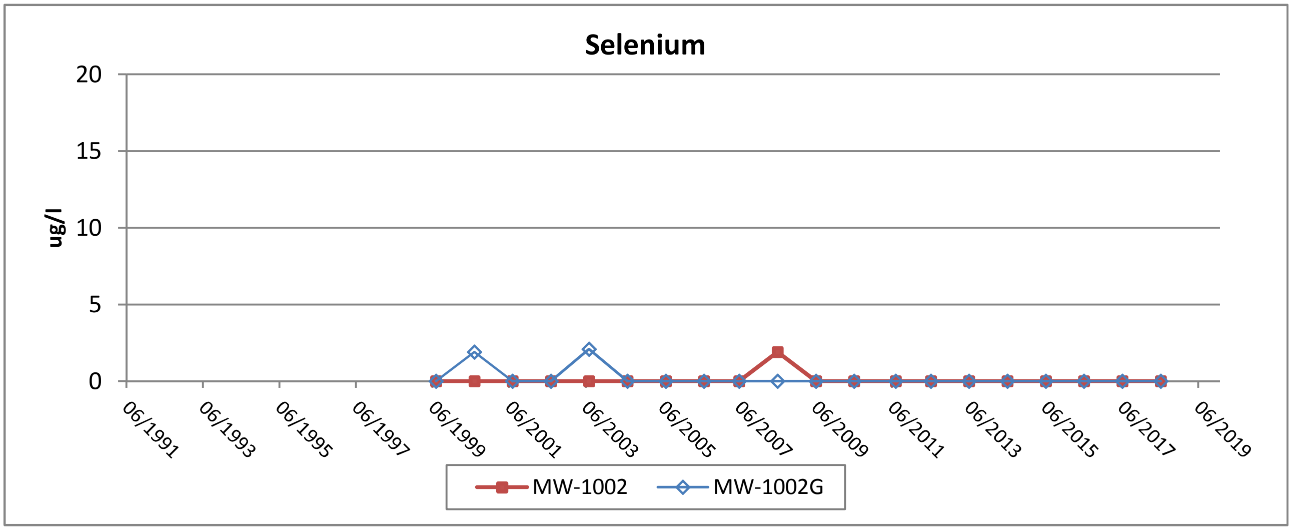
GROUNDWATER TREND GRAPHS - ANNUAL

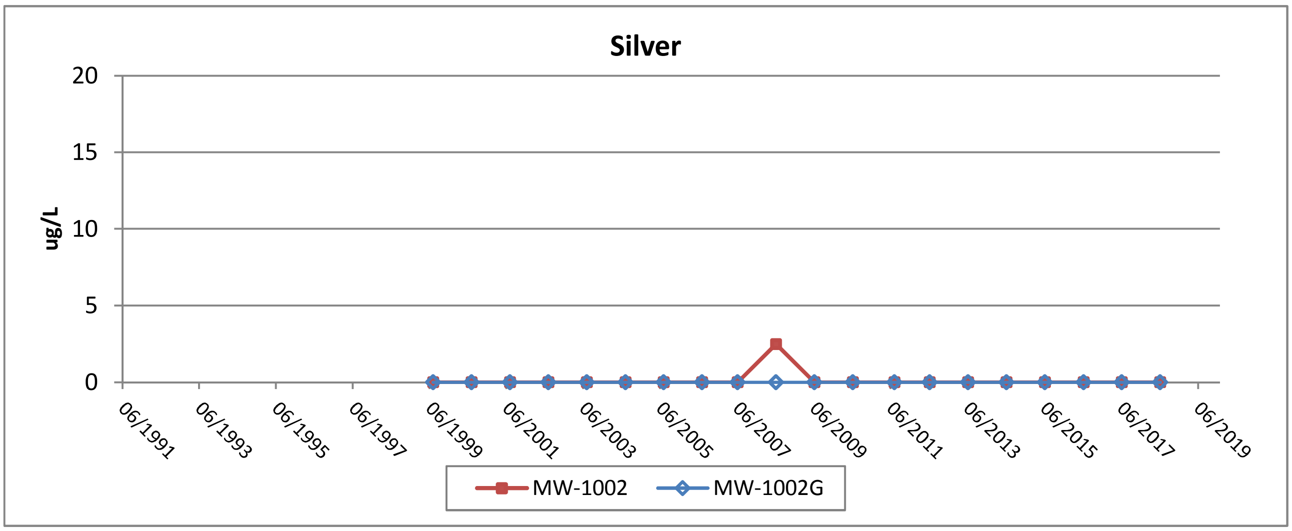
MW-1002/MW-1002G

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





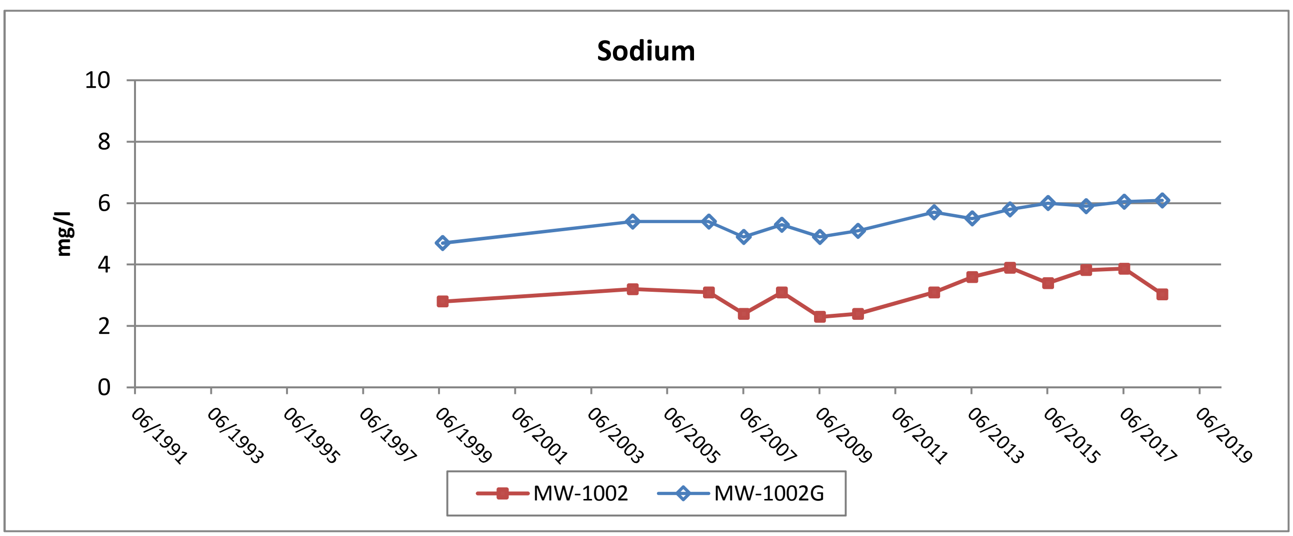


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FIGURE 4-2d

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1002/MW-1002G

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm

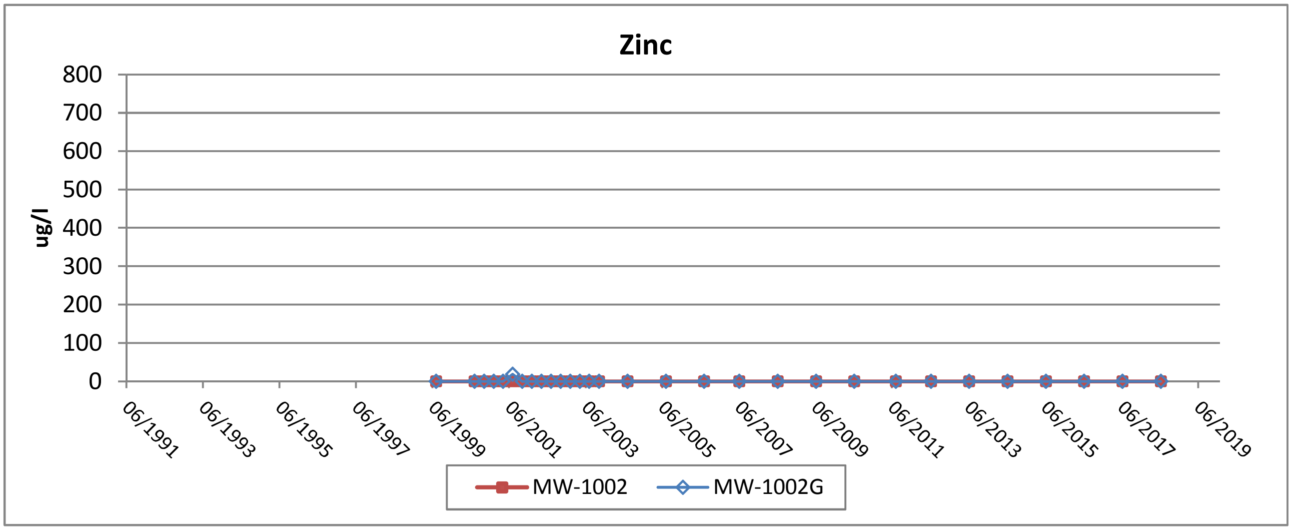

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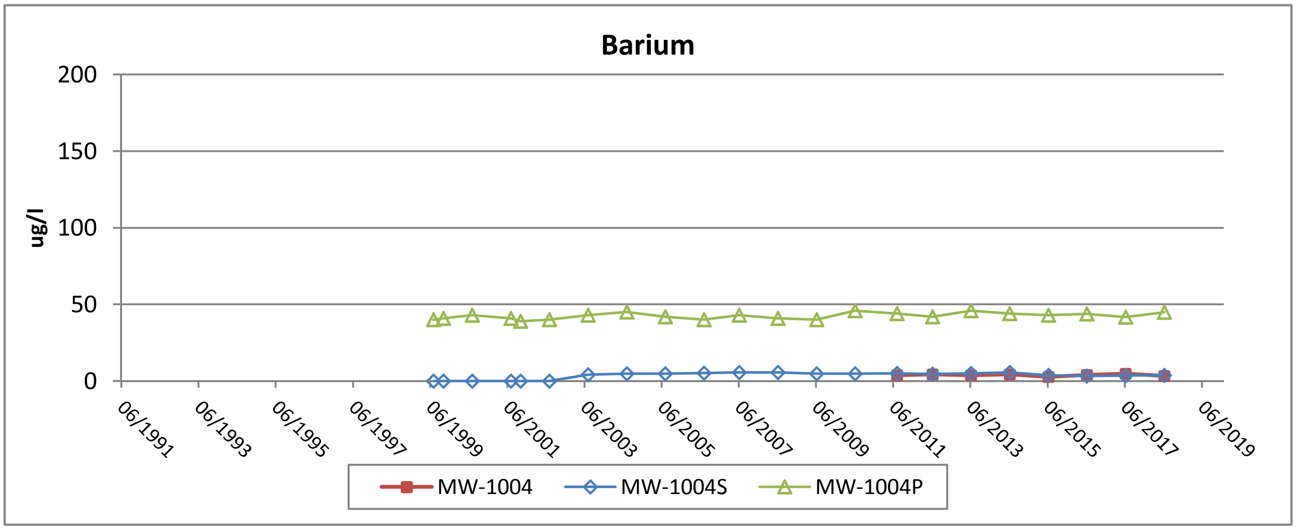
FIGURE 4-2e

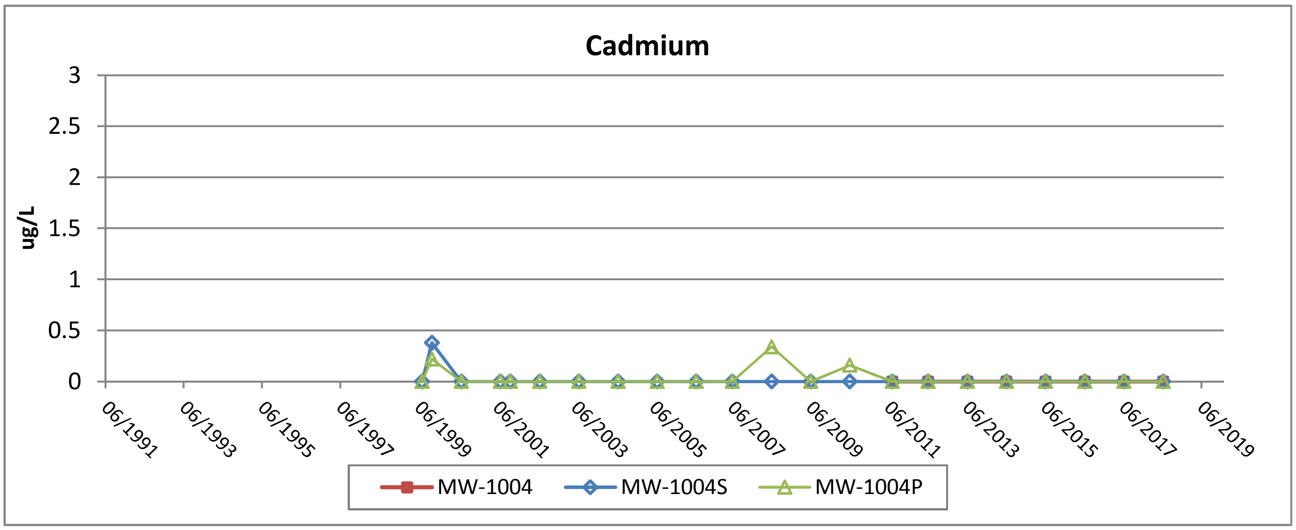
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1002/MW-1002G

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





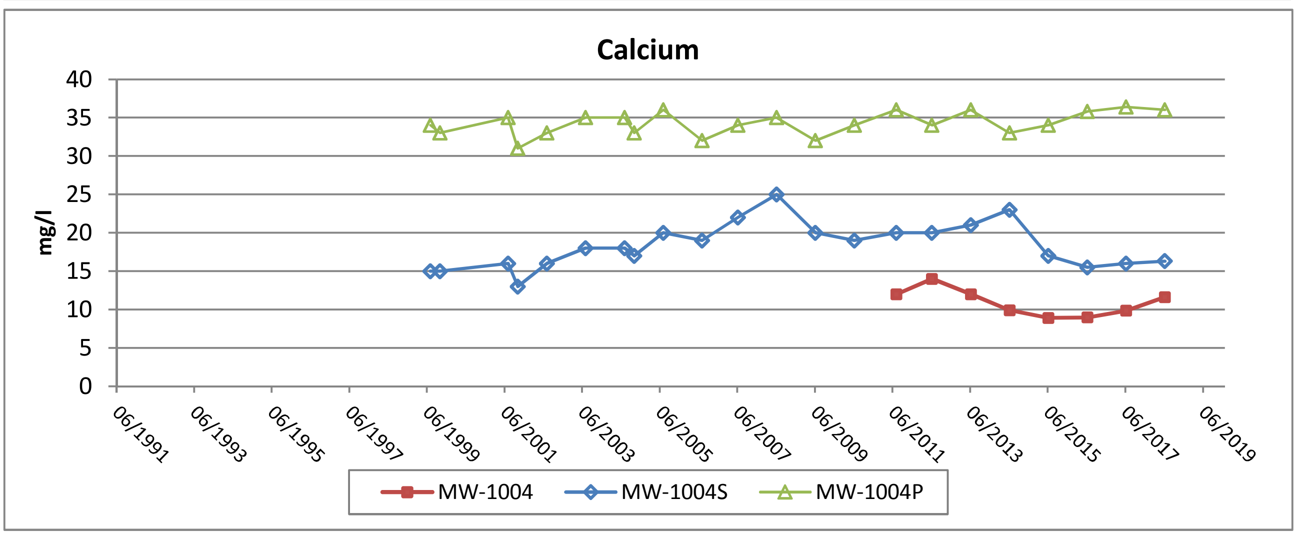


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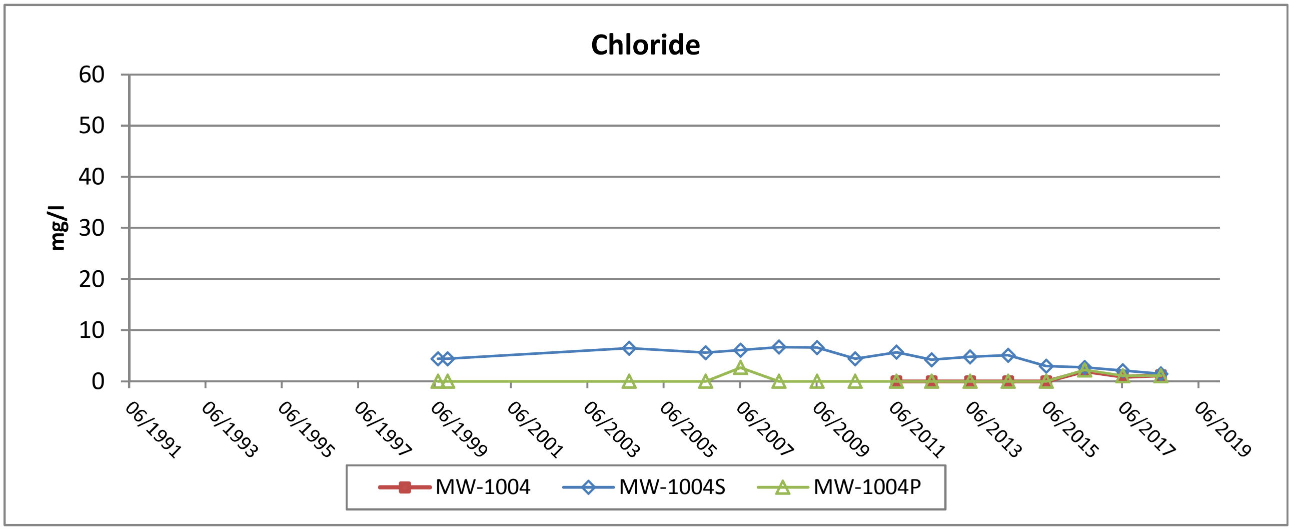
FIGURE 4-3a

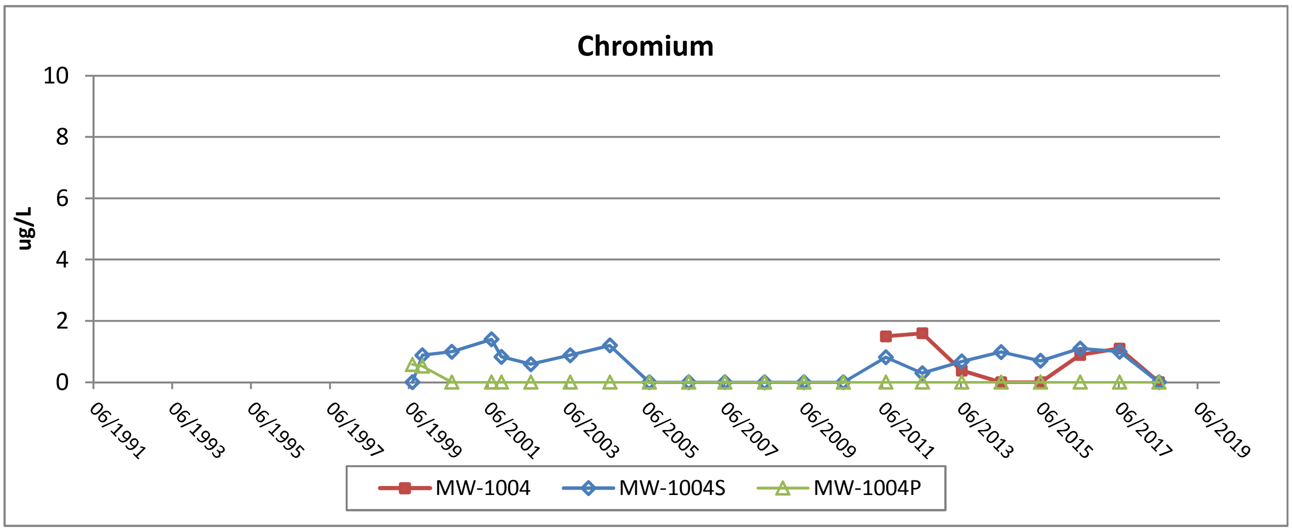
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





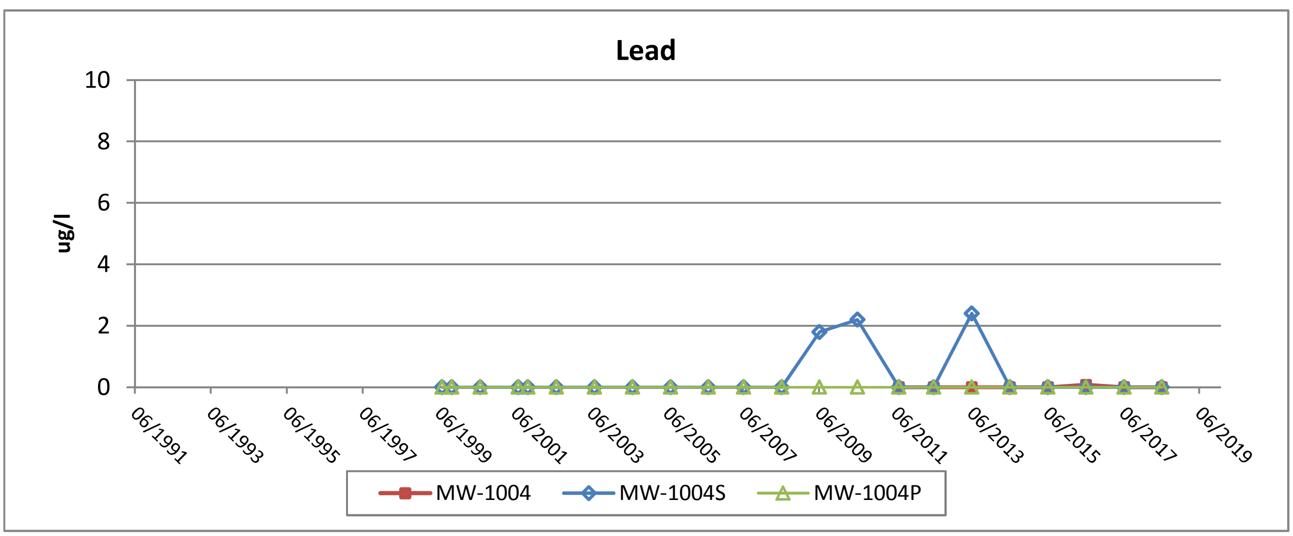


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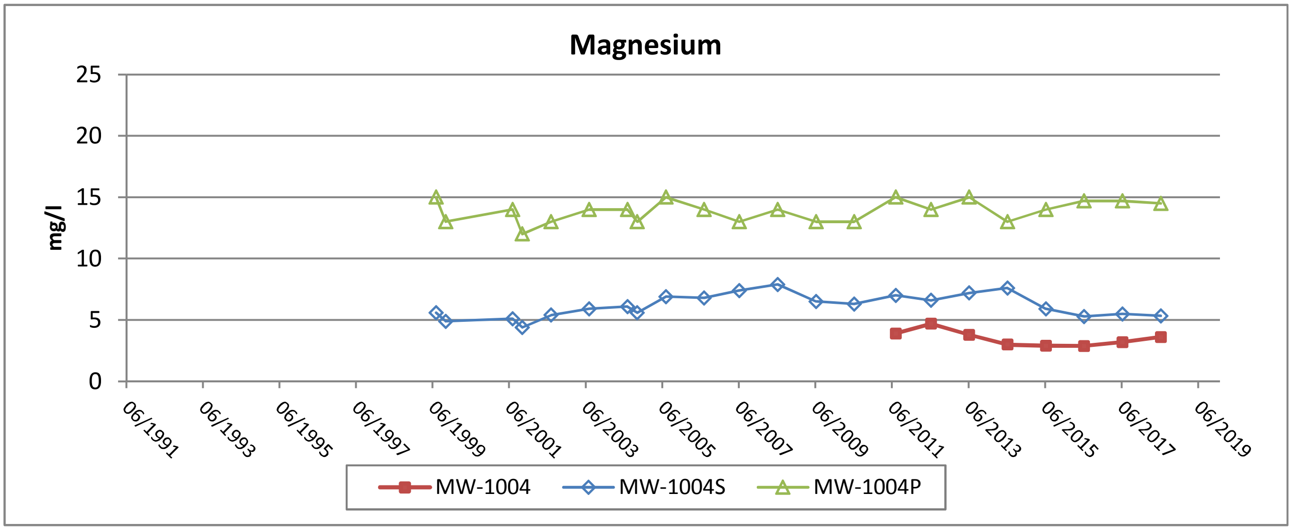
FIGURE 4-3b

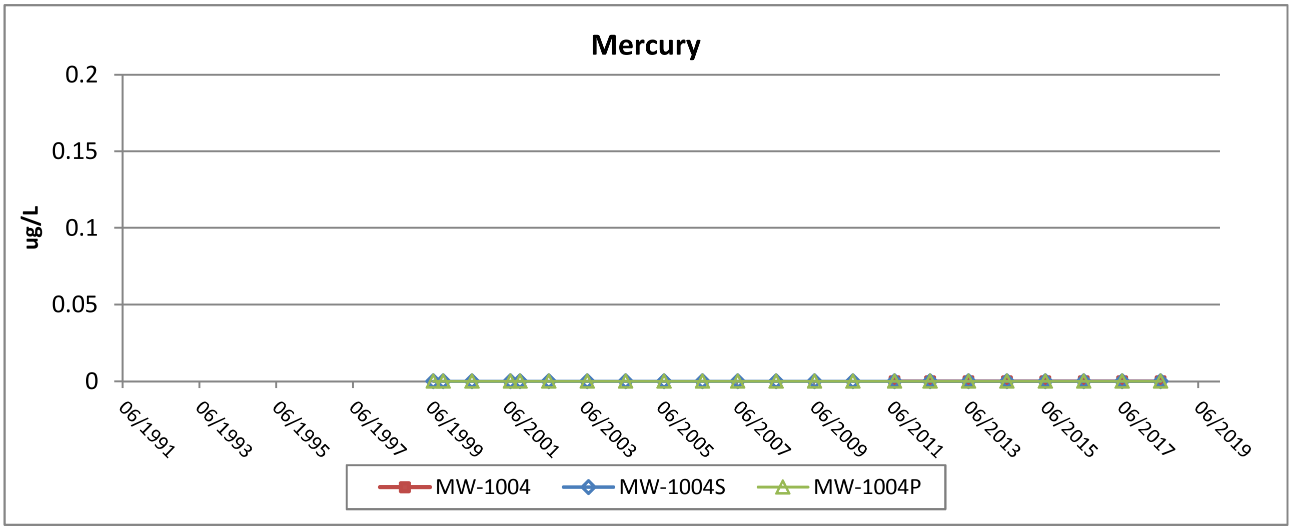
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





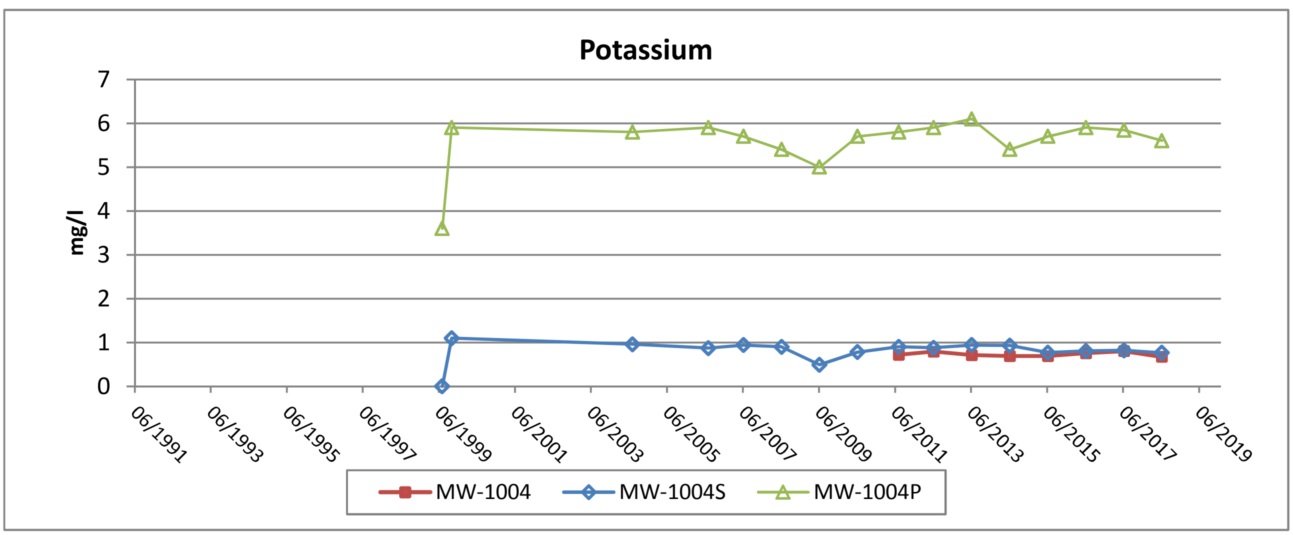


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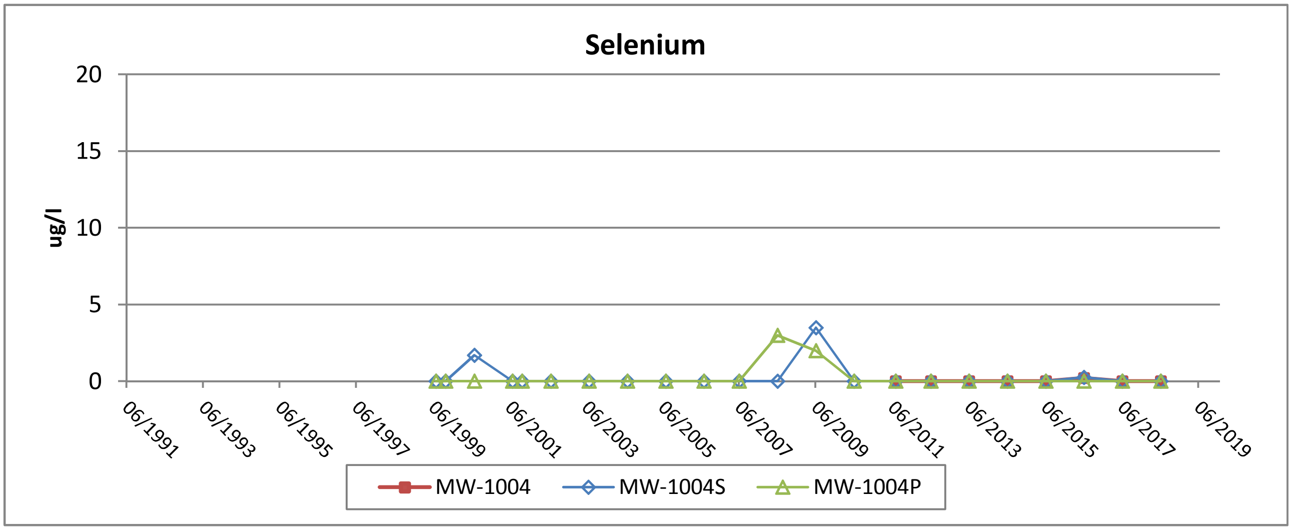
FIGURE 4-3c

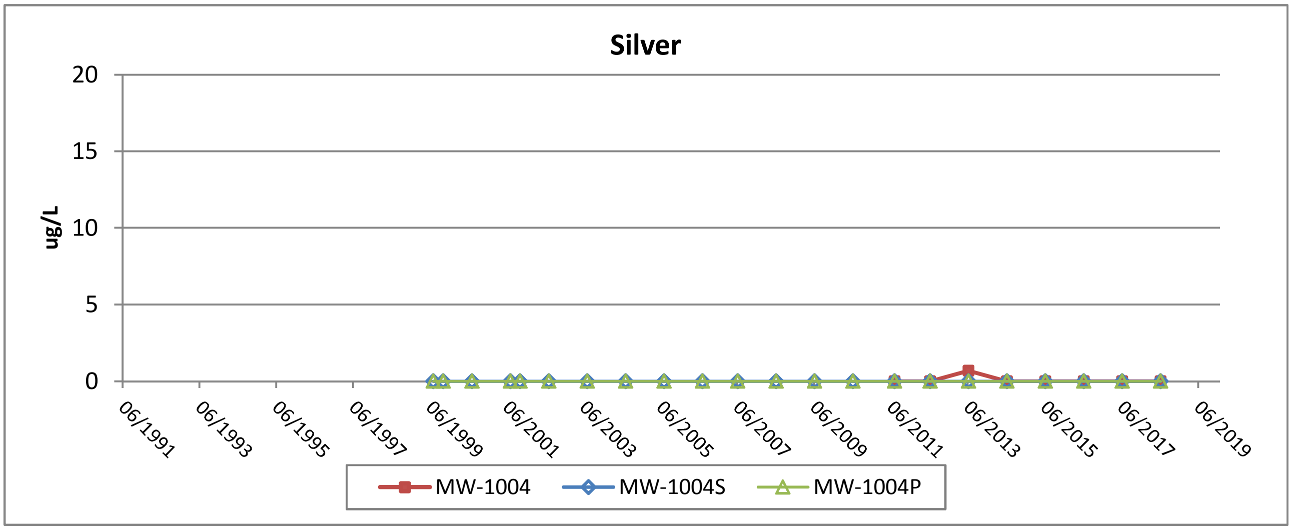
GROUNDWATER TREND GRAPHS - ANNUAL

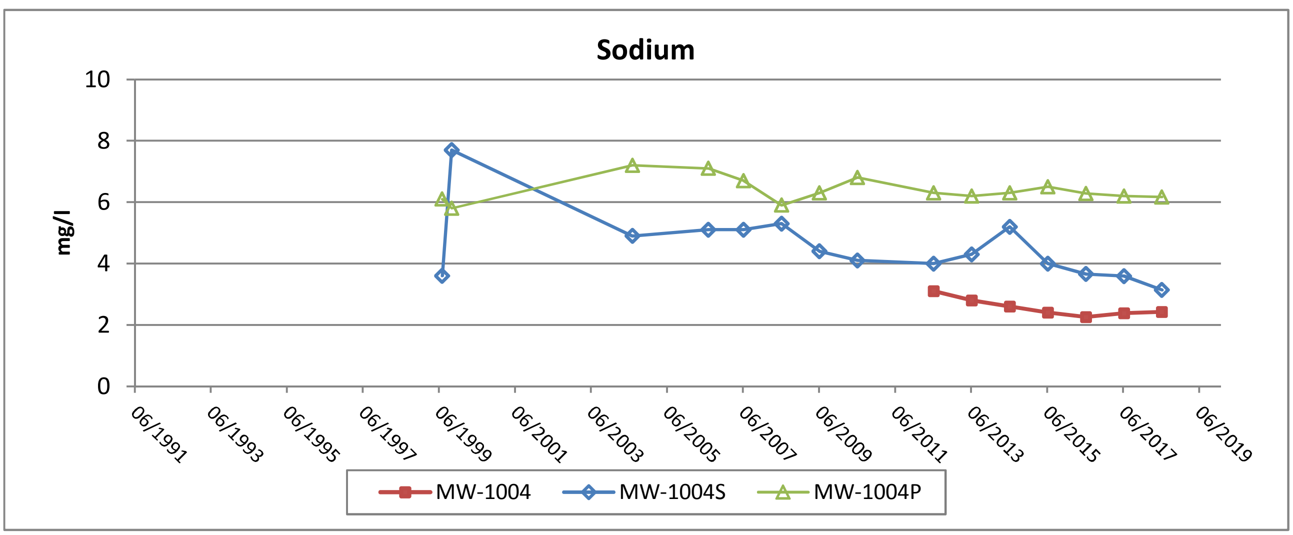
MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm







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Foth Infrastructure & Environment, LLC

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FIGURE 4-3d

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

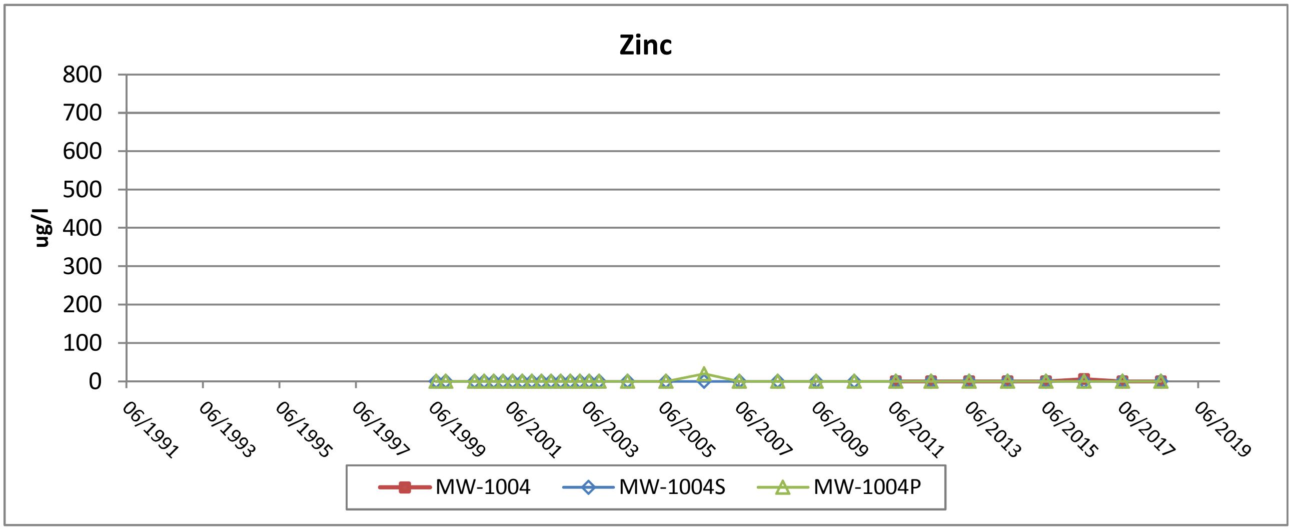

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FIGURE 4-3e

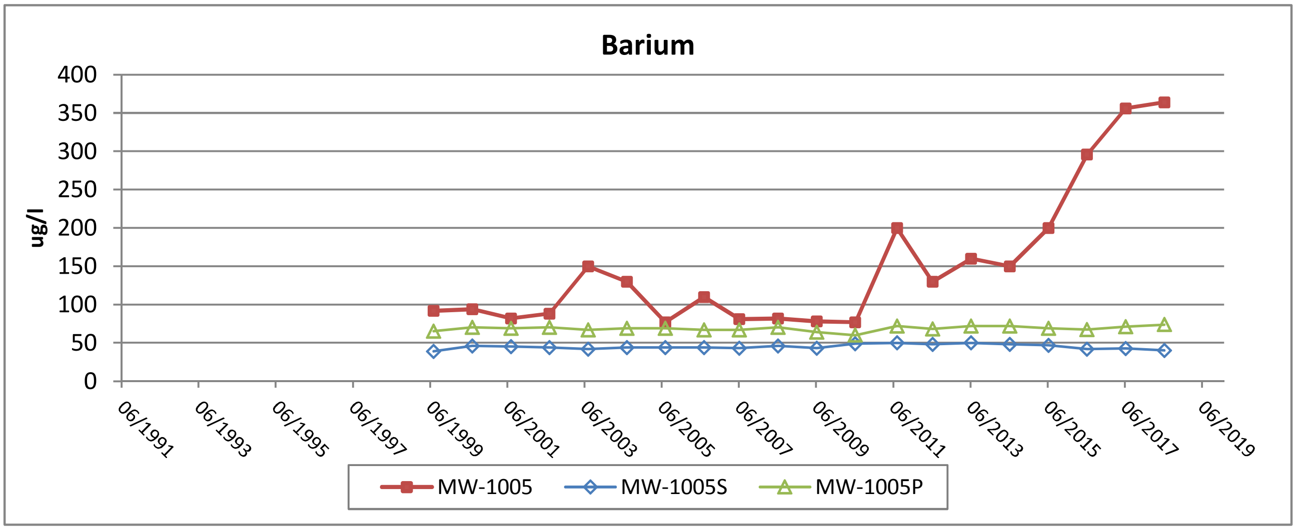
GROUNDWATER TREND GRAPHS - ANNUAL

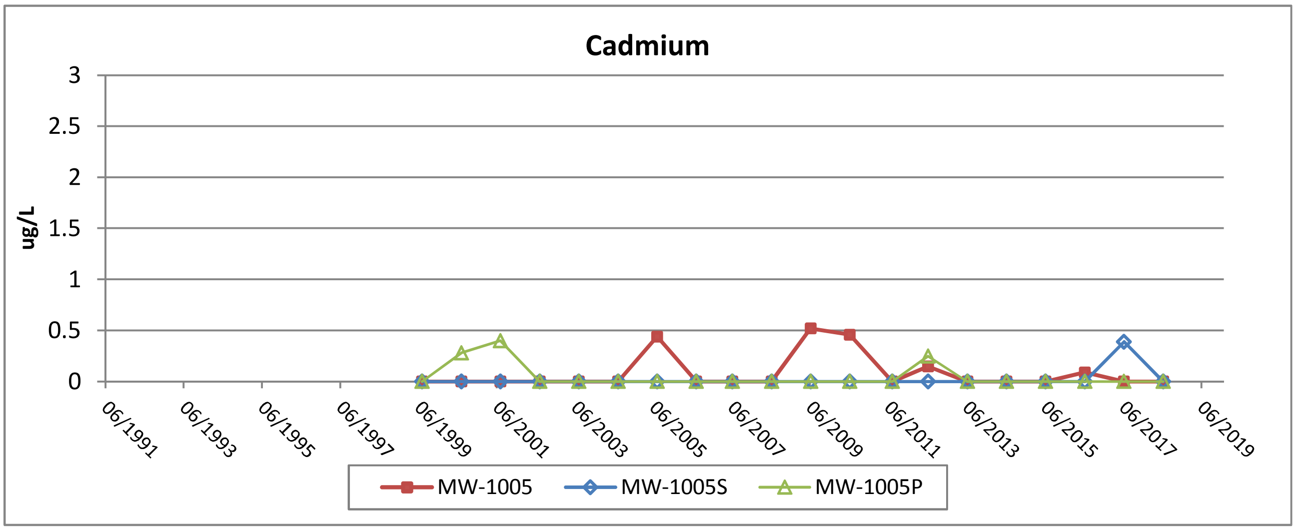
MW-1004/MW-1004S/MW-1004P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





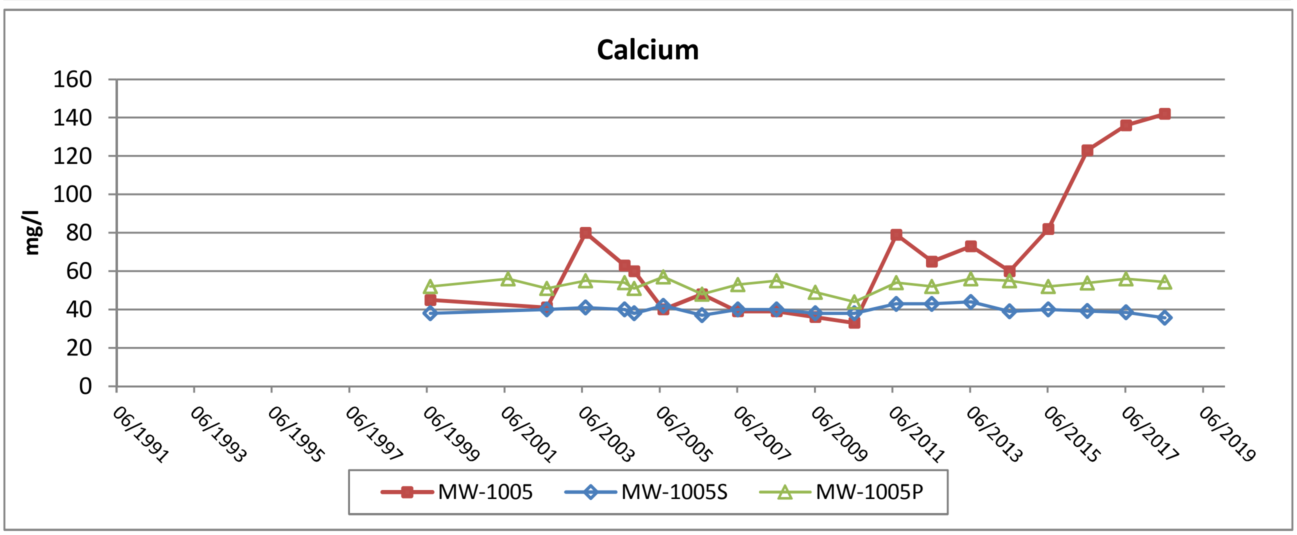


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FIGURE 4-4a

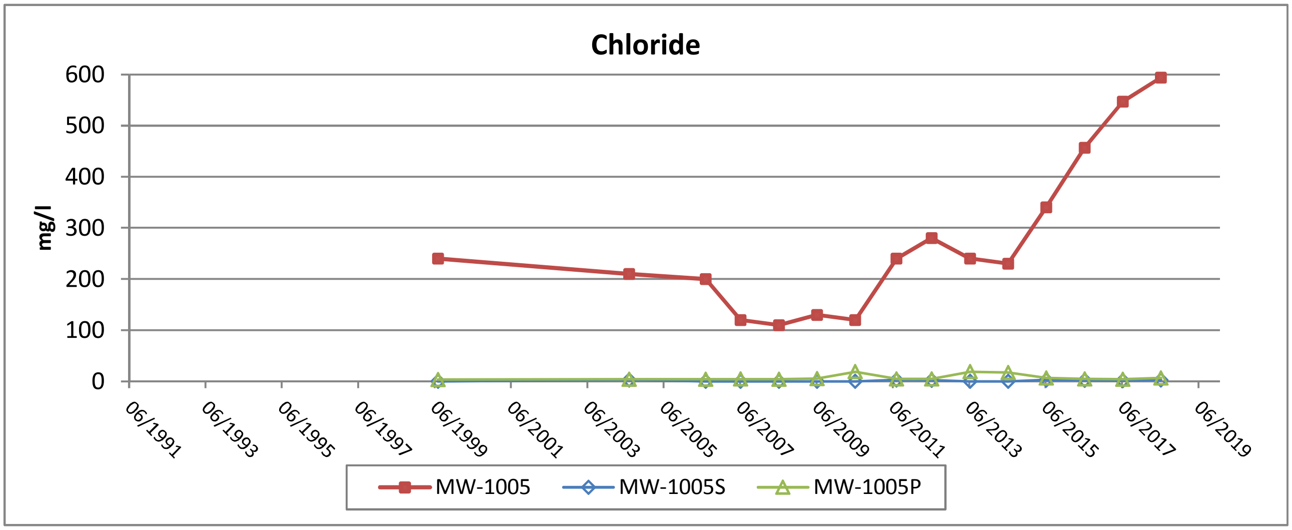
GROUNDWATER TREND GRAPHS - ANNUAL

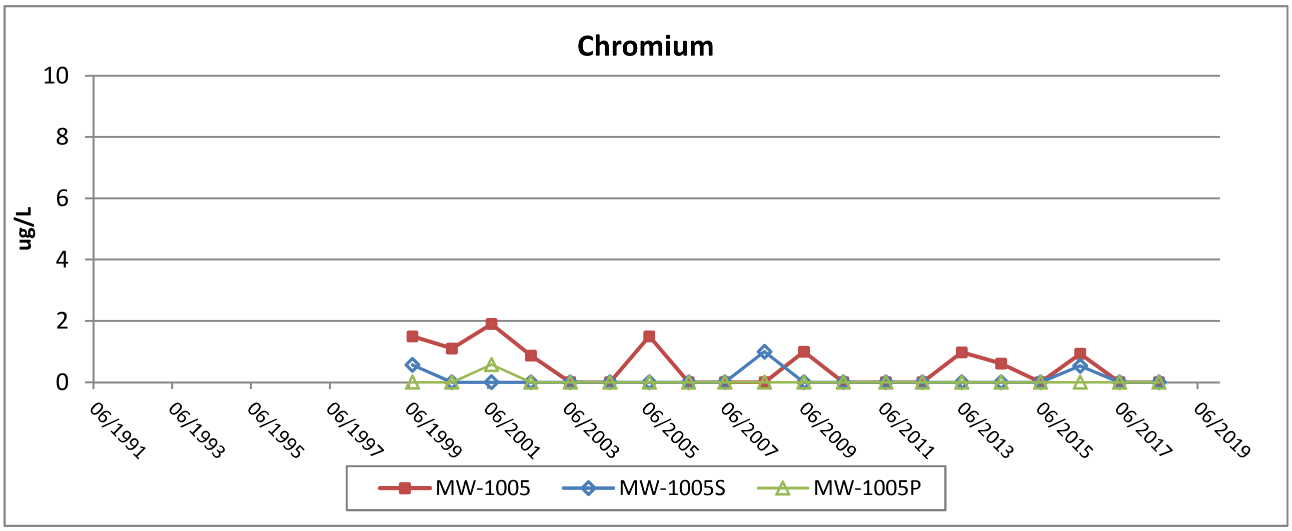
MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018

Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





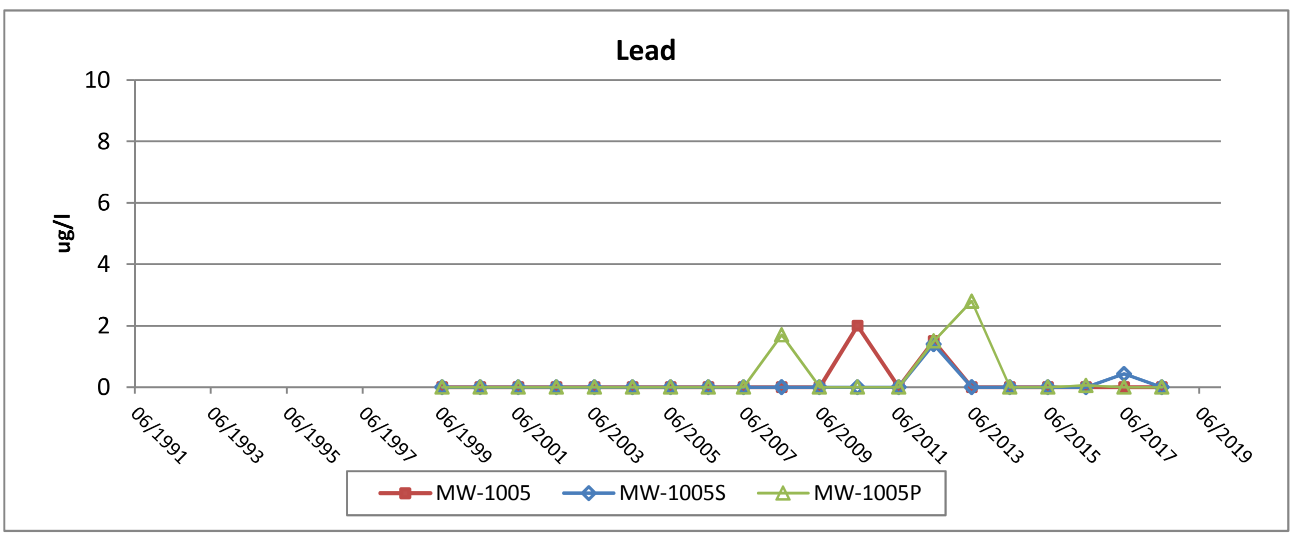


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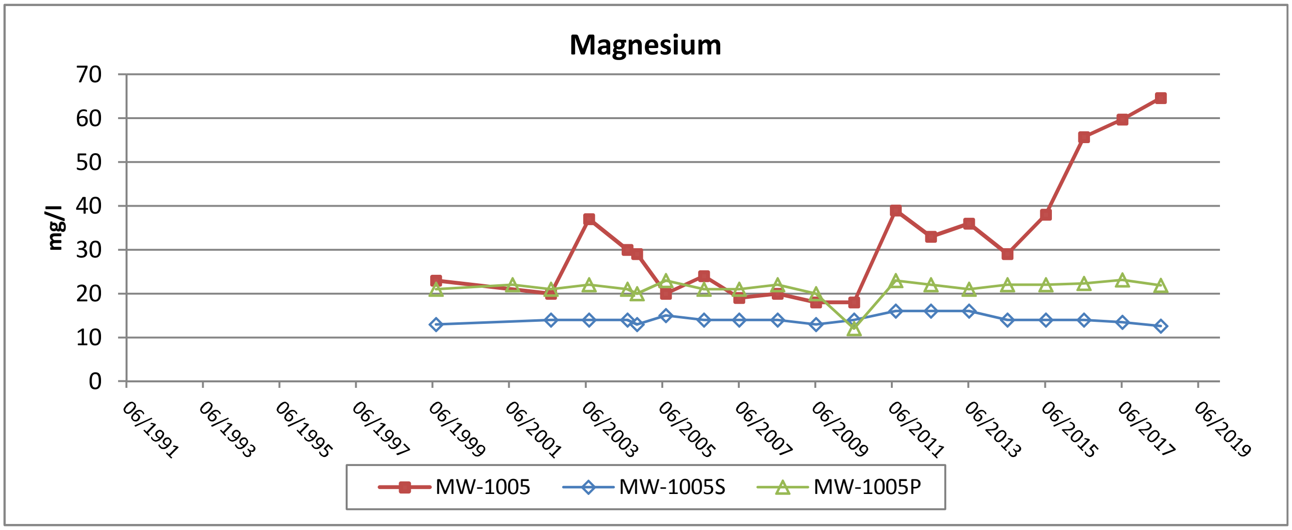
FIGURE 4-4b

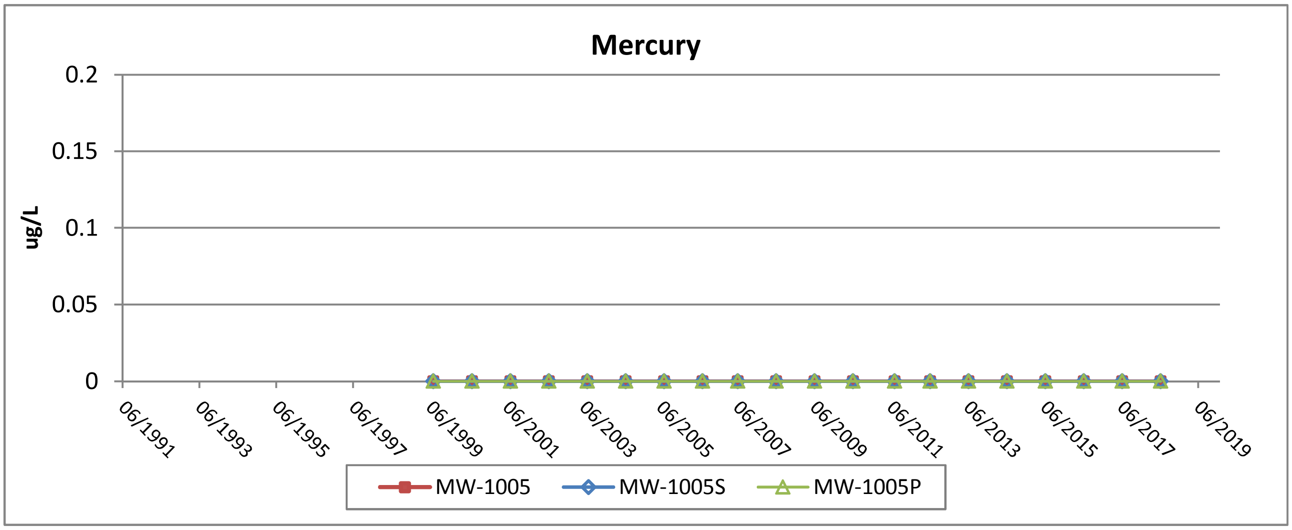
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





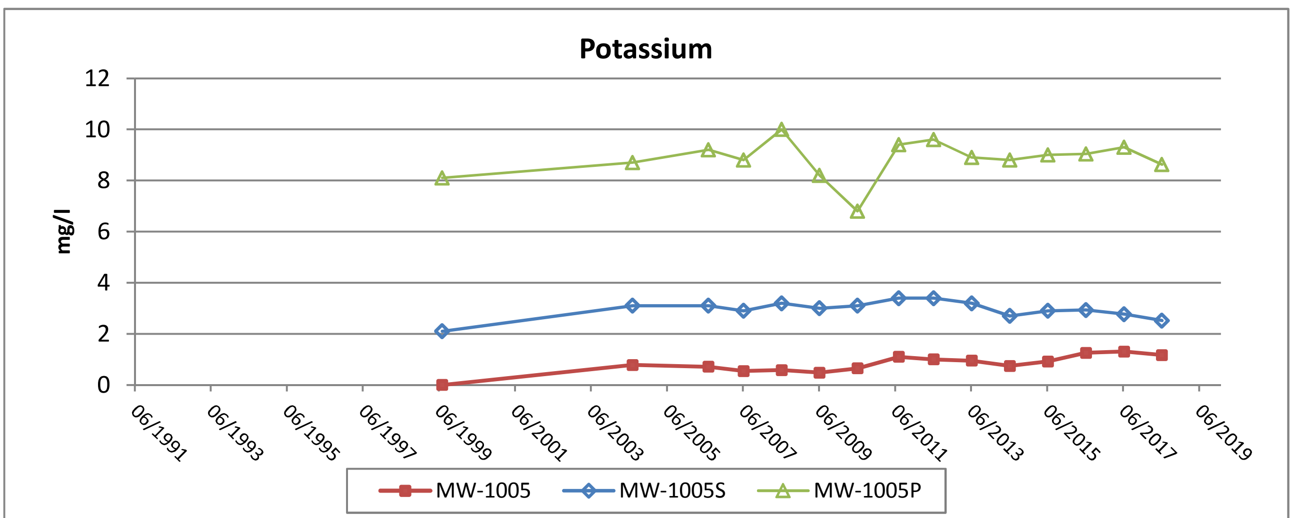


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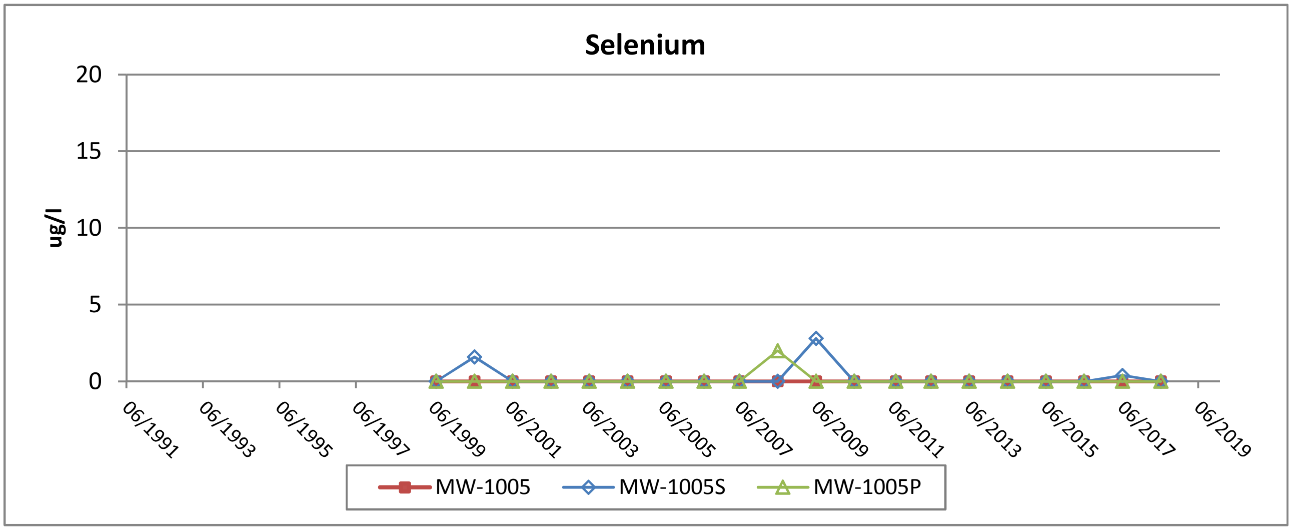
FIGURE 4-4c

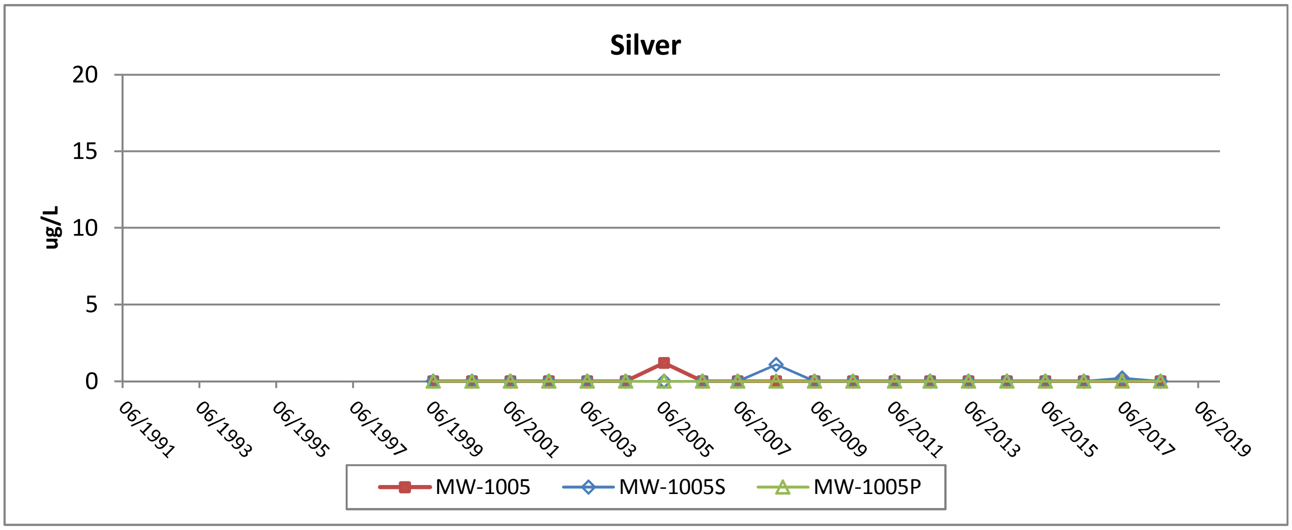
Groundwater Trend Graphs - Quarterly Results

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





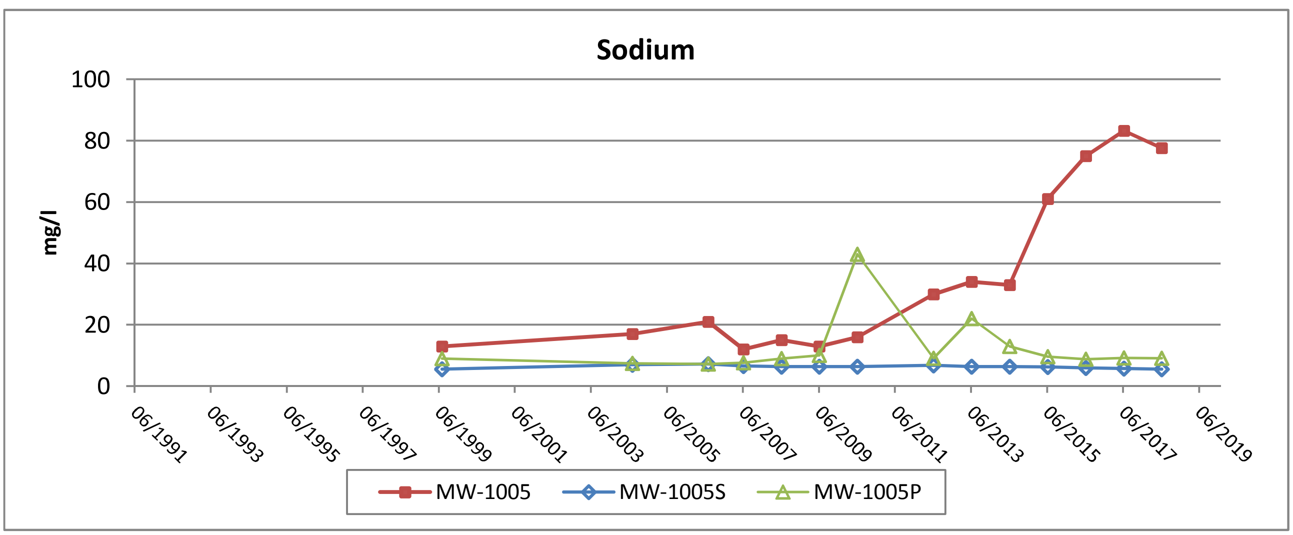


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FIGURE 4-4d

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1005/MW-1005S/MW-1005P

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm

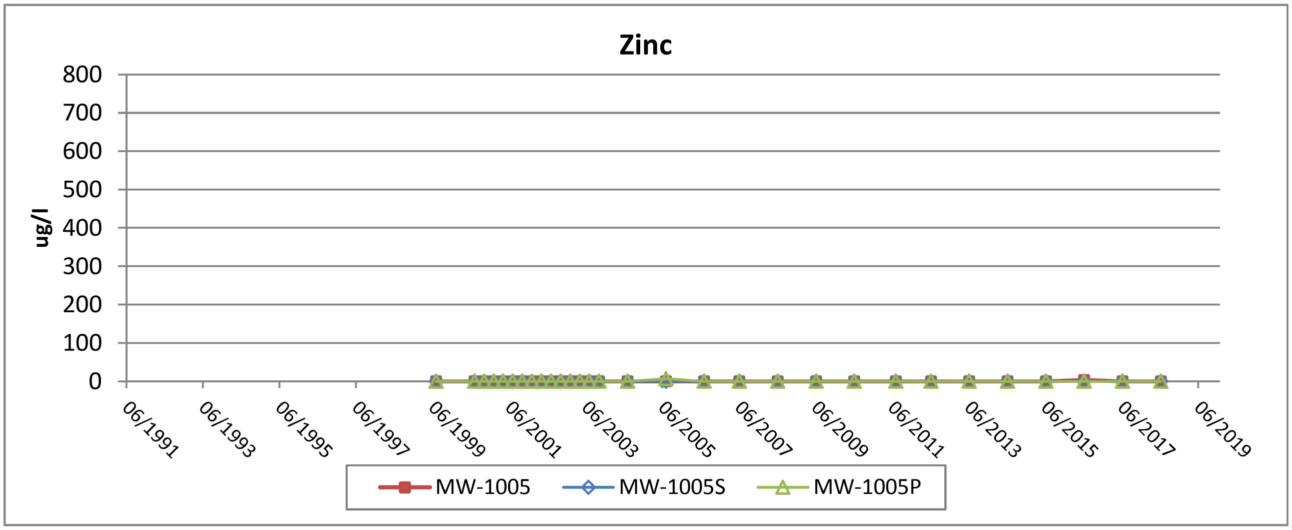

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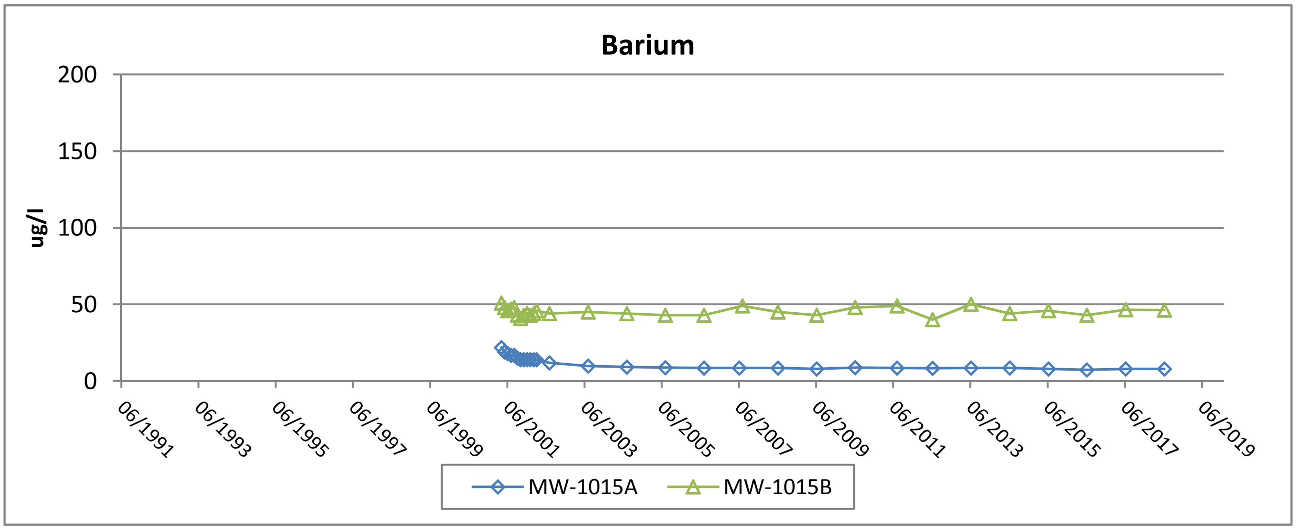
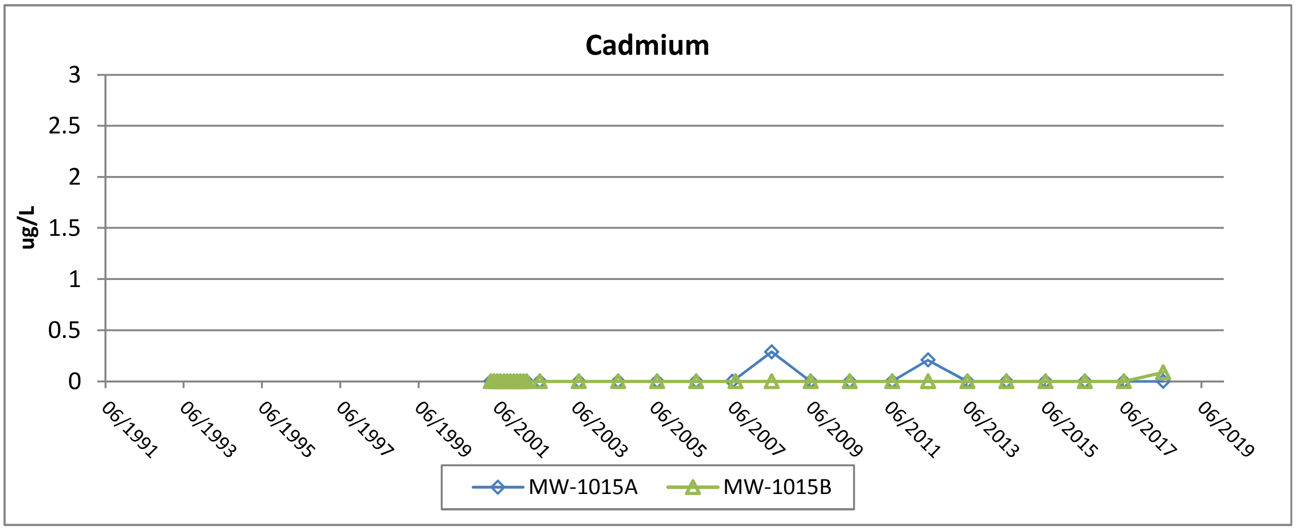
FIGURE 4-4e GROUNDWATER TREND GRAPHS - ANNUAL MW-1005/MW-1005S/MW-1005P		
Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





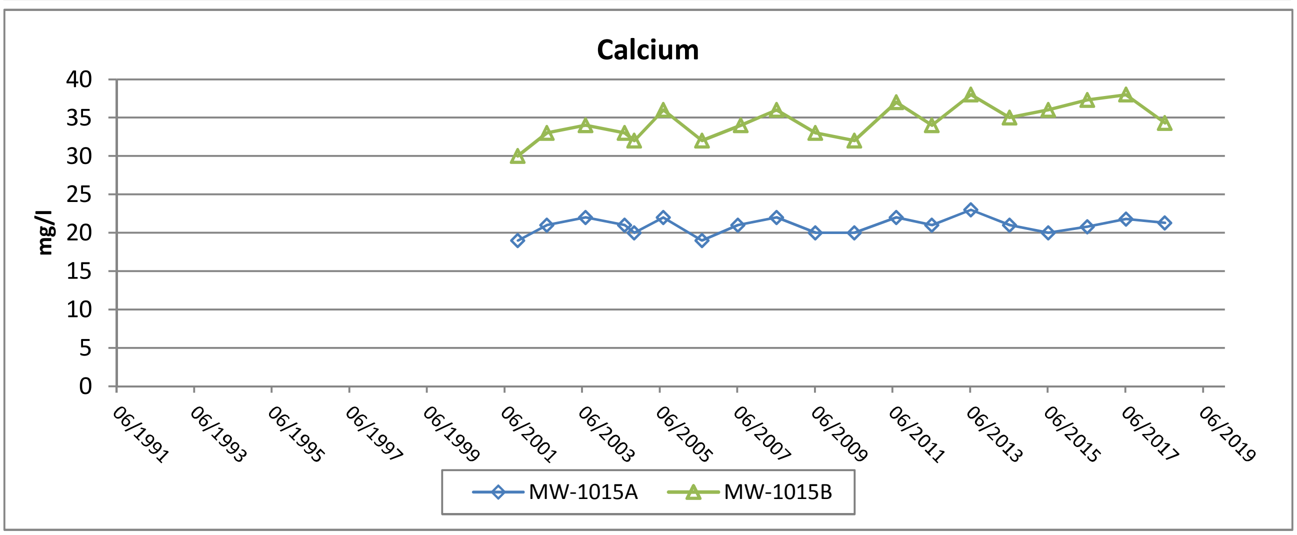


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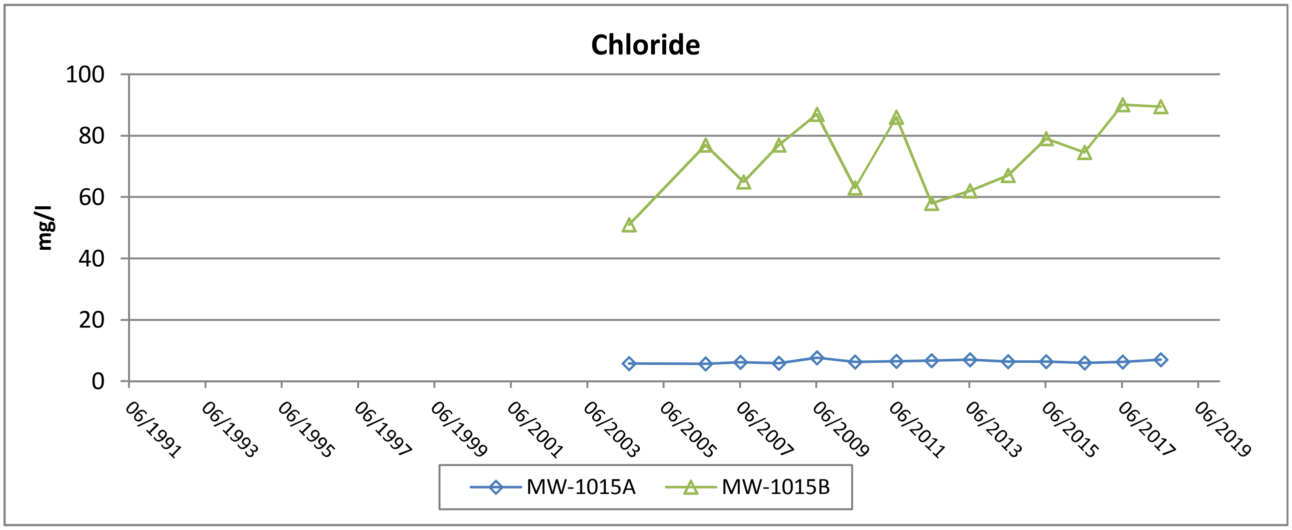
FIGURE 4-5a

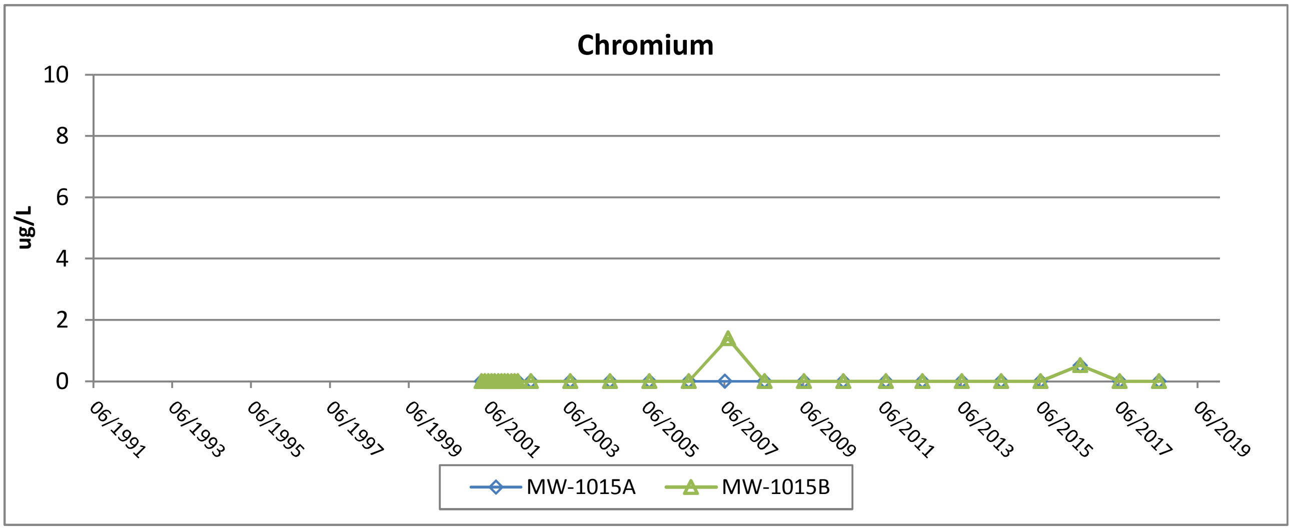
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





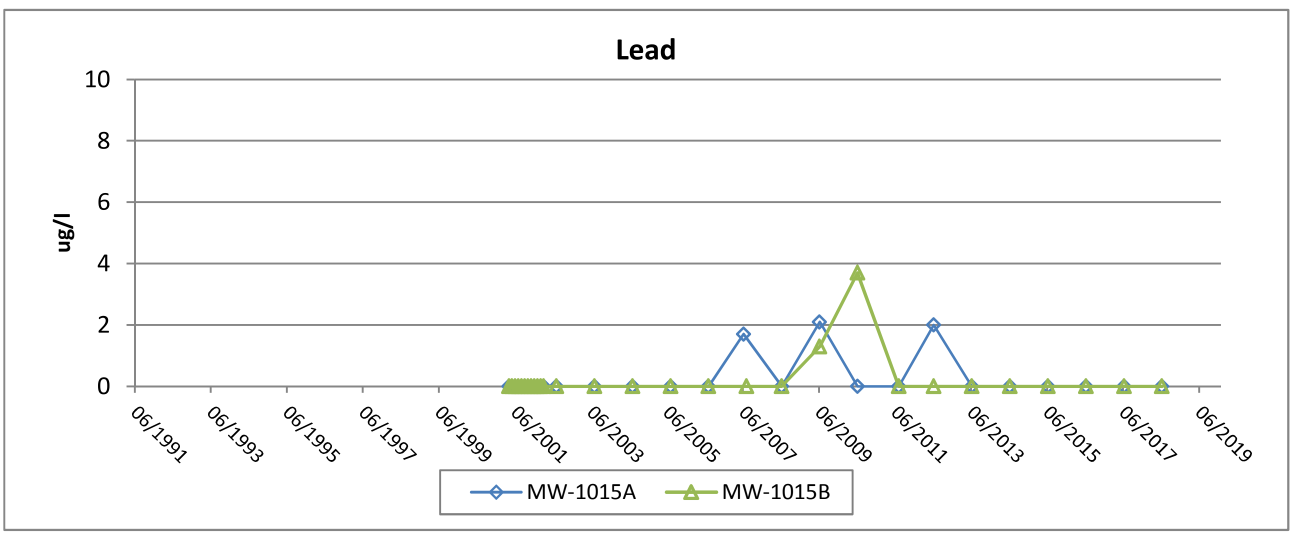


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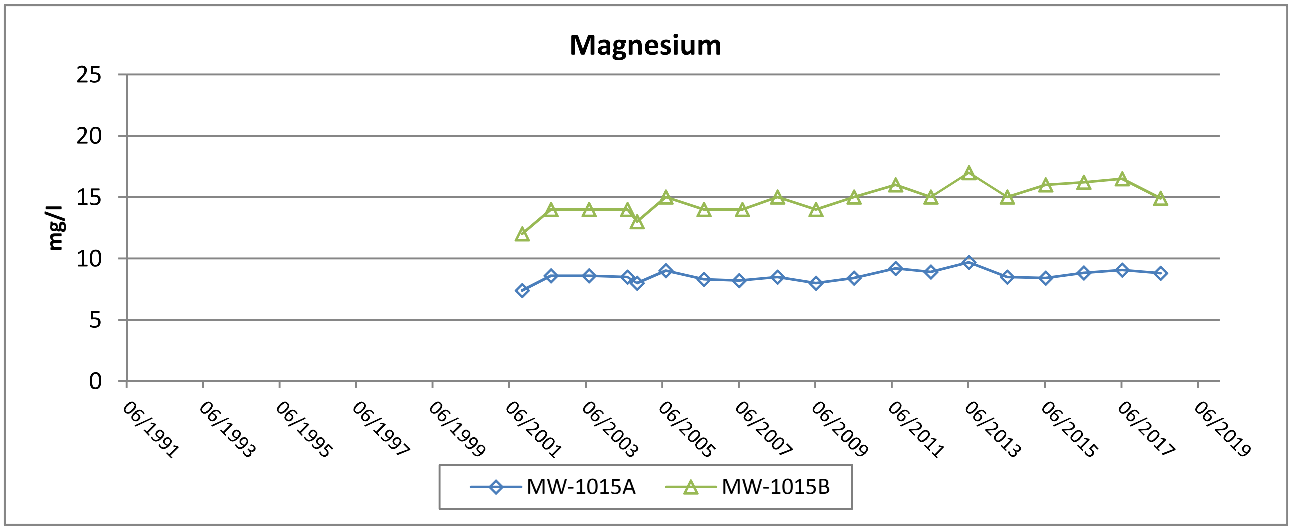
FIGURE 4-5b

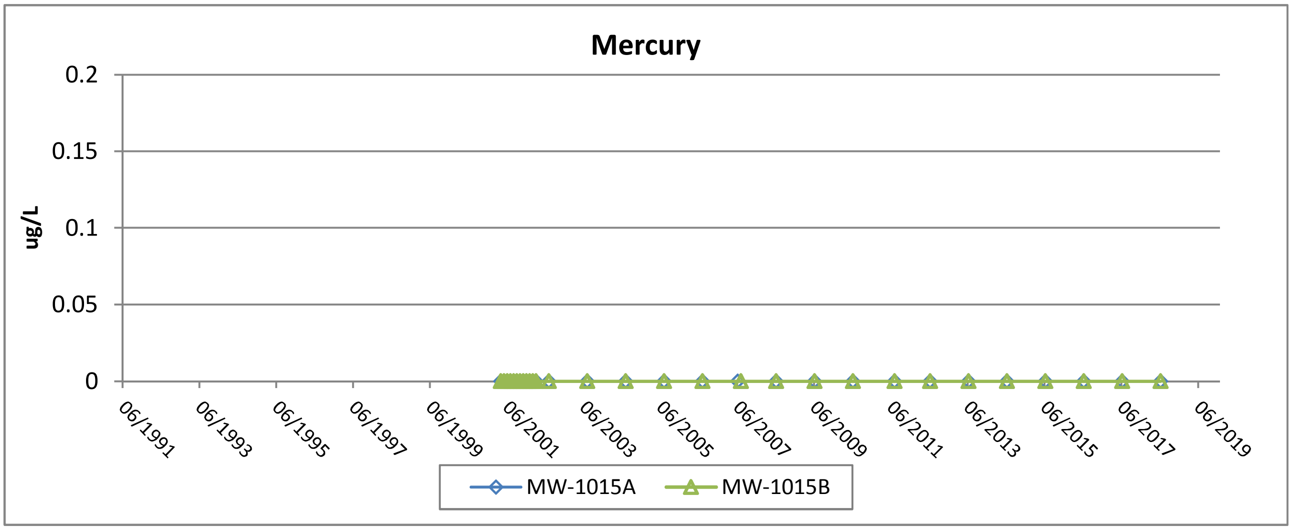
GROUNDWATER TREND GRAPHS - ANNUAL

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm





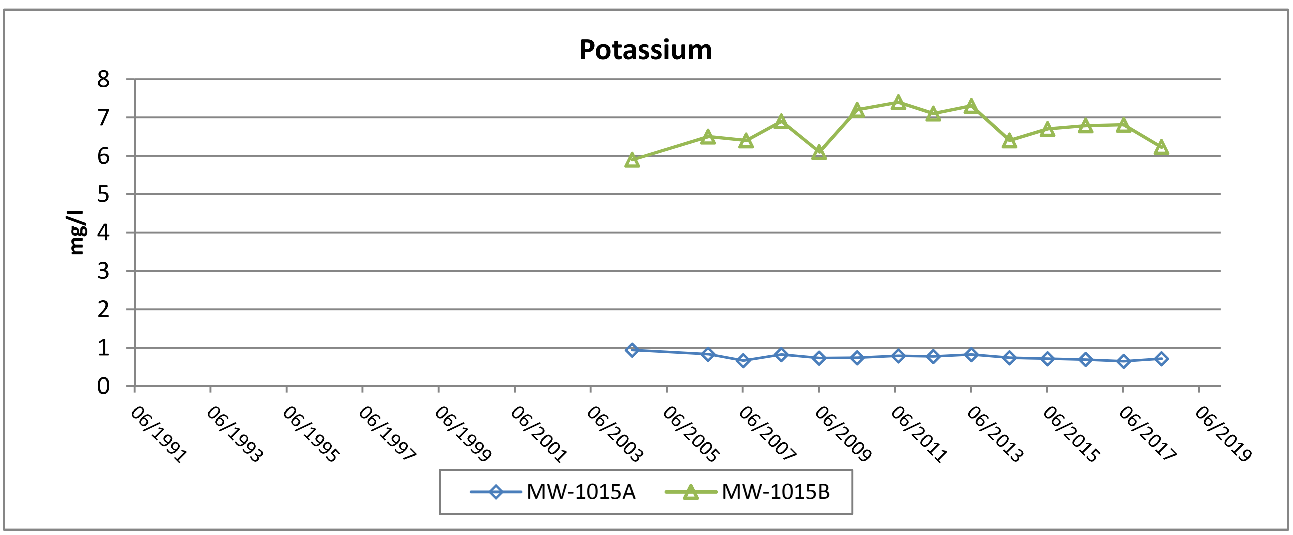


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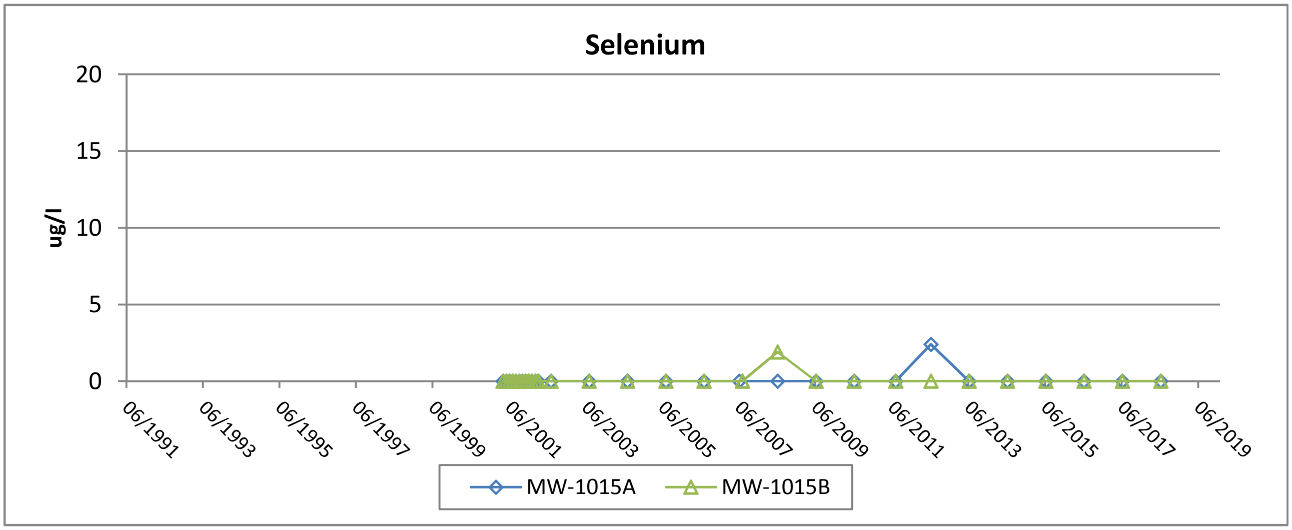
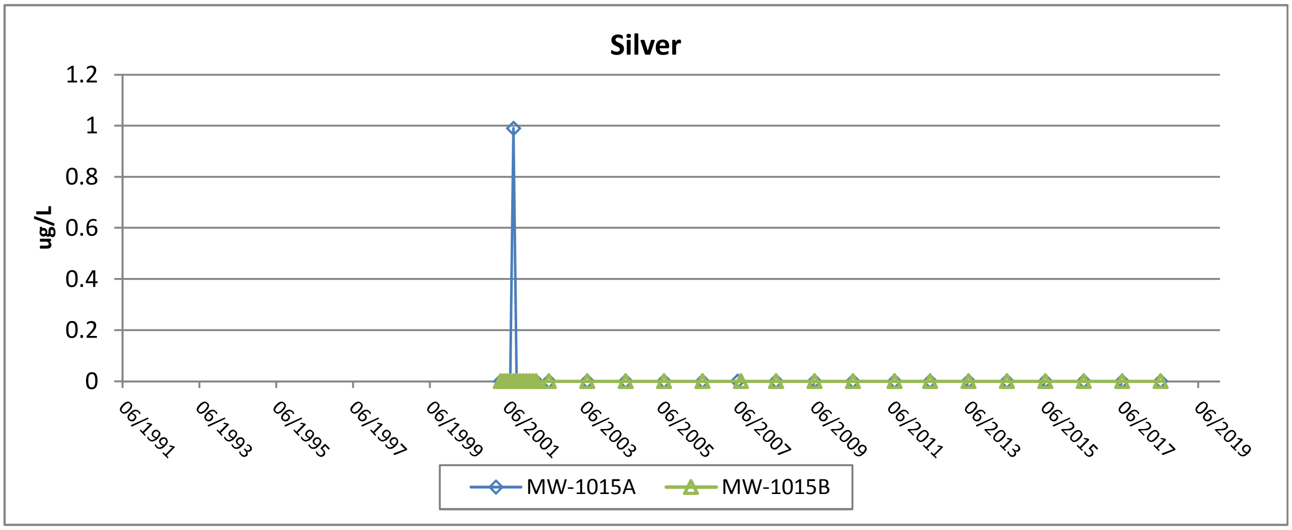
FIGURE 4-5c

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00





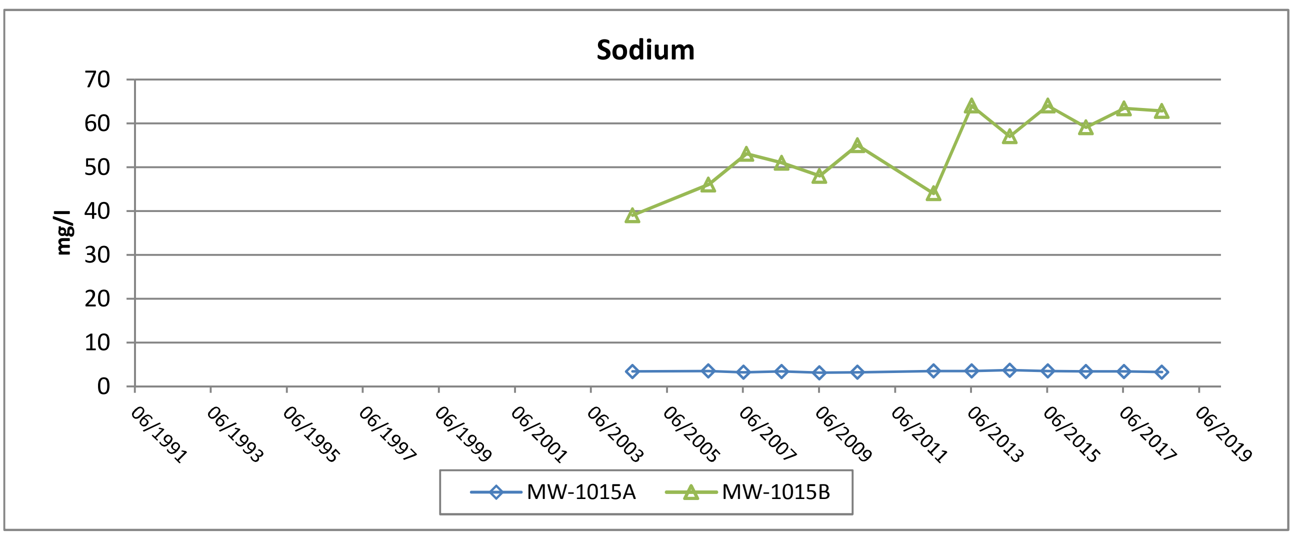


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FIGURE 4-5d

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

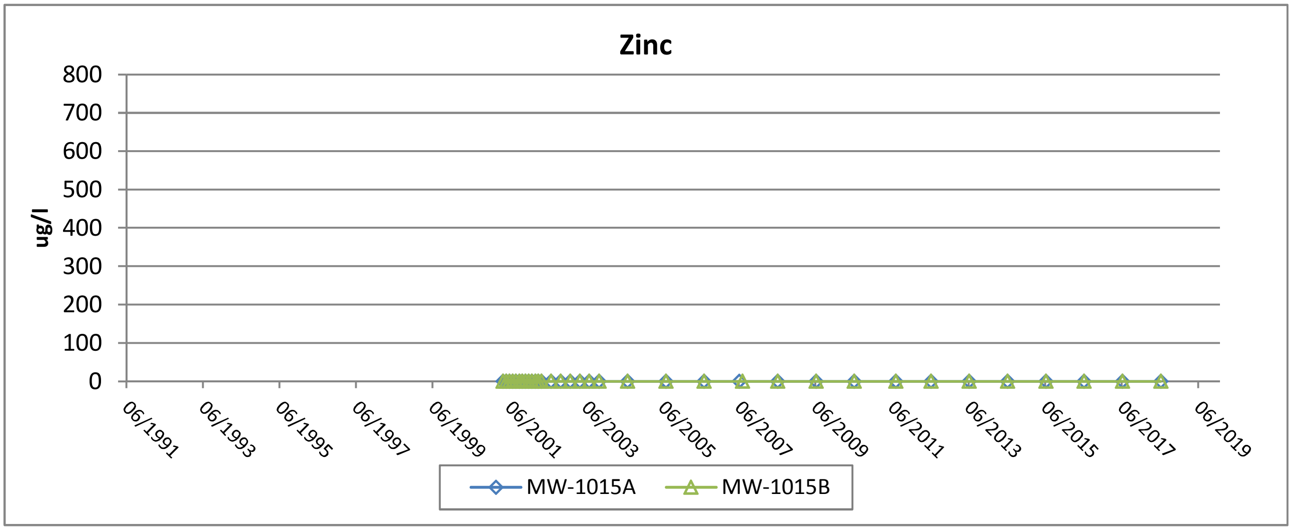

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FIGURE 4-5e

GROUNDWATER TREND GRAPHS - ANNUAL

MW-1015A/MW-1015B

Scale: NA	Date: August 2018	
Prepared By: SGL	Checked By: SVF	Scope: 17F777-00

pw:\\Flambeau Mining\0017F777.00\12000 Design Data and Calculations\Monitoring Reduction\GWGraphs_Ann thru 2018Q3.xlsm

Attachment 3

Reclaimed Flambeau Mine Infrared Vegetation Photography, Subsidence, Wetland Evaluation Reduction, and Annual Reporting Requirements

Technical Memorandum

Green Bay Location

2121 Innovation Court, Suite 300
P.O. Box 5126 • De Pere, WI 54115-5126
(920) 497-2500 • Fax: (920) 497-8516
www.foth.com

November 9, 2018

TO: Dave Cline, Flambeau Mining Company
Leland Roberts, Rio Tinto

CC: File: 17F777-5000

FR: Steve Donohue, P.H., Foth Infrastructure & Environment, LLC
Sharon Kozicki, P.G., P.M.P., Foth Infrastructure & Environment, LLC

RE: Reclaimed Flambeau Mine Infrared Vegetation Photography, Subsidence, Wetland Evaluation Reduction, and Annual Reporting Requirements

1 Introduction

From 1994 through 1998, Flambeau Mining Company (Flambeau) mined an ore body adjacent to the Flambeau River using an open pit method. Upon cessation of mining, the site commenced reclamation, which included backfilling the pit and demolition of most of the site infrastructure.

Long term monitoring, maintenance, and reporting has been ongoing in accordance with the *Mine Permit* (IH-89-14) and *Updated Monitoring Plan* (FVD, 1991). Flambeau petitioned for a Certificate of Completion (COC) in January 2007. The COC signifies that the mine has fulfilled its duties under the reclamation plan. A public hearing was held, and a COC was received in August 2007 for the entire site except for a 32-acre parcel known as the Industrial Outlot.

Monitoring includes:

- Vegetation monitoring by aerial and color infrared photography
- Wetland staff gauge monitoring
- Subsidence monitoring

Results from monitoring activities are reported in the Annual Report for the facility, submitted in January following the reporting year.

2 Purpose

The purpose of this memorandum is to:

- Provide a summary of the historic trends and current status of the site vegetation, subsidence, and wetland WT1 based on monitoring results.
- Describe the criteria that applies to vegetation, subsidence, and wetland monitoring.
- Provide documentation to support a formal request to reduce the scope of these elements of monitoring.
- Present a streamlined format for the Annual Report.

3 Regulatory Framework and Monitoring Results

The following subsections briefly describe the regulatory framework and criteria by which each monitoring element listed in Section 2 is evaluated. The results of the monitoring activities are then summarized.

3.1 Aerial and Color Infrared Vegetation Photography

The revegetation phase of reclamation at Flambeau began in spring of 1998 Seeding was completed in 2001. Consistent with the intended re-purposing of the site, the majority of the site was seeded and reclaimed to wildlife habitat and non-consumptive vegetation for passive recreational use. Vegetation evaluations using infrared photography techniques were completed annually during the subsequent four year monitoring period, between 2002 and 2006 in accordance with the requirements of Section 3.1.6 of the *Updated Monitoring Plan*. The purpose of the monitoring is to evaluate the vegetation coverage and type and identify any areas of erosion. In a letter dated July 9, 2003, the Department authorized Flambeau to reduce the breadth of the aerial and color infrared photography as requested.

After receipt of the COC, vegetation evaluations took place every five years in 2012 and 2017. Section 3.1.6 of the *Updated Monitoring Plan* (Foth, 1991) states that aerial and color infrared photography will be completed in the late summer for four consecutive years following completion of closure and every five years thereafter throughout the 40-year long term care and maintenance period to monitor the success of revegetation. The next infrared photography analysis under the current plan is due in 2022 and every five years thereafter through 2047.

The aerial imagery from 2017 is included as Figure 1. The figure shows the normalized difference vegetation index (NDVI). NDVI is a method that uses the red and IR data from the aerial imagery as compiled using the following mathematical equation, NDVI= (NIR-Red)/(NRI+Red). The result of this calculation is a vegetation index number that is valued between zero and two hundred and fifty five (0-255). A value of 255 would be areas of the most "greenness" or most plant vigor/density and 0 would be areas that have the least or no greenness. NDVI is often used to evaluate vegetation health, greenness, and levels of chlorophyll and can be used to identify areas of vegetation stress in both natural and agricultural landscapes (Foth, 2018a).

Applicable vegetative requirements listed in the Mine Permit Application, Section 5.11.4.8 included:

- 70% percent coverage averaged over the site.
- Diversity of no less than 80% of the initially planted species.
- Survivorship of no less than 80% of the initially planted species.

The report entitled, *Analysis of Revegetation Success for Reclamation of the Flambeau Mine, Ladysmith, Wisconsin, in 2003* (AES, 2003), has been used as a baseline for vegetation evaluation. It documents an average of 93% plant cover across the site with the Industrial Outlot portion averaging 91% plant cover.

The 2017 Vegetation Monitoring using Aerial Imagery Interpretation memo, prepared by AES, for Foth Infrastructure & Environment, LLC (Foth), made the following conclusions:

- The three main plant communities: wetland, woodland, and upland grasslands remain in the same areas as originally planted.

- Greater than 90% of the reclaimed Flambeau mine site has excellent vegetation cover.

- No areas of erosion or areas of dead or devoid vegetation were observed over the site.

The results described above show that the vegetation has grown and matured into a stable, sustainable landscape that meets the intended passive recreational use and minimizing erosion potential, fulfilling Flambeau reclamation responsibilities. The state of the vegetation is anticipated to continue in similar manner, subject to any climate changes affecting the region.

3.2 Wetland Staff Gauge Monitoring

The *Updated Monitoring Plan*, Sections 2.4.6 and 3.1.4.3, required water levels at staff gauges in Wetlands 1, 5c, 7, 10a, and 6c be monitored starting two months after project permits were granted to document preconstruction water levels. After the pit was backfilled, the wetland water levels were compared to preconstruction levels considering the recent precipitation history for the region. Wetland surface water elevations were monitored at least three times per year in five wetlands surrounding the mine. A request to discontinue wetland staff gauge monitoring was submitted in May 2001. With the exception of Wetland 1 (staff gauge WT-5), the Department accepted the request to discontinue monitoring in the wetland areas. Wetland 1 is located on the west side of the reclaimed mine site just south of Kennecott Drive. WT-5 continued to be monitored three times per year (spring, summer, and fall).

Water level observations have shown that Wetland 1 has been consistently wet with active groundwater seeps. On occasion, due to seasonal variation in the past, water levels have dropped so that there is no standing water, but the soils remain moist. Data and observations are documented in Annual Reports year 1999 through year 2017. Mitigation water has not been needed since 2001.

The *Updated Monitoring Plan* states that the wetland monitoring should continue until water levels in monitored groundwater monitoring wells stabilize. The *Flambeau Mine Groundwater Monitoring Reduction Evaluation – Intervention Boundary and Other Wells used for Groundwater Elevation Monitoring* (Foth, 2018b) concludes that groundwater levels are stable. Therefore, the requirement to discontinue monitoring at Wetland 1 has been met and can be discontinued at WT-5.

3.3 Subsidence Monitoring

Surface subsidence monitoring of the reclaimed mine pit has been completed in accordance with Section 3.1.7 of the *Updated Monitoring Plan* which states surface subsidence monitoring will consist of topographically mapping of the 32-acre reclaimed mine pit by aerial survey. The initial survey was performed in September 1998 following the completion of reclamation activities in the area of the pit. Subsequent surveys then occurred in the 3rd, 10th, and 20th year with the final survey to take place in the 40th year after reclamation activities in the area of the pit are completed. The Mine Permit Application (Foth and Van Dyke, 1989) estimated that settling would be less than 5%, approximately 12 feet. Surface subsidence monitoring was completed in 2001, 2008, and 2018, with each monitoring event being compared to the 1998 aerial mapping topography. The final monitoring event is currently scheduled to take place in year 40 (year 2038). The 2008 subsidence monitoring showed that no subsidence was evident (Foth, 2009). The difference between 2008 and 1998 elevations was an average increase in elevation of 0.6 feet, which is within the accuracy range of the measurement technique. The maximum observed subsidence between 2008 and 1998 elevations was 4.1 feet in isolated areas, which is below the anticipated of 5% (approximately 12 feet).

The 2018 survey and aerial mapping was compared to the 2008 and 1998 surveys as presented on Figures 2 and 3. The difference between 2018 and 1998 surface elevations was an average increase in elevation of less than 1 foot, which is within the accuracy range of the measurement technique. And the difference between 2018 and 2008 surface elevations was an average increase in elevation of less than 1 foot, which is within the accuracy range of the measurement technique. The maximum observed subsidence between 2018 and 1998 elevations was 3.5 feet in isolated areas, which is below the threshold of 5% (approximately 12 feet). This is similar to what was observed in 2008 and is significantly less than the 5% settlement (or 12 feet) due to compaction control measures taken during backfilling. Based on the results of the 2008 and 2018 surveys, sufficient data has been collected to document subsidence in the backfilled pit. These consistent observations suggest that any additional subsidence will be less than what was the 5% threshold, and therefore no additional surveys are required.

4 Streamlining the Annual Report

An Annual Report for Flambeau has been submitted to the Department by January 31, since 1991. The report summarizes operating activities, reclamation activities, site monitoring. Other activities are reported in appendices as required by the *Mine Permit; Part 1*, *condition 8*, *Part 2*, *conditions 4,6,7,* Part 4, condition 9, and the *Water Withdrawal Approval, condition 1*.

The Annual Report currently consists of 4 sections and 2 standard appendices. The text contains a comprehensive background description, various sections that are no longer relevant to the current conditions of the site. The standard appendices include the backfilled pit water quality assessment and the groundwater quality and elevation/surface water quality trends. Additional appendices are added as needed and have included memoranda documenting any additional monitoring or other site activities.

With current site conditions showing completed reclamation and monitoring and maintenance activities being greatly reduced, a simplified design of the annual summary is appropriate starting with the 2018 summary. The purpose of the annual summary is to summarize the previous year's activities and report the results of the previous year's data and evaluations. Many of the items are no longer applicable and can be removed while still meeting the conditions in the *Permit* and *Water Withdrawal Approval*. Therefore, it is recommended that the report be changed to a memorandum style.

The purpose of the annual memorandum will continue to summarize the environmental activities at the site, present the current potentiometric surface for the shallow groundwater and wells screened at mid-depths, and present the groundwater and surface water trend graphs with a trend evaluation.

Also, if there are any activities related to any other permit conditions including; exploration, incidents, or permit modifications, those will be reported.

The outline of the annual memorandum is proposed as follows:

1. Purpose and Need
2. Site Monitoring
    2.1. Groundwater Quality Sampling and Analysis
    2.2. Trend Analysis
    2.3. Other Activities
3. References
4. Submittals

Figures
4-1 – Potentiometric Surface, Shallow Groundwater Levels
4-2 – Potentiometric Surface, Wells Screened at Mid-Depths
4-3 – Mine Pit Cross Section A-A' with in-Pit Groundwater Monitoring Wells

Appendices
A – Groundwater Quality & Elevation/Surface Water Quality Trends

5 Conclusions and Recommendations

Infrared vegetation photography has shown that the vegetation at Flambeau is very well established and stable with good coverage. The infrared photography analysis would be due again in 2022 and every five years thereafter through 2047, however, further photography would likely not reveal any changes and should be discontinued. The annual inspection of vegetation will continue to document that vegetation is healthy and meets the intentions of the reclamation plan.

Analysis of groundwater data has shown that groundwater levels are stable, thus wetland surface water conditions have reached equilibrium state with groundwater. Since the standards have been met, as laid out in the *Updated Monitoring Plan,* monitoring should be terminated at WT-5.

Subsidence monitoring has not identified any significant subsidence since monitoring began in 2001. The latest results from 2018 indicate stable conditions compared with 10 years ago. Additional subsidence monitoring should be discontinued.

Present conditions support elimination of the infrared photography, monitoring at WT-5, and the year 40 subsidence evaluation. Elimination of these long term monitoring elements based on the results presented herein is recommended.

6 References

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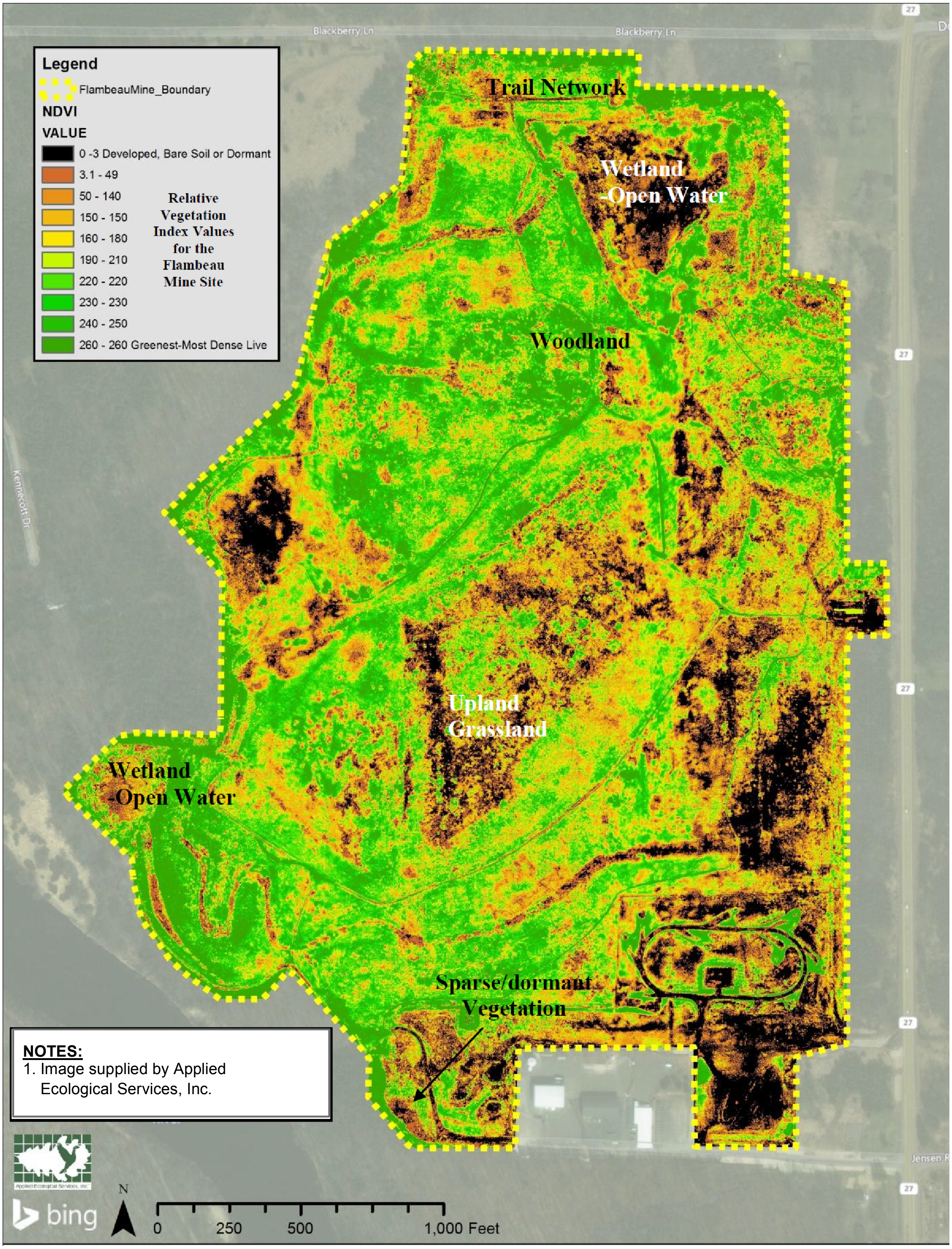
Wisconsin Department of Justice, 1991. Decision Findings of Fact Conclusions of Law and Permits; Findings of Fact, Conclusions of Law and Mine Permit, Docket No. IH-89-14, Pages 76-124. January 14, 1991.

Figures



Foth Infrastructure & Environment, LLC				
REVISED	DATE	BY	DESCRIPTION	
PREPARED BY:	SVF			DATE: NOV. '18
REVIEWED BY:	AKM			DATE: NOV. '18
APPROVED BY:	SVD1			DATE: NOV. '18

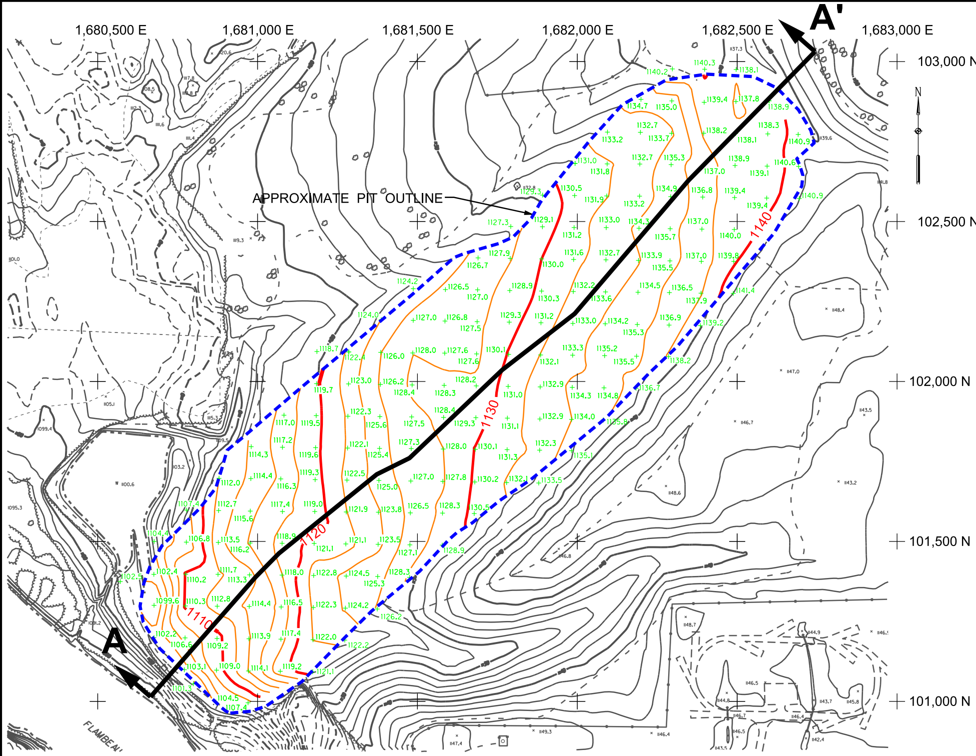
FLAMBEAU MINING COMPANY

FIGURE 1

2017 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Scale: AS SHOWN	Date: NOVEMBER 2018
Drafted by: DAT	Project: 17F777

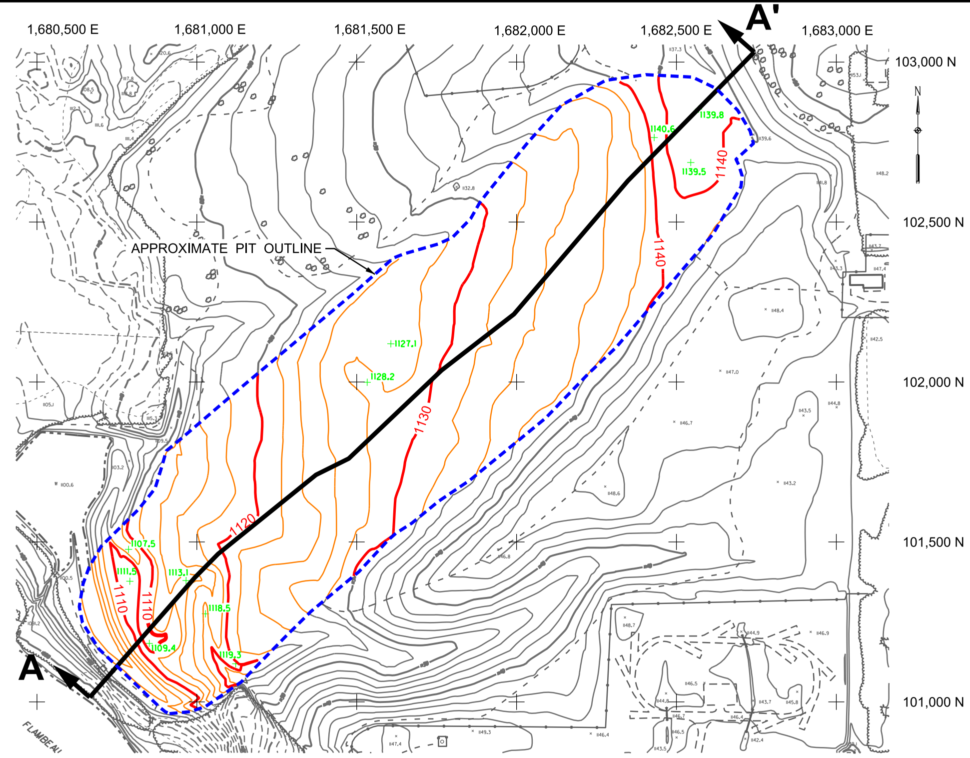
Path: Q:\Flambeau Mining Company\17F777\GIS\mxd\GW Reduction Tech Memo 3\Figure 1.mxd Date: 11/5/2018



RECLAIMED MINE PIT RECORD
EXISTING CONDITIONS
SEPTEMBER 1998 GROUND SURVEY

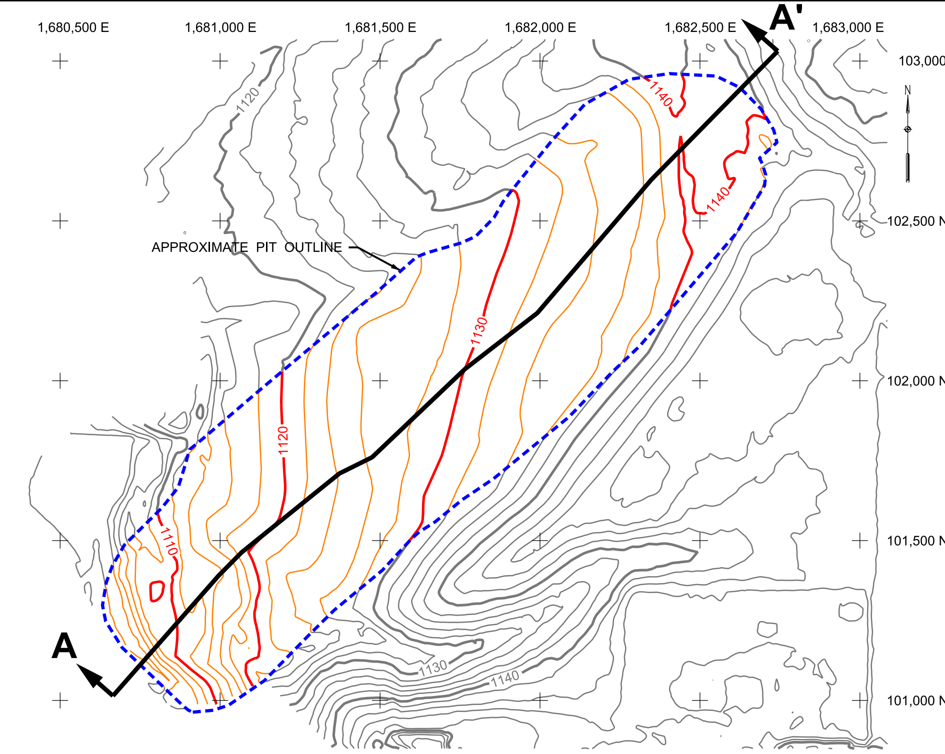
0 200' 400'

NOTE:
CONTOURS INSIDE THE PIT OUTLINE FROM THE RECLAIMED MINE PIT SURFACE RECORD SURVEY, SEPTEMBER 16, 1998.
CONTOURS OUTSIDE THE PIT OUTLINE FROM HORIZONS, INC. DATE OF PHOTOGRAPHY, SEPTEMBER, 1998.



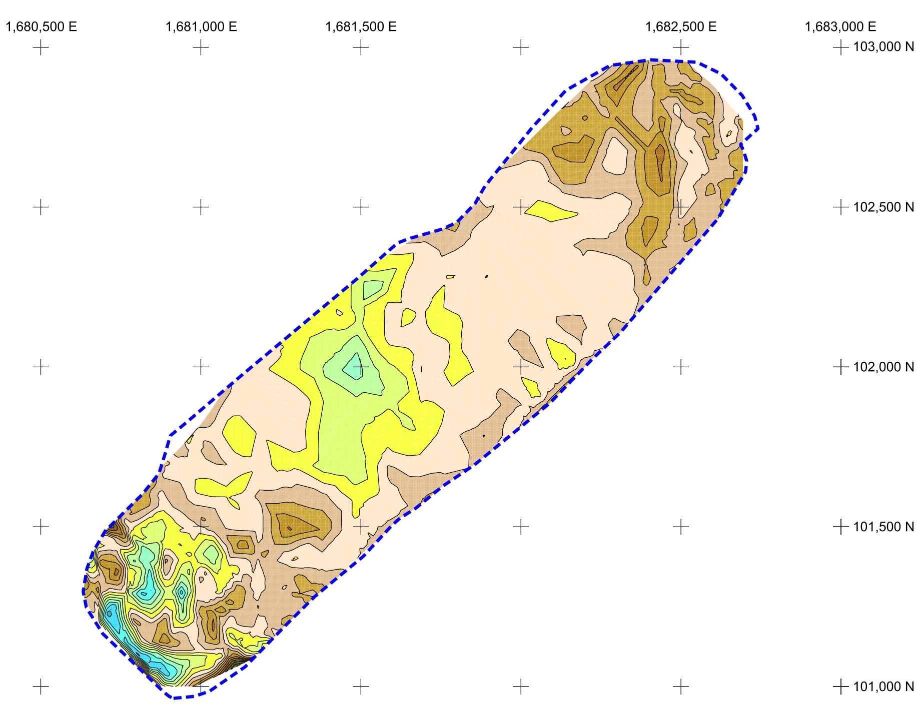
EXISTING CONDITIONS MAY 17, 2008
AERIAL FLIGHT BY AERO-METRIC, INC.

0 200' 400'



EXISTING CONDITIONS MAY 22, 2018
DRONE FLIGHT BY FOTH

0 200' 400'



ISOPACH MAP
EXISTING CONDITIONS SEPTEMBER, 1998
VS EXISTING CONDITIONS MAY 22, 2018

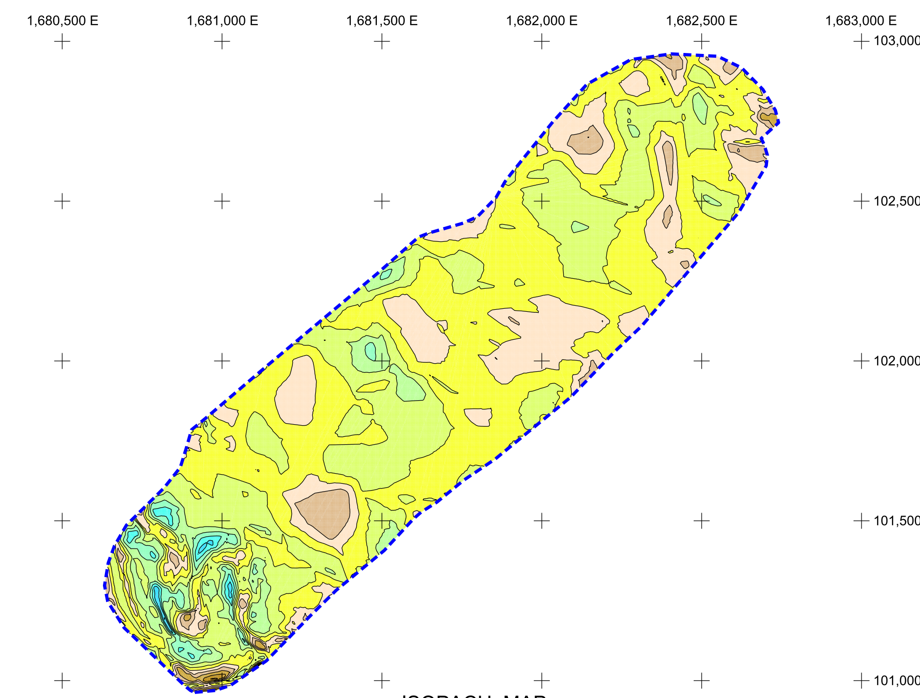
0 200' 400'

DIFFERENCE CONTOURS

DIFFERENCE (ISOPACH) CONTOURS SHOWN REPRESENT 1998 OR 2008 EXISTING CONDITIONS VS 2018 EXISTING CONDITIONS

- 2.5' - 3.0' 2018 HIGHER THAN 1998 OR 2008
- 2.0' - 2.5' 2018 HIGHER THAN 1998 OR 2008
- 1.5' - 2.0' 2018 HIGHER THAN 1998 OR 2008
- 1.0' - 1.5' 2018 HIGHER THAN 1998 OR 2008
- 0.5' - 1.0' 2018 HIGHER THAN 1998 OR 2008
- 0.0' - 0.5' 2018 HIGHER THAN 1998 OR 2008

- 0.0' - 0.5' 2018 LOWER THAN 1998 OR 2008
- 0.5' - 1.0' 2018 LOWER THAN 1998 OR 2008
- 1.0' - 1.5' 2018 LOWER THAN 1998 OR 2008
- 1.5' - 2.0' 2018 LOWER THAN 1998 OR 2008
- 2.0' - 2.5' 2018 LOWER THAN 1998 OR 2008
- 2.5' - 3.0' 2018 LOWER THAN 1998 OR 2008



ISOPACH MAP
EXISTING CONDITIONS MAY 17, 2008
VS EXISTING CONDITIONS MAY 22, 2018

0 200' 400'

NOTE:
1. Horizontal Datum Based on NAD 1983.
Horizontal Coordinates Based on Wisconsin State Plane North (Feet).

Flambeau Mining Co.

Foth Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

PREPARED BY:	JRB2	DATE:	NOV. '18
REVIEWED BY:	SVF	DATE:	NOV. '18
APPROVED BY:	SVD1	DATE:	NOV. '18

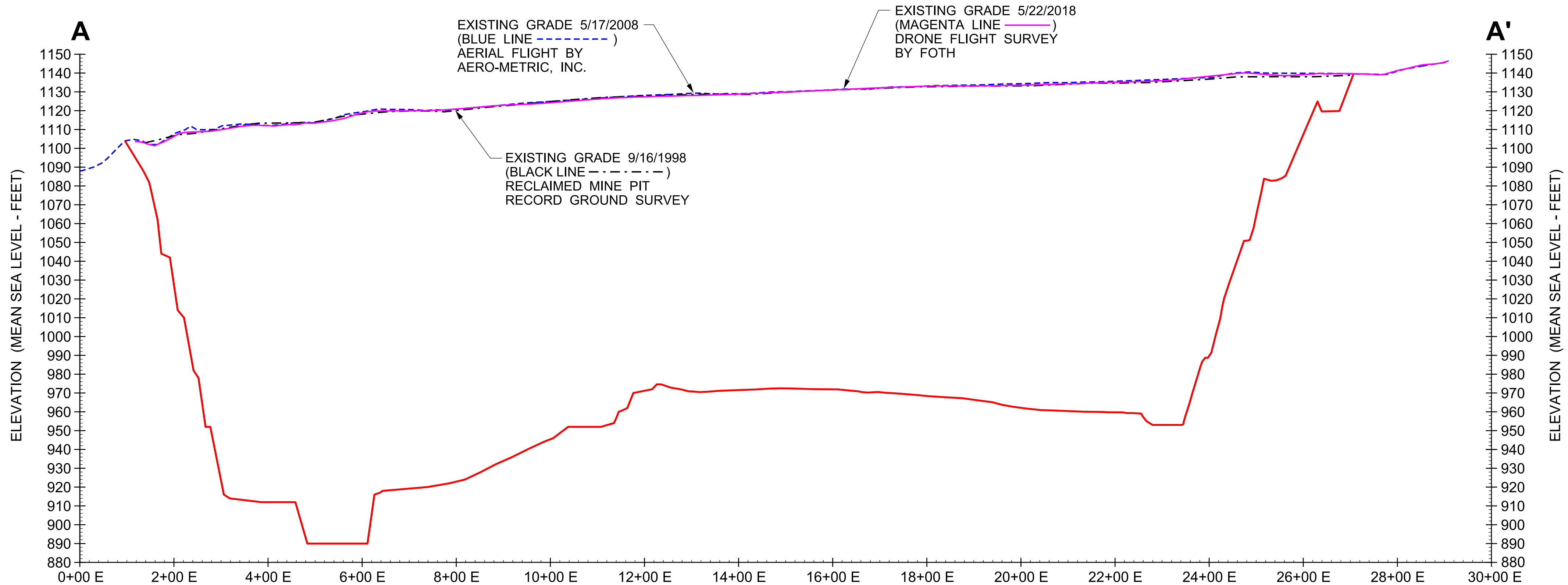
FLAMBEAU MINING COMPANY

FIGURE 2

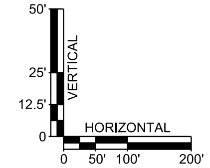
EXISTING CONDITIONS AND ISOPACH MAPS
1998 - 2008 - 2018
SUBSURFACE SUBSIDENCE ANALYSIS

Scale:	AS SHOWN	Date:	NOV. 2018
Drafted By:	JRB2	Project No.	17F777.18

pw:\\PW-APS1.foth.com:PW_IE\Documents\Clients\Flambeau Mining\0017F777.00\CAD\Figures\Subsurface Subsidence GWMR\GWMR Fig 2 - Existing Conditions and Isopachs.dgn
11/5/2018 4:15:14 PM dat



SECTION A - A'



SCALE

NOTE:

1. Horizontal Datum Based on NAD 1983.
   Horizontal Coordinates Based on Wisconsin State Plane North (Feet).

Flambeau Mining Co.

Foth Infrastructure & Environment, LLC			
REVISED	DATE	BY	DESCRIPTION

PREPARED BY:	JRB2	DATE:	NOV. '18
REVIEWED BY:	SVF	DATE:	NOV. '18
APPROVED BY:	SVD1	DATE:	NOV. '18

FLAMBEAU MINING COMPANY

FIGURE 3
CROSS SECTION A - A'
1998 - 2008 - 2018
SUBSURFACE SUBSIDENCE ANALYSIS

Scale:	AS SHOWN	Date:	NOVEMBER 2018
Drafted By:	JRB2	Project No.	17F777.18

Attachment 4

Redlined Updated Monitoring Plan

DRAFT Plan

Updated Monitoring Plan

Reclaimed Flambeau Mine

Project I.D.: 17F777.18

Flambeau Mining Company
Ladysmith, Wisconsin

July 1991 (updated)
November 2018

Green Bay Location

2121 Innovation Court, Suite 300
P.O. Box 5126 • De Pere, WI 54115-5126
(920) 497-2500 • Fax: (920) 497-8516
www.foth.com

November XX, 2018

Type recipient's name
Type company name
Type recipient's address

Dear Type Salutation:

RE: Subject of letter

Type your text here.

Sincerely,

Foth Infrastructure & Environment, LLC

Type your name here
Type your title here

cc:

Updated Monitoring Plan

Distribution

No. of Copies	Sent To

Updated Monitoring Plan

Project ID: 17F777.18

Prepared for

Flambeau Mining Company

Ladysmith, Wisconsin

Prepared by

Foth Infrastructure & Environment, LLC

July 1991 (updated)
November 2018

2121 Innovation Court, Ste. 300 • PO Box 5126 • De Pere, WI 54115-5126 • (920) 497-2500 • Fax: (920) 497-8516 • www.foth.com

Updated Monitoring Plan

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Updated Monitoring Plan

Executive Summary

List of Abbreviations, Acronyms, and Symbols

CAD	computer aided drafting
Foth	Foth Infrastructure & Environment, LLC

1 Long-Term Care and Maintenance Phase

Long-term care for the site ~~will commence~~commenced at the completion of site closure. This ~~will be~~was the point in time when final site grading and initial site revegetation, as defined in the site reclamation plan, ~~have been~~was completed in 1998.

The following discussion addresses specific long-term care and maintenance requirements as per NR 132.08, NR 182.09, NR 182.16, and NR 182.19. These requirements relate to the procedures to be used, the estimated costs and financial responsibility for the 40-year long-term care period.

1.1 Procedures

Long-term care and maintenance for the project relates to inspections of the site; maintenance of landforms, vegetation and monitoring devices; and monitoring groundwater, surface water, vegetation, terrestrial ecology, and surface subsidence. Each of these topics is discussed in the succeeding paragraphs. Sampling and analytical procedures to be used during the long-term care and maintenance period for groundwater and surface water monitoring will be the same as described in Section 2.0.

1.1.1 Inspections

Flambeau ~~will inspect~~inspected the reclaimed site semi-annually for the first four years during the long-term care and maintenance period, and has inspected once per year thereafter. ~~The semi-annual inspections will occur in the spring and fall.~~ The annual inspection ~~will~~ occurs in the late summer. The inspections will be performed by a person qualified to evaluate conditions associated with erosion, vegetation growth, settling and monitoring device integrity.

1.1.2 Maintenance

Maintenance activities for purposes of this plan will consist of landform, vegetative and monitoring device maintenance.

~~1.1.2.1 Landform~~

~~The method of backfilling the pit and the nature of the backfilled material will result in only a slight amount of settling. In the eastern portion of the pit, a mounding will be provided to compensate for anticipated settling. It is calculated that an approximate six-foot mound will allow for the final grade over the pit to be near the original grade following settlement. In the west end of the pit, a few feet of settling will augment the formation of the proposed wetland located in that area. Current plans are to revegetate the open pit site and allow the land to settle to a final form. Erosion control will consist of regrading and revegetating eroded areas.~~

~~1.1.2.2 Vegetation~~

~~After reclamation has been certified as complete, additional revegetation of eroded areas will be completed on an as-needed basis. Revegetation techniques will be those specified in Section 5.11 of the December 1989 Mining Permit Application for revegetation of the site as a whole.~~

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~~1.1.2.3~~1.1.2.1 Monitoring Devices

Flambeau will ~~immediately~~ notify the WDNR if for any reason a groundwater monitoring well or device is destroyed or fails to function properly. Unless otherwise notified in writing by WDNR, Flambeau will restore or properly abandon and replace destroyed or failed monitoring devices within 60 days of the written notification referred to above.

1.1.3 Groundwater Monitoring

Groundwater monitoring will include water level measurements and water quality data collection in monitoring wells located both in the backfilled pit and outside the pit. In addition, water level measurements will be made in selected piezometers outside the pit.

1.1.3.1 Groundwater Quality Monitoring Outside the Backfilled Pit

Water quality monitoring and water level measurements outside the pit perimeter will include four well nests (MW-1000, MW-1002, MW-1004, and MW-1005) and monitoring well MW-1010P (Figure 3-1). Well nests MW-1000 and MW-1004 and well MW-1010P are included in the program since they are located downgradient of the backfilled pit. Well nest MW-1002 is included since it is downgradient of the Type I stockpile. Well nest MW-1005 is included as the upgradient well nest for background water quality data purposes.

Sampling was performed quarterly until the end of 2018 when a request was submitted to reduce the groundwater monitoring frequency. Going forward sampling will be performed ~~quarterly~~ annually (~~January, April, July, and October~~June or July) during the remaining long-term care and maintenance period. Analyses will be performed for the following parameters:

♦ Specific ~~Conductance~~ Conductivity (Field)	♦ Calcium
♦ pH (Field ~~and Lab~~)	♦ Chloride
♦ ORP	♦ Copper
♦ Turbidity	♦ Iron
♦ Color	♦ Magnesium
♦ Odor	♦ Manganese
♦ Total Dissolved Solids	♦ Potassium
♦ Total Alkalinity	♦ Sodium
♦ Total Hardness	♦ Sulfate
♦ Arsenic	♦ Zinc

~~Once per year, during the June monitoring round, each of the above monitoring wells will also be monitored for the following metals:~~

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1.1.3.2 Groundwater Quality Monitoring Inside the Backfilled Pit

As shown on Figure 3-1, ~~two~~ monitoring well nests ~~will be~~ MW-1013 and MW-1014 were placed in the backfilled pit following the completion of reclamation construction activities. ~~Each nest will consist of two wells. In each nest, the deeper wells, MW-1013P and MW-1014P, will be bottomed in Type II waste rock material approximately 30 feet above the bottom of the backfilled pit. The shallower wells, MW-1013G and MW-1014G, will be bottomed in backfilled till and/or outwash on top of the backfilled saprolite layer. Monitoring wells MW-1013G and MW-1014G shall be constructed with screened intervals 10 feet long and wells MW-1013P and MW-1014P shall have screened intervals 15 feet long. The specific planned well construction details for each of the four wells are shown on Figures 3-2 through 3-5.~~

~~After installation and upon the water level in the backfilled pit reaching each well, *in situ* permeability tests will be conducted and then monitoring of the wells for water quality will commence.~~ Each well will be monitored ~~quarterly~~ annualy (~~January, April, July, and October~~in June or July) ~~for two years~~ for the parameters listed below:

♦ Specific Conductivity (Field)	♦ Calcium
♦ pH (Field)	♦ Chloride
♦ ORP	♦ Copper
♦ Turbidity	♦ Iron
♦ Color	♦ Magnesium
♦ Odor	♦ Manganese
♦ Total Dissolved Solids	♦ Potassium
♦ Total Alkalinity	♦ Sodium
♦ Total Hardness	♦ Sulfate
♦ Arsenic	♦ Zinc
~~♦ Specific Conductance (Field)~~	~~♦ Iron~~
~~♦ pH (Field and Lab)~~	~~♦ Manganese~~
~~♦ Total Dissolved Solids~~	~~♦ Copper~~
~~♦ Total Alkalinity~~	~~♦ Sulfate~~
~~♦ Total Hardness~~	

~~During each July sampling round, the following metals will be added to the parameter list:~~

~~♦ Arsenic~~	~~♦ Mercury~~
~~♦ Barium~~	~~♦ Selenium~~
~~♦ Cadmium~~	~~♦ Silver~~
~~♦ Total Chromium~~	~~♦ Zinc~~
~~♦ Lead~~	

Water quality monitoring of the four wells ~~will be~~was conducted quarterly at ~~all~~ the wells until ~~at least eight samples have been collected from each well~~2018 when a request to reduce the monitoring frequency was requested by Flambeau. ~~At that time, a reduction in monitoring frequency will be requested by Flambeau. Provided that the monitoring results confirm the~~

~~predictive modelling of water quality within the backfilled material and verify that no adverse impacts to water quality within the Flambeau River will occur, the WDNR has gone on record indicating it may approve such a request. The provisions of NR 140, Wis. Adm. Code, shall be used to determine statistically significant changes in the groundwater quality.~~

1.1.3.3 Water Level Measurements in Selected Wells

Quarterly water level measurements at wells MW-1013G, 1013P, 1014G, and 1014P, as well as all wells used for this purpose during construction and operations monitoring (Figure 2-1) ~~shall be continued into the long-term care and maintenance period,~~ occurred until water levels ~~are~~ stabilized. Water levels ~~shall be~~were deemed ~~as~~ stable in a memorandum prepared in August 2018 and water levels will be collected from the wells shown on Figure 2-X. ~~when no significant net annual changes occur in water levels over a two-year period. An acceptable range of annual fluctuations in groundwater levels shall be based on a statistical analysis of observed pre-mining annual fluctuation ranges of those wells with a pre-mining monitoring record which are to be included in the long-term monitoring program. To the extent technically feasible, the entire record of pre-mining water level measurements from the applicable wells shall be considered when determining the normal or acceptable annual fluctuation range.~~

~~The average annual range will be based on the combined average of the annual fluctuation ranges of all the wells presently on-site that are to be included in the long-term monitoring program, plus or minus one standard deviation. During the post-reclamation period as the water table recovers, the net annual fluctuation should be relatively large, showing an upward movement of the water table. As stability is approached, this net upward fluctuation will be reduced through time, eventually falling back into the average annual range that exists today. When the average annual fluctuation falls within this range for two consecutive years, the water table will then be deemed to have stabilized. At this point, water level measurements will only be taken at wells for which water quality sampling is performed.~~

~~1.1.4 Surface Water~~

~~The objective of the post-operational monitoring of surface waters is to confirm the findings of the monitoring during operations. In the unlikely event that operational monitoring results link increases in certain metals to the site, the proposed surface water monitoring program proposed in this section may need to be revised.~~

~~At the time at which the groundwater conditions in the reclaimed pit have rebounded so that there is a groundwater flow toward the Flambeau River, the groundwater data will be evaluated. If the conditions predicted by groundwater flow and water quality modelling are met, the post-operational surface water monitoring program will be deemed complete and no additional monitoring will be required.~~

~~Following is a discussion of the targeted long-term care and maintenance surface water monitoring program.~~

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1.1.4.1 Sediments, Macroinvertebrates, and Fish

After discharges from the wastewater treatment facilities have ceased, sediments, crayfish and fish will be collected once each year for two years at the same location shown on Figure 2-7.

During the third year after the cessation of wastewater discharges and for each year thereafter, until the notice of completion of reclamation is issued by Flambeau, crayfish will be sampled and analyzed according to methods discussed in Section 2.4.3. Fish will be sampled during the year that the certificate of completion is issued according to methods discussed in Section 2.4.2.

1.1.4.2 Water Quality

During the two years following the cessation of the wastewater discharge, three surface water samplings will be made at the locations shown on Figure 2-7. Two of these samplings will occur at the time of spring runoff during each of these years.

One additional sample will be taken during a stormwater runoff event so that the downstream sample taken in the Flambeau River includes runoff from the mine site. All surface water sampling will be terminated two years after the cessation of the wastewater discharge.

1.1.4.3 Wetland Surface Flows

If water level measurements collected during the construction and operation monitoring program indicate significant drawdown effects on a monitored wetland which is attributable to the project, then wetland surface flows will be monitored at that location during the long-term care and maintenance period three times per year (spring, summer, and autumn) until water levels in monitored groundwater monitoring wells stabilize. At this point in time, monitoring will cease.

1.1.5 Vegetation and Wildlife Habitat

Monitoring of vegetation will occur between the time planting has been completed and the certificate of completion of reclamation has been issued by the WDNR. The procedures to be followed during the vegetation and wildlife habitat monitoring program are described below. Monitoring will occur annually, beginning prior to submittal of the notice of completion of reclamation, and ending at certification of completion and consist of the following measurements.

1.1.5.1 Percent Cover

Acceptable cover will constitute no less than 70 percent cover averaged over the site at 90 percent statistical confidence during interim revegetation periods for purposes of site stabilization and for final reclamation at the notice of completion of reclamation and for certificate of completion. Cover will be determined as total cover as measured by the coverage of the canopy (vertical projection of plant parts) and will be recorded by species. Cover will be measured annually during any and all reclamation over the entire revegetated site at no less than 160 randomly-placed one-square-meter quadrats. The timing for measurement will approximate peak biomass during the period from mid-August to early September. These measurements should correlate with the aerial color infrared photography. Sampling will be designed so as to

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accommodate different community types (i.e., along moisture gradients). The actual number of sample units per community type will be determined at the time of sampling based on mean/variance tests and may be fewer than 160 quadrats.

1.1.5.2 Biomass

Total above-ground herbaceous biomass will be determined once for the notice of completion and once at the certificate of completion as a relative measure of temporal productivity. Biomass will be harvested at no less than 25 randomly-placed quadrats of one square meter in size. The biomass at the certificate of completion should be no less than 80 percent of the biomass during the notice of completion at 90 percent statistical confidence. Burning of grassland will be planned so as not to interfere with biomass measurements.

1.1.5.3 Diversity

The frequency of occurrence by species will be reflective of its relative ratio in the seed mix or planting schedule. The similarity of the standing crop should be no less than 80 percent of the original mixture at 90 percent statistical confidence with a minimum of 15 planted species per community type.

1.1.5.4 Survivorship of Woody Plant Stock

A representative population sample of woody species will occur at the time of the notification of completion of reclamation and again at the time of the certificate of completion. No less than 80 percent of the initially planted species must survive in a similar proportion to the initial planting and show signs of vigor and health.

1.1.5.5 Wetland Vegetation

Vegetation measurements will consist of frequency occurrence and density. The similarity of the standing crop will be no less than 80 percent of the initial planting at 90 percent statistical confidence with a minimum of 12 planted species.

1.1.5.6 Wildlife Habitat

Beginning two years after revegetation has commenced, and once a year for three years thereafter, a habitat evaluation (i.e., HEP analysis, U.S. Fish and Wildlife Services) will be conducted on the wetland and terrestrial areas that have been reclaimed.

1.1.6 Terrestrial Ecology

Aerial and color infrared photography will be completed in the late summer for four consecutive years following completion of closure and every five years thereafter throughout the long-term care and maintenance period to monitor the success of revegetation. The area to be surveyed will be the same as described in Section 2.5.

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1.1.7 Surface Subsidence

Surface subsidence monitoring will consist of topographically mapping, following reclamation, the ground surface of the 32-acre pit area by aerial photography. The initial survey will be performed during the fall or early spring immediately following the completion of reclamation activities in the area of the pit. Subsequent surveys will occur in the third, tenth, twentieth, and fortieth year after reclamation activities in the area of the pit are completed. Following the completion of each aerial survey, a topographic map of the 32-acre pit area will be produced. The map will have a two-foot contour interval. Each map that is produced will be submitted to the WDNR with the appropriate annual report of reclamation activities required under Condition 26(d) of Part 3 of the Mining Permit. A brief discussion will be included in the report addressing changes in the surface topography of the pit area that are noted as a result of aerial mapping work.

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2 Reporting

Monitoring data and results will be submitted to the WDNR within 30 days after completion of the required analyses. ~~The results of the wetland surface flow monitoring will be submitted quarterly with the water quality monitoring results. Meteorological data and average monthly pit inflow rates will be summarized annually and submitted with the project's annual report.~~

~~Air monitoring data will be submitted in accordance with guidelines provided by the Air Monitoring Section of the Bureau of Air Management. A hard-copy transmittal letter and summary of missing data will be included with each submission. The letter will contain an explanation relating to any missing data.~~

A summary of the year's monitoring activities and a discussion of any observed trends in the monitoring data will be included in the Aannual Rreport required per Condition 8, Part 1 of the Mine Permit.

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3 Spills or Releases

Immediately following any unforeseen spill or release of gasoline, fuel oil, diesel fuel, or other organic compounds in the course of construction, operation or closure of the mine, Flambeau will inform the WDNR in accordance with the provisions of Sec. 144.76, Stats., and undertake monitoring of wells as the WDNR may require pursuant to the provisions of Sec. 144.768, Stats.

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