**Faro Mine Complex, June 2016 Groundwater Sampling**

Prepared for:

**Government of Yukon**

Prepared by:

**Hemmera Envirochem Inc.**

230 – 2237 2nd Avenue

Whitehorse, YT Y1A 0K7

**Ecological Logistics & Research Ltd**.

204-105 Titanium Way

Whitehorse, YT Y1A 0E7

File: 1343-005.30

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# Introduction

Hemmera Envirochem Inc. (Hemmera) and Ecological Logistics & Research Ltd. (ELR) were retained by the Government of Yukon (GY), Assessment and Abandoned Mines (AAM) to conduct a groundwater sampling program at the Faro Mine Complex (FMC). The program consists of two sampling events: June and September, 2016. This report summarizes the activities completed and analytical results from the June 2016 sampling event.

This Work was performed in accordance with contract C00033457 between Hemmera and the Government of Yukon (“Client”), dated May 13, 2016 (“Contract”). This Report has been prepared by Hemmera/ELR, based on fieldwork conducted by Hemmera/ELR, for sole benefit and use by the Government of Yukon. In performing this work, Hemmera has relied in good faith on information provided by others, and has assumed that the information provided by those individuals is both complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the Report was produced. The conclusions and recommendations contained in this Report are based upon the applicable guidelines, regulations, and legislation existing at the time the Report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

## Site Location

The FMC is located approximately thirteen (13) kilometres (km) northeast of the Town of Faro, Yukon (20 km by road). The FMC consists of two distinct areas, the Faro Mine Area and the Vangorda/Grum Area (**Figure 1-1**), which are connected by a fourteen (14) km roadway (the Haul Road; **Figure 1-1**). Groundwater sampling stations exist throughout the FMC and surrounding area, a series of which were sampled during the June 2016 program. Specific sampling locations and general sample site distribution are described in **Sections 1.2** and **1.3**.

## Scope of Work

The scope of work (SOW) included the coordination and execution of the June 2016 groundwater sampling program and the preparation of this summary report. This report provides a summary of the sampling program activities, methodologies (including any deviations from standard methodologies), field *in-situ* and laboratory analytical results, concentrations of contaminants exceeding applicable guidelines, and recommendations relating to sample procedures and monitoring well conditions. This report does not provide an interpretation of the analytical results or provide recommendations relating to the program. The groundwater sampling event at the FMC was conducted over a three (3) day period between June 1 and June 3, 2016. A total of fifty-three (53) groundwater wells were specified by AAM for the event (**Table 1-1**), forty (40) of which were newly added to the SOW and had not been sampled previously by Hemmera (Hemmera, 2015a). Sampling was conducted by a team of four (4) field staff from Hemmera/ELR.

At each well (sampling station) the groundwater level and depth to bottom of the well were measured, the well was purged appropriately, and field parameters were measured (pH, water temperature, conductivity, oxidation-reduction potential, and dissolved oxygen). Groundwater samples were collected following field measurements and purging, and were analysed for general groundwater quality chemistry (dissolved metals, major anions/cations, and physical parameters). A detailed description of the sampling methodology is provided in **Section 2**, below.

## Sample Sites

June 2016 groundwater sampling was conducted at fifty-three (53) wells across seven (7) different areas of the FMC (**Table 1-1**; **Figures 1-1** to **1-4**). Fifty-two (52) of the fifty-three (53) wells identified for the event were successfully located. The other one (1) well (sampling station S3) was not located in the field and is presumed to have been destroyed. The majority of the sample sites included in the program were located in the Faro Mine Area (49 wells), with the remaining wells located in the Vangorda/Grum Area (4 wells). A large portion of the wells sampled in the Faro Mine Area were located in the S-Wells Area (18 wells; **Figure 1-3**), with additional wells in the surrounding areas. Wells in the Vangorda/Grum Area were primarily located in the vicinity of the Grum Sulphide Cell (**Figure 1-4**). **Table 1-1** summarizes sample sites included in the sampling program, while **Figures 1-2** through **1-4** show locations and general distribution of the sites. Photographs of each sample site are included as **Appendix  A**.

Table 1-1 Summary of Groundwater Sample Sites Identified for June 2016 Program

| Area | Well Name | UTM (Zone 8N) | Well Status | Sample Successfully Collected | QA/QC Sample Collected |
| --- | --- | --- | --- | --- | --- |
| Easting | Northing |
| Cross Valley Dam (CVD) | P01-02A | 579962 | 6914224 | Good | **** | Duplicate |
| P01-02B | 579962 | 6914224 | Partially Obstructed \* | **** | - |
| P01-11 | 580092 | 6914486 | Good | **** | - |
| P05-01-02 | 580056 | 6914505 | Good | **** | - |
| P05-01-04 | 580056 | 6914505 | Good | **** | - |
| P05-02 | 580036 | 6914439 | Good | **** | - |
| P05-03 | 579982 | 6914346 | Good | **** | - |
| Down Gradient of CVD | P01-01A | 579701 | 6914854 | Good | **** | - |
| P01-01B | 579701 | 6914854 | Good | **** | Duplicate, Field Blank |
| X16A | 579446 | 6914842 | Good | **** | - |
| X16B | 579446 | 6914842 | Good | **** | - |
| X17A | 579756 | 6914648 | Good | **** | - |
| X17B | 579756 | 6914648 | Good | **** | - |
| X18A | 579986 | 6914713 | Good | **** | - |
| X18B | 579986 | 6914713 | Good | **** | - |
| Emergency Tailings (ETA) / Mill Area | P09-ETA-2 | 582700 | 6913812 | Good | **** | - |
| P96-8A | 583220 | 6914072 | Good | **** | - |
| P96-8B | 583220 | 6914072 | Good | **** | - |
| Intermediate Dam | P01-03 | 580516 | 6914255 | Good | **** | - |
| P01-04A | 580372 | 6914074 | Good | **** | - |
| P01-04B | 580372 | 6914074 | Good | **** | - |
| X24-96D | 580544 | 6914298 | Good | **** | - |
| X25-96A | 580544 | 6914298 | Good | **** | - |
| X25-96B | 580407 | 6914119 | Good | **** | - |
| Northeast Waste Rock Dump Area | BH14A | 585584 | 6914005 | Good | **** | - |
| BH14B | 585584 | 6914005 | Good | **** | - |
| CH15-107-MW029 | 585765 | 6914129 | Good | **** | - |
| CH15-107-MW030 | 585832 | 6914180 | Good | **** | - |
| CH15-107-MW032 | 585763 | 6914249 | Good | **** | - |
| CH15-107-MW033 | 585764 | 6914248 | Good | **** | - |
| CH15-107-MW034 | 585752 | 6914496 | Good | **** | Duplicate, Field Blank |
| S-Wells Area | CH14-107-MW007A | 584491 | 6913091 | Good | **** | - |
| CH14-107-MW007B | 584489 | 6913092 | Good | **** | - |
| CH14-107-MW009 | 584499 | 6913099 | Good | **** | Duplicate |
| CH14-107-MW010 | 584497 | 6913098 | Good | **** | - |
| P96-7 | 584127 | 6913287 | Good | **** | - |
| S1A | 584433 | 6913114 | Good | **** | - |
| S1B | 584433 | 6913114 | Slow Recharge | **** | - |
| S2A | 584471 | 6913123 | Good | **** | - |
| S2B | 584471 | 6913123 | Good | **** | - |
| S3 | 584481 | 6913091 | Not located / Destroyed \*\* | - | - |
| SRK05-SP-4A | 584506 | 6913110 | Good | **** | Duplicate, Field Blank |
| SRK05-SP-4B | 584506 | 6913110 | Good | **** | - |
| SRK05-SP-5 | 584467 | 6913133 | Good | **** | - |
| SRK08-SBR2 | 584484 | 6913123 | Good | **** | - |
| SRK08-SBR3 | 584394 | 6913146 | Dry | - | - |
| SRK08-SBR4 | 584447 | 6913140 | Good | **** | - |
| SRK08-SP-7A | 584437 | 6913095 | Good | **** | - |
| SRK08-SP-7B | 584437 | 6913095 | Good | **** | - |
| Vangorda/Grum | P2001-02A | 593132 | 6902866 | Good | **** | - |
| P2001-02B | 593132 | 6902866 | Slow Recharge | **** | - |
| P96-9A | 592648 | 6903345 | Good | **** | - |
| SRK05-9 | 592949 | 6903158 | Good | **** | - |

**Notes:**

\* Although groundwater well P01-02B was found partially obstructed in the field, this did not prevent sampling of the well and is not anticipated to have reduced sample quality.

\*\* Groundwater well S3 was not located in the field and is presumed to have been destroyed.

Figure 1-1 Site Location – Faro Mine Complex

Figure 1-2 Groundwater Sampling Locations – Faro Mine Area

Figure 1-3 Groundwater Sampling Locations – S-Wells Area

Figure 1-4 Groundwater Sampling Locations – Vangorda/Grum Mine Area

# Methodology

## Protocols

Groundwater purging and sampling conducted by Hemmera/ELR was in accordance with Yukon Environment’s *Protocol for the Contaminated Sites Regulation #7 – Groundwater Monitoring Well Installation, Sampling and Decommissioning* (Yukon Environment, March 2011). Methods used were also consistent with the ASTM *D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells* (ASTM, 2013), the *D6452-99 Guide for Purging Methods for Wells used for Groundwater Quality Investigations* (ASTM, 2012) and in accordance with *Standard Methods for the Examination of Water and Wastewater* (Riceet al.,2012*)*.

## Well Measurements and Purging

Upon arriving at each location, the well structure and casing were inspected for damage, closure, and general conditions. Several measurements were recorded from each well, including depth to water (DTW; m), depth to bottom (DTB; m), well diameter (cm), and well stick-up height (m).

DTB and DTW were measured using either a Solinst - Model 102 Water Level Meter (for 2.54 cm diameter wells) or a Heron Water Tape (for wells with diameter greater than 2.54 cm). DTB and DTW were measured from (in order of preference): 1) a black mark drawn on the top of the well; 2) the bottom of the most significant notch found on the top of the PVC if a mark was not present; or 3) a line was drawn on the highest point of the well and measurement taken from that line if no distinguishable point of measure was present. Based on information reviewed by Hemmera/ELR, it is unknown where the point of measurement was for previous sampling programs. Stick-up height was measured from the lowest point on the bottom of the well casing to the highest point (or distinguishing mark) on the well. Water level meters were decontaminated between each sample site using a combination of Alconox low-foaming phosphate-free detergent solution and de-ionized water.

Following the initial checks and measurements described above, groundwater wells were purged and sampled using one of three (3) techniques: 1) Hydrolift electric inertial pump using dedicated high density polyethelene (HDPE) Waterra tubing and footvalve, 2) Manual purging using dedicated HDPE Waterra tubing and footvalve, or 3) GeoPump peristaltic pump using dedicated HDPE and silicone tubing. The purging technique chosen for each well was that which would produce the most representative groundwater sample.

Groundwater wells were determined to be sufficiently purged when either three (3) successive field parameter measurements were recorded to be within an allowable tolerance level (as summarized in **Table 2-1**, below), or when a volume of groundwater equivalent to three (3) standing well volumes of groundwater had been purged. Groundwater turbidity measured in Nephelometric Turbidity Units (NTU) or Attenuation Units (AU) was also measured prior to sampling and was used as an indication of sample quality. Where possible samples were not collected until turbidity was less than 50 NTU.

Purge volume measurements were collected using a graduated container and stop watch. All well measurements, purging details, and additional field notes were recorded on field forms, this information is presented in **Table 3-1**.

Table 2-1 Groundwater Sampling – Field Parameter Purging Criteria

|  |  |
| --- | --- |
| Field Parameter | Allowable Variance Across 3 Consecutive Readings |
| Temperature (°C) | ±3% |
| pH (pH Units) | ±0.1 |
| Conductivity (µS/cm) | ±3% |

## Field Parameters

Hemmera/ELR measured general field parameters using a YSI Professional Plus multi-parameter meter and Lamotte 2020we turbidity meter. Where possible, field parameters were collected using a flow through cell in order to minimize field parameter variability. Field parameters recorded at each sample site included: groundwater temperature (oC), conductivity (μs/cm), specific conductivity (μs/cm), pH (pH Units), oxidation-reduction potential (ORP; mV), dissolved oxygen (mg/l and percent saturation), and turbidity (NTU).

During purging, field parameters were monitored at 3-5 minute intervals, or at volume related intervals (e.g., every 500 mL) in the case of wells with slow recharge. In-situ measurements for reporting purposes were recorded at the conclusion of purging.

## Groundwater Quality Sample Collection

Groundwater quality samples were collected and preserved in accordance with laboratory directions, and using techniques consistent with Standard Methods for the Examination of Water and Wastewater (Rice et al., 2012). ALS Global was the analytical subcontractor chosen for this project, and an example summary of the sample set collected at each sample location, including parameters analysed and preservation techniques, is provided in **Table 2-2**.

Table 2-2 Groundwater Sampling – Preservation and Intended Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Bottle Type | Parameters Analyzed | Sample Treatment | Preservation Added |
| 120 mL (Plastic) | Dissolved Metals (excluding mercury) | Field Filtered and Preserved | HNO3 |
| 1 L (Plastic) | Acidity, alkalinity, chloride, conductivity, pH, hardness, sulfate, total suspended solids (TSS) | - | None |

## Data Analysis

Groundwater analytical results were compared to the Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL; CCME, 2016). All relevant CCME FAL guidelines are presented in **Table 3-2**.

## Quality Assurance and Quality Control (QA/QC)

### Field QA/QC

Several controls were used by Hemmera/ELR staff while in the field to help ensure that sample integrity was maintained and that data was recorded completely and accurately. All equipment used during the sampling process was dedicated to individual wells, including HDPE tubing and Waterra footvalves, laboratory provided pre-cleaned sample bottles, disposable filters, and disposable syringes. Field staff wore dedicated disposable nitrile gloves for all measurements, purging, and sampling. Water level meters were cleaned using Alconox low-foaming phosphate-free detergent and de-ionized water and between wells, and field instruments (YSI field meters and turbidity meters) were checked and/or calibrated before each site visit to ensure the parameters recorded were as accurate as possible.

Project-specific field data sheets were created for the sampling event to help ensure that all required measurements were taken, and that information was recorded correctly. Field data sheets have been included as **Appendix B** of this report.

### Laboratory and Sampling QA/QC

Laboratory and sampling QA/QC measures taken as part of the June 2016 sampling program include the collection of duplicates and field blanks, and the inclusion of a travel blank, as outlined in the SOW and as per standard industry practice. Five (5) duplicate samples were collected in relation to fifty-one (51) regular samples. Additionally, three (3) field blanks were collected, and one (1) travel blank accompanied the analytical supplies and samples during shipping to and from the laboratory.

The variation between sample and duplicate values was calculated as relative percent difference (RPD). RPD provides a measure of the relative difference between two values in comparison to their mean value, and is calculated as the difference between a sample and its field duplicate over the average of two values. RPD values greater than 20% indicates a greater variance than would normally be anticipated and may be due to a number of factors (e.g., short term change in parameter concentration, sediment in the sample, sampling or instrument error, large relative % difference but very low actual difference in concentration, such as 0.0001 vs 0.0002 mg/L). RPD was calculated according to the following formula:

$$\%RPD=\left(\frac{χ\_{1}-χ\_{2}}{\left(\frac{χ\_{1}+χ\_{2}}{2}\right)}\right) x 100$$

Where *X1* is the sample result and *X2* is the corresponding duplicate result. RPD is not considered valid and is therefore not calculated if either the sample or the field duplicate concentration is less than five times the detection limit.

The analytical results for field and travel blanks were reviewed to determine whether any of the parameters tested were detected (i.e., result exceeding the detection limit). In such cases, the parameter or element in question and its concentration were reviewed to determine potential sources of contamination or error.

# Results

Summary tables of the laboratory analytical results are presented in **Table 3-1** of this report, including comparisons of results to CCME FAL guidelines. A summary of the QA/QC sampling results is also attached, including analytical data for duplicates, field blanks, and travel blanks (**Table 3-2**). Laboratory analytical reports are provided as **Appendix C**.

## Groundwater Sampling Summary

Groundwater sampling was completed between June 1 and June 3, 2016. Weather conditions varied throughout the sampling program, with ambient air temperature ranging from 7°C to 20°C. Weather conditions were predominantly overcast, with occasional sunny periods and light rain. Fifty-two (52) of the fifty-three (53) groundwater wells specified for the June 2016 sampling event were located and assessed by Hemmera/ELR. As noted in **Section 1.2**, one (1) well (sampling station S3) could not be located in the field. Groundwater samples were successfully collected from fifty-one (51) of the fifty-two (52) wells located, as outlined in **Table 1-1**. The one (1) well that could not be sampled (SRK08-SBR3) was found dry during the time of sampling. Of the fifty-one (51) wells that were successfully sampled, one (1) well was found to be partially obstructed by an unidentified object (sampling station P01-02B). Despite being partially obstructed, this well was sampled and the quality of the sample obtained was believed to be good. A summary of groundwater wells sampled during the June 2016 sampling event, including field parameters and well measurements, is provided in **Table 3-3**. All samples were received by the laboratory within the required holding times and temperature limits.

A summary of the sampling results in the context of CCME-FAL guideline exceedances is provided in the following sections, organized by area.

Table 3-3 Groundwater Field Parameters and Well Measurements for June 2016 Sampling Program

| **Area** | **Well Name** | **Sample Date** | **Well Status** | **Stick up Height (m)** | **Depth To Water (m)** | **Depth To Bottom (m)** | **Standing Water volume (L)** | **Volume Purged (L)** | **Purge Start time** | **Purge End Time** | **Elapsed Purge Time** | **Purge Rate (l/min)** | **Criteria 1** **(3WV / PS / DS)** | **Draw Down (m)** | **pH (pH Units)** | **Temperature (°C)** | **Conductivity (µs/cm)** | **Specific Conductivity (µs/cm)** | **Oxidation Reduction Potential (mV)** | **Dissolved Oxygen (mg/L)** | **Field Turbidity (NTU)** | **Method Used** | **Well diameter (cm)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cross Valley Dam (CVD Area) | P01-02A | 02/06/2016 | Good | 0.610 | 1.924 | 14.37 | 25.23 | 3.4 | 9:54 | 10:15 | 0:21 | 0.16 | PS | 0.016 | 7.47 | 4.7 | 446.8 | 731 | 41.7 | 0.12 | 0.7 | Peri. Pump | 5.08 |
| P01-02B | 02/06/2016 | Partially Obstructed | 1.600 | 0.255 | 29.851 | 59.99 | 3.83 | 13:19 | 13:31 | 0:12 | 0.32 | PS | 0.645 | 7.67 | 8.7 | 394.9 | 574 | -118.1 | 0.21 | 3.83 | Peri. Pump | 5.08 |
| P01-11 | 02/06/2016 | Good | 1.390 | 0.965 | 11.01 | 20.36 | 4.6 | 12:32 | 12:58 | 0:26 | 0.18 | PS | 0.005 | 6.39 | 5.3 | 2440 | 3911 | -44 | 0.19 | 7.28 | Peri. Pump | 5.08 |
| P05-01-02 | 02/06/2016 | Good | 0.480 | 0.293 | 20.769 | 2.59 | 5.25 | 14:06 | 14:27 | 0:21 | 0.25 | PS | NR\* | 6.24 | 5 | 2357 | 3812 | -1.5 | 0.18 | 2.03 | Peri. Pump | 1.27 |
| P05-01-04 | 02/06/2016 | Good | 0.530 | 1.969 | 12.293 | 1.31 | 3.25 | 13:33 | 13:54 | 0:21 | 0.15 | PS | NR\* | 6.29 | 5.7 | 2437 | 3863 | -12.4 | 0.18 | 8.99 | Peri. Pump | 1.27 |
| P05-02 | 02/06/2016 | Good | 1.895 | 2.614 | 5.879 | 6.62 | 4.25 | 11:37 | 12:03 | 0:26 | 0.16 | PS | 0.004 | 6.21 | 4.8 | 2263 | 3688 | 3.1 | 0.3 | 0.68 | Peri. Pump | 5.08 |
| P05-03 | 02/06/2016 | Good | 0.820 | 4.378 | 7.986 | 7.31 | 4 | 10:50 | 11:11 | 0:21 | 0.19 | PS | 0.478 | 6.72 | 3.9 | 1338 | 2243 | -29.9 | 0.12 | 1.62 | Peri. Pump | 5.08 |
| Down Gradient of CVD Area | P01-01A | 02/06/2016 | Good | 0.600 | 3.56 | 20.312 | 33.95 | 40 | 15:29 | 15:47 | 0:18 | 2.22 | 3WV | 0.032 | 6.98 | 2.3 | 1122 | 1984 | 68.8 | 0.92 | 0.35 | Hydrolift | 5.08 |
| P01-01B | 02/06/2016 | Good | 0.560 | 3.716 | 35.296 | 64.01 | 45 | 15:56 | 16:12 | 0:16 | 2.81 | 3WV | 0.03 | 7.34 | 2.6 | 904 | 1580 | -42 | 0.84 | 0.24 | Hydrolift | 5.08 |
| X16A | 02/06/2016 | Good | 0.820 | 3.503 | 5.357 | 2.11 | 2 | 14:00 | 14:18 | 0:18 | 0.11 | PS | 0.003 | 7.72 | 4.4 | 220.6 | 363.3 | -4.1 | 2.59 | 0.47 | Peri. Pump | 3.81 |
| X16B | 02/06/2016 | Good | 1.050 | 3.683 | 14.783 | 50.62 | 40 | 14:36 | 14:55 | 0:19 | 2.11 | PS | 0.017 | 7.86 | 3.3 | 241.2 | 412.2 | 17.1 | 4.7 | 8.97 | Hydrolift | 7.62 |
| X17A | 03/06/2016 | Good | 0.850 | 2.285 | 6.09 | 4.34 | 2.9 | 15:58 | 16:25 | 0:27 | 0.11 | PS | 0.002 | 7.25 | 3.5 | 373.7 | 634 | -9.7 | 0.13 | 0.03 | Peri. Pump | 3.81 |
| X17B | 03/06/2016 | Good | 0.490 | 1.852 | 22.41 | 93.75 | 80 | 16:35 | 16:47 | 0:12 | 6.67 | PS | NR\* | 6.88 | 3.1 | 913 | 1576 | -68.4 | 0.2 | 914 AU3 | Manual | 7.62 |
| X18A | 02/06/2016 | Good | 0.620 | 4.009 | 9.465 | 11.06 | 2.85 | 15:14 | 15:35 | 0:21 | 0.14 | PS | 0.581 | 6.8 | 4.1 | 1010 | 1682 | -38.3 | 0.27 | 2.81 | Peri. Pump | 5.08 |
| X18B | 02/06/2016 | Good | 0.650 | 3.8 | 10.739 | 14.06 | 3.55 | 15:50 | 16:16 | 0:26 | 0.14 | PS | 0.04 | 6.73 | 3.6 | 1094 | 1854 | 23.1 | 0.31 | 0.7 | Peri. Pump | 5.08 |
| Emergency Tailings Area (ETA) | P09-ETA-2 | 03/06/2016 | Good | 0.715 | 11.115 | 18.535 | 15.04 | 25 | 14:33 | 15:08 | 0:35 | 0.71 | PS | NR\* | 6.24 | 4.4 | 3945 | 6497 | -19.9 | 1.43 | 2.96 | Hydrolift | 5.08 |
| P96-8A | 03/06/2016 | Good | 0.790 | 2.474 | 4.876 | 4.87 | 1.5 | 13:24 | 13:45 | 0:21 | 0.07 | PS | 0.01 | 3.32 | 7.6 | 57.1 | 85.4 | 346 | 3.96 | 0.24 | Peri. Pump | 5.08 |
| P96-8B | 03/06/2016 | Good | 0.700 | 2.36 | 9.083 | 13.63 | 0.75 | 13:54 | 14:08 | 0:14 | 0.05 | PS | 0.004 | 4.9 | 7.6 | 6147 | 9203 | 161.9 | 0.15 | 0.4 | Peri. Pump | 5.08 |
| Intermediate Dam | P01-03 | 02/06/2016 | Good | 0.400 | 1.763 | 9.611 | 15.91 | 2.2 | 9:41 | 10:05 | 0:24 | 0.09 | PS | 1.287 | 6.14 | 4.3 | 2438 | 4029 | -31.9 | 0.2 | 28.6 | Peri. Pump | 5.08 |
| P01-04A | 02/06/2016 | Good | 0.200 | 0.19 | 53.134 | 107.31 | 60 | 11:32 | 11:54 | 0:22 | 2.73 | PS | 0.239 | 6.64 | 3.5 | 715 | 1212 | -23.8 | 0.69 | 2.42 | Hydrolift | 5.08 |
| P01-04B | 02/06/2016 | Good | 0.180 | 0.808 | 19.027 | 36.93 | 40 | 12:01 | 12:15 | 0:14 | 2.86 | 3WV | 0.01 | 6.74 | 3.3 | 1798 | 3075 | -52.2 | 0.79 | 0.25 | Hydrolift | 5.08 |
| X24-96D | 02/06/2016 | Good | 0.950 | 2.525 | 28.372 | 52.39 | 50 | 8:52 | 9:24 | 0:32 | 1.56 | 3WV | 21.765 | 6.19 | 3.5 | 2225 | 3778 | -15 | 2.36 | 25 | Hydrolift | 5.08 |
| X25-96A | 02/06/2016 | Good | 0.480 | 1.908 | 9.489 | 15.37 | 1.8 | 10:24 | 10:42 | 0:18 | 0.10 | PS | 0 | 6.92 | 4.7 | 1158 | 1891 | -63.8 | 0.14 | 1.12 | Peri. Pump | 5.08 |
| X25-96B | 02/06/2016 | Good | 0.450 | 1.816 | 19.698 | 36.24 | 2.2 | 10:52 | 11:11 | 0:19 | 0.12 | PS | 0.054 | 7.59 | 4.8 | 4.5 | 7.3 | -114.8 | 9.79 | 0.64 | Peri. Pump | 5.08 |
| Northeast Dumps | BH14A | 03/06/2016 | Good | 0.050 | 3.678 | 6.439 | 5.60 | 0.85 | 11:55 | 12:09 | 0:14 | 0.06 | PS | 0.19 | 6.66 | 4.1 | 2556 | 4252 | 117.4 | 0.56 | 2.21 | Peri. Pump | 5.08 |
| BH14B | 03/06/2016 | Good | 0.640 | 4.285 | 10.119 | 11.82 | 1.1 | 11:29 | 11:44 | 0:15 | 0.07 | PS | 0.653 | 6.79 | 4.7 | 2357 | 3845 | 102.7 | 0.36 | 11.8 | Peri. Pump | 5.08 |
| CH15-107-MW029 | 03/06/2016 | Good | 0.850 | 1.595 | 3.665 | 16.78 | 1.5 | 10:51 | 11:09 | 0:18 | 0.08 | PS | 0.015 | 7.18 | 2.4 | 1058 | 1864 | 111.1 | 7.41 | 2.52 | Peri. Pump | 10.16 |
| CH15-107-MW030 | 03/06/2016 | Good | 0.880 | 4.084 | 4.478 | 3.19 | 1.45 | 10:18 | 10:34 | 0:16 | 0.09 | PS | 0 | 7.03 | 2.5 | 1191 | 2086 | 114.2 | 7.85 | 3.49 | Peri. Pump | 10.16 |
| CH15-107-MW032 | 03/06/2016 | Good | 1.000 | 2.309 | 9.083 | 54.92 | 1.65 | 9:41 | 10:02 | 0:21 | 0.08 | PS | 0.303 | 7.54 | 3.8 | 1539 | 2589 | 104.6 | 0.84 | 1.42 | Peri. Pump | 10.16 |
| CH15-107-MW033 | 03/06/2016 | Good | 1.030 | 2.525 | 3.894 | 11.10 | 2 | 9:13 | 9:34 | 0:21 | 0.10 | PS | 0.18 | 6.88 | 3.3 | 1208 | 2063 | 129.8 | 3.55 | 1.54 | Peri. Pump | 10.16 |
| CH15-107-MW034 | 03/06/2016 | Good | 0.980 | 3.205 | 6.109 | 23.54 | 1.8 | 8:26 | 8:45 | 0:19 | 0.09 | PS | 0.061 | 6.71 | 3.6 | 566 | 958 | 119.5 | 6.16 | 9.93 | Peri. Pump | 10.16 |
| S-Wells Area | CH14-107-MW007A | 01/06/2016 | Good | 0.890 | 3.617 | 5.755 | 4.33 | 3.55 | 11:52 | 12:26 | 0:34 | 0.10 | PS | 0.217 | 5.94 | 5.7 | 2821 | 4464 | 83.4 | 0.27 | 6.82 | Peri. Pump | 5.08 |
| CH14-107-MW007B | 01/06/2016 | Good | 0.650 | 4.027 | 9.69 | 45.91 | 7.8 | 12:44 | 13:16 | 0:32 | 0.24 | PS | 0.013 | 5.92 | 3.1 | 1044 | 1793 | 30.2 | 0.38 | 1.25 | Peri. Pump | 10.16 |
| CH14-107-MW009 | 01/06/2016 | Good | 1.050 | 4.296 | 12.021 | 62.63 | 3.1 | 10:06 | 10:27 | 0:21 | 0.15 | PS | 0.004 | 5.86 | 3.5 | 794 | 1347 | 179 | 0.87 | 0.94 | Peri. Pump | 10.16 |
| S-Wells Area | CH14-107-MW010 | 01/06/2016 | Good | 1.025 | 2.735 | 32.84 | 244.07 | 60 | 11:04 | 11:30 | 0:26 | 2.31 | PS | 0.473 | 5.87 | 2.4 | 481.8 | 847 | 66.3 | 3.72 | 10.78 | Hydrolift | 10.16 |
| P96-7 | 01/06/2016 | Good | 0.850 | 5.936 | 9.868 | 7.97 | 1.35 | 15:39 | 15:59 | 0:20 | 0.07 | PS | 0.06 | 7.2 | 4 | 1801 | 3011 | 99.2 | NR | 1.72 | Peri. Pump | 5.08 |
| S1A | 01/06/2016 | Good | 1.318 | 4.691 | 13.08 | 17.00 | 3.6 | 15:49 | 16:11 | 0:22 | 0.16 | PS | 0 | 5.79 | 4 | 1151 | 1920 | 78.2 | 0.39 | 1.55 | Peri. Pump | 5.08 |
| S1B2 | 02/06/2016 | Slow Recharge | 1.175 | 4.48 | 5.14 | 1.34 | 1.15 | 15:30 | 15:43 | 0:13 | 0.09 | -2 | 4.48 | 6.52 | 5.4 | 545 | 870 | 121.6 | 1.96 | 9.38 | Peri. Pump | 5.08 |
| S2A | 01/06/2016 | Good | 1.230 | 5.1 | 12.614 | 15.23 | 45 | 12:34 | 13:00 | 0:26 | 1.73 | 3WV | 4.504 | 6.06 | 3.1 | 1161 | 1997 | 55.4 | NR | 78.2  | Peri. Pump | 5.08 |
| S2B | 01/06/2016 | Good | 0.465 | 4.356 | 7.049 | 5.46 | 1.45 | 13:09 | 13:31 | 0:22 | 0.07 | PS | 0.526 | 6.13 | 4.6 | 2616 | 4285 | 36.9 | NR | 27.9 | Peri. Pump | 5.08 |
| S3 | - | Not Located | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| SRK05-SP-4A | 01/06/2016 | Good | 0.698 | 4.498 | 22.433 | 36.35 | 2.1 | 10:01 | 10:27 | 0:26 | 0.08 | PS | 0.005 | 5.89 | 2.8 | 696 | 1210 | 46 | NR | 6.01 | Peri. Pump | 5.08 |
| SRK05-SP-4B2 | 02/06/2016 | Good | 0.82 | 3.995 | 4.727 |  | 0.5 | 10:49 | 10:56 | 0:07 | 0.07 | -2 | 0.126 | 5.79 | 2.8 | 5488 | 9526 | 69.6 | NR | 9.44 | Peri. Pump | 5.08 |
| SRK05-SP-5 | 01/06/2016 | Good | 0.980 | 7.406 | 14.719 | 14.82 | 1.6 | 13:48 | 14:09 | 0:21 | 0.08 | PS | 0.589 | 5.65 | 6.7 | 6981 | 10717 | 153 | NR | 8.44 | Peri. Pump | 5.08 |
| SRK08-SBR2 | 01/06/2016 | Good | 1.060 | 6.563 | 19.065 | 25.34 | 2.35 | 11:20 | 11:44 | 0:24 | 0.10 | PS | 0.157 | 5.83 | 4.4 | 1305 | 2152 | 215.5 | NR | 18.9 | Peri. Pump | 5.08 |
| SRK08-SBR3 | 01/06/2016 | Dry | 0.98 | - | 13,208 | 0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 5.08 |
| SRK08-SBR4 | 01/06/2016 | Good | 0.570 | 7.229 | 21.209 | 28.34 | 1.55 | 14:34 | 14:52 | 0:18 | 0.09 | PS | 0.007 | 5.77 | 5 | 5766 | 9325 | 154.3 | NR | 1.95 | Peri. Pump | 5.08 |
| SRK08-SP-7A | 01/06/2016 | Good | 1.050 | 2.637 | 17.776 | 30.68 | 91 | 14:28 | 15:00 | 0:32 | 2.84 | 3WV | 0.323 | 6.16 | 2.5 | 715 | 1253 | 46.1 | 0.77 | 40.3 | Manual | 5.08 |
| SRK08-SP-7B | 01/06/2016 | Good | 1.135 | 2.714 | 8.753 | 12.24 | 6.1 | 13:44 | 14:11 | 0:27 | 0.23 | PS | 0.007 | 6.51 | 2.7 | 136.4 | 237.8 | 9 | 0.11 | 4.87 | Peri. Pump | 5.08 |
| Vangorda/ Grum | P2001-02A | 03/06/2016 | Good | 0.380 | 3.984 | 27.528 | 47.72 | 28 | 9:13 | 10:03 | 0:50 | 0.56 | PS | NR\* | 6.69 | 4.8 | 2324 | 3785 | -4.3 | 1.68 | 9.93 | Hydrolift | 5.08 |
| P2001-02B | 03/06/2016 | Slow Recharge | 0.600 | 4.193 | 6.384 | 4.44 | 4.2 | 8:39 | 9:05 | 0:26 | 0.16 | PS | 1.387 | 6.63 | 7.2 | 2627 | 3975 | 4.5 | 1.27 | 45.6 | Peri. Pump | 5.08 |
| P96-9A | 03/06/2016 | Good | 0.894 | 5.8 | 9.412 | 0.46 | 3.2 | 10:53 | 11:16 | 0:23 | 0.14 | PS | 0.084 | 6.72 | 3 | 1662 | 2869 | 100.3 | 1.43 | 1.62 | Peri. Pump | 1.27 |
| SRK05-9 | 03/06/2016 | Good | 0.510 | 2.844 | 3.984 | 1.30 | 4 | 12:20 | 12:39 | 0:19 | 0.21 | PS | 0.04 | 7.33 | 3 | 1200 | 2071 | 115.7 | 5.5 | 0.7 | Peri. Pump | 3.81 |

**Notes:**

NR = Not recorded in the field due to equipment errors, NR\* = Not recorded due to limiting diameter of well casing, or risk of equipment damage

‘-‘ = Not Applicable.

1 3WV = Three Well Volumes, PS=Parameters Stable, DS=Direct Sampled

2 Groundwater wells SRK05-SP-4B and S1B had slow recharge rates, and was therefore purged dry on June 1 and sampled the following day (June 2, 2016).

3 AU= Attenuation Units. This alternate unit of measure is reported by the turbidity meter in cases of turbidity >500. They are comparable to NTU, but are measured using transmitted rather than scattered light.

## Analytical Results

Analytical results, including a brief summary of CCME FAL guideline exceedances and factors which may have influenced data precision, are provided below. In some instances the reportable detection limits (RDL) exceeded applicable CCME FAL standards (values shaded in light grey in **Table 3-1**). This occurs when samples with high levels of some elements or compounds require dilution in order for the lab to properly analyse the sample. Accordingly, the laboratory detection limit must then be increased. For the purpose of this report, samples where the reported RDL is higher than the applicable guideline have not been reported as CCME FAL exceedances.

### Cross Valley Dam

Groundwater wells located in the Cross Valley Dam (CVD) area were sampled on June 2, 2016. Samples were obtained from all seven (7) of the wells within this area identified for the sampling event. Groundwater well P01-02B was found to be partially obstructed by an unidentified object. This obstruction did not prevent sampling of the well and is not anticipated to have reduced the quality of the sample collected, however it would be advisable to investigate the blockage and remove it if possible.

Concentrations of dissolved aluminum, arsenic, cadmium, iron, and zinc in groundwater exceeded the CCME FAL guidelines in one or more samples collected in the CVD area. Field dissolved oxygen concentrations were below the CCME FAL minimum guideline concentration for all measurements collected in this area. Field and/or laboratory groundwater pH was below the CCME FAL guideline range in four (4) of the seven (7) wells.

Groundwater turbidity of all CVD samples was less than 50 NTU.

### Down Gradient of Cross Valley Dam

Groundwater wells located down gradient of the CVD area were sampled between June 2 and June 3, 2016. Samples were obtained from all eight (8) wells within this area identified for the sampling event.

Concentrations of dissolved cadmium, iron, and selenium in groundwater exceeded the CCME FAL guidelines in one or more samples collected down gradient of the CVD area. Field dissolved oxygen concentrations were below the CCME FAL minimum guideline concentration for all measurements collected in this area.

Groundwater was extremely turbid at site X17B (914 AU) during the time of sampling. Groundwater turbidity of all other collected samples down gradient of the CVD area was less than 50 NTU.

### ETA / Mill Area

Groundwater wells located in the ETA area were sampled on June 3, 2016. Samples were obtained from all three (3) wells in this area identified for the sampling event.

Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, selenium, uranium, and zinc in groundwater exceeded the CCME FAL guidelines in one or more samples collected in the ETA. Field and/or laboratory groundwater pH was outside the CCME FAL guideline range and field dissolved oxygen was below the minimum CCME FAL guideline concentration for all samples collected in this area.

Groundwater turbidity in all samples within this area was less than 50 NTU.

### Intermediate Dam

Groundwater wells located within the intermediate dam area were sampled on June 2, 2016. Samples were collected from all six (6) wells within this area identified for the sampling event.

Concentrations of dissolved cadmium, iron, nickel, selenium, and zinc in groundwater exceeded the CCME FAL guidelines in one ore more samples collected within the intermediate dam area. Field and/or laboratory groundwater pH in the intermediate dam area was outside the CCME FAL guideline range in two (2) of the six (6) samples. Dissolved oxygen concentrations were below the CCME FAL minimum guideline concentration for five (5) of the six (6) measurements collected in this area.

Groundwater turbidity in all samples within this area was less than 50 NTU.

### Northeast Waste Rock Dump

Groundwater wells located within the northeast waste rock dump area were sampled on June 3, 2016. Samples were collected from all seven (7) wells within this area identified for the sampling event.

Concentrations of dissolved cadmium, copper, nickel, selenium, uranium, and zinc in groundwater exceeded the CCME FAL guidelines in one or more samples collected within the northeast waste rock dump area. Field dissolved oxygen concentrations were less than the CCME FAL guideline level for all measurements collected in this area.

Groundwater turbidity in all samples within this area was less than 50 NTU.

### S-Wells Area

Groundwater wells located in the S-Wells area were sampled between June 1 and June 2, 2016. Samples were collected from sixteen (16) of the eighteen (18) wells in this area identified for the sampling event. Groundwater well S3 was not located in the field and is presumed to have been destroyed, potentially by road maintenance or general construction activities in the area. Groundwater well SRK08-SBR3 was found dry during the time of sampling.

Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, uranium, and zinc in groundwater exceeded the CCME FAL guidelines in one or more samples collected from the S-Wells area. Field and/or laboratory groundwater pH in the S-Wells area was outside the CCME FAL guideline range in thirteen (13) of the sixteen (16) samples collected. Field dissolved oxygen concentrations were below the CCME FAL minimum guideline concentration for eight (8) of sixteen (16) samples collected in this area.

Groundwater was found to be turbid at site S2A (78.2 NTU) during the time of sampling. Groundwater turbidity of all other collected samples down gradient of the CVD area was less than 50 NTU.

0.9 m of the well casing had to be removed from well S2A in order to be able to purge the well. This is not considered to have affected groundwater quality, and no repairs are considered necessary at this well.

### Groundwater Vangorda/Grum

Groundwater wells located in the Vangorda/Grum area were sampled on June 3, 2016. Samples were collected from all four (4) wells in this area identified for the sampling event.

Concentrations of dissolved arsenic, cadmium, iron, uranium, and zinc in groundwater exceeded the CCME FAL guidelines in one or more samples collected from the Vangorda/Grum area. Field dissolved oxygen concentrations were below the CCME FAL minimum guideline concentration for all measurements collected in this area.

Groundwater turbidity in all samples within this area was less than 50 NTU.

## Quality Assurance and Quality Control Results

Five (5) duplicate groundwater samples were collected during the June 2016 sampling event. One (1) travel blank was provided by the laboratory and accompanied the samples throughout the program. Three (3) field blanks were prepared during the sampling program between June 1 and June 3, 2016. The detailed results of the QA/QC sampling program are provided in **Table 3-2**, including RPD values for all duplicate and sample pairs collected.

### Field and Travel Blanks

All field blank and travel blank analytical results were reported less than the Reportable Detection Limit (RDL) with exception of acidity as CaCO2 which was detected in one (1) field blank (FB1), as well as the laboratory supplied travel blank. In both cases, acidity was measured slightly greater than the RDL (1.2 and 1.6 mg/L, RDL <1.0; **Table 3-2**). The program analytical supplier (ALS Global) indicated that this occurs periodically through the absorption of carbon dioxide into deionized water, and that it should not be considered as a form of contamination at the field or laboratory level.

All other travel blank and field blank analytical results were reported as less than the RDL.

### Field Duplicates

#### P01-02A / DUP3

The RPD value for acidity (44.90%), between P01-02A and DUP3, was reported outside the acceptable range of variability (<20%). Field notes and measurements do not identify any potential source of contamination or suggest variability in groundwater quality during the purging process (**Table 3-3**). All other analytical results for this duplicate pair were within the 20% RPD threshold limit (**Table 3-2**).

#### P01-01B / DUP4

The RPD values for all corresponding pairs of results between P01-01B and DUP4 were within the 20% QA/QC threshold, indicating that sampling variation was within acceptable limits.

#### CH15-107-MW034 / DUP5

The RPD values for all corresponding pairs of results between CH15-107-MW034 and DUP5 were within the 20% QA/QC threshold, indicating that sampling variation was within acceptable limits.

#### CH15-107-MW009 / DUP2

The RPD value for acidity (39.18%), between CH15-107-MW009 and DUP2, was reported outside the acceptable range of variability. Field notes and measurements do not identify any potential source of contamination or suggest variability in groundwater quality during the purging process (**Table 3-3**). All other analytical results for this duplicate pair were within the 20% RPD threshold limit (**Table 3-2**).

#### SRK05-SP-4A / DUP1

The RPD value for acidity (34.78%), between SRK05-SP-4A and DUP1, was reported outside the acceptable range of variability. Field notes and measurements do not identify any potential source of contamination or suggest variability in groundwater quality during the purging process (**Table 3-3**). All other analytical results for this duplicate pair were within the 20% RPD threshold limit (**Table 3-2**).

### Quality Assurance and Quality Control Summary

Results for the QA/QC analytical program did not show evidence of sample contamination, and show only minor variability of one parameter during the field collection and laboratory processes. Overall, amongst the three (3) field blanks, analytical results show no detections related to contamination. Results from the one (1) travel blank that accompanied the samples throughout the program also show no detections related to contamination. This suggests that the reported results are likely reflective of current onsite conditions and that no contamination occurred during field collection or sample transportation.

Duplicate and duplicate pair analytical results demonstrated several isolated cases of variability in acidity. Overall, amongst five (5) duplicate sample pairs, cases of RPD exceedances occurred in three (3) for acidity, which is considered to be related to variations in local chemistry and not field contamination. Additionally, the variances observed appeared to be isolated, and did not constitute a systematic difference amongst various parameters. Accordingly, the observed RPD exceedances are not considered to be the result of a sampling bias or error, but rather the result of slight variations in groundwater quality during sampling.

# Recommendations

Hemmera/ELR prepared the following recommendations based on the observations and results of the June 2016 groundwater sampling program.

1. Wells that produce consistently turbid groundwater should be re-developed in order to allow for the collection of a more representative sample.

Groundwater was found to be extremely turbid at sites X17B (914 AU) and S2A (78.2 NTU) during the time of sampling. These conditions may improve if these wells are re-developed. Both wells were observed to have excellent recharge and could be re-developed without any external water additions or repeat visits.

1. Destroyed wells should be removed from the SOW to avoid confusion during future sampling events.

Well S3 was not located during the June 2016 sampling event. This information was communicated to AAM during the site field visit. Groundwater well S3 has likely been destroyed during maintenance work within the area.

1. Well P01-02B should be assessed using a downhole camera to determine what the blockage is, and whether it may be possible to remove it. If the assessment determines that it can be removed without risk of worsening the blockage, then a removal attempt should be made.

# Closure

We have appreciated the opportunity of working with you on this project and trust that this report is satisfactory to your requirements. Please feel free to contact the undersigned regarding any questions or further information that you may require.

Report prepared by:

ELR

per: Aaron Nicholson, B.Sc., EP

Environmental Scientist

aaron@elr.ca

Report peer reviewed by:

Hemmera Envirochem Inc.

Natasha Sandys, B.Sc., EP

Environmental Scientist

nsandys@hemmera.com

Report senior reviewed by:

ELR

Chris Jastrebski, M.Sc., R.P.Bio.

Project Manager

chris@elr.ca

Report senior reviewed by:

Hemmera Envirochem Inc.

Jason Wilkins, P.Ag., EP, CSAP

Director, Land Development and Projects

jwilkins@hemmera.com

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TABLES

Appendix A

Site Photos

Appendix B

Field Forms

Appendix C

Laboratory Analytical Reports

Appendix D

Response to Comments Received on Draft Report