Mount Nansen Care and Maintenance Project

Project Proposal

Appendix 6A

Hydrogeology Existing Conditions

September, 2017

Government of Yukon

Energy, Mines and Resources

Assessment and Abandoned Mines

Executive Summary

Yukon government, Assessment and Abandoned Mines (AAM) is preparing for an assessment of proposed care and maintenance activities at the Mount Nansen Site (the Site), an abandoned gold and silver mine located approximately 45 km west of Carmacks, YT. In support of that application, this report describes the current understanding of hydrogeology at the Mount Nansen Site. This report outlines the findings of hydrogeological investigations conducted from 2004 to 2013, including field investigations and information from the existing groundwater monitoring network at the Mount Nansen Site.

The Site monitoring network consists of existing monitoring wells from previous hydrogeological investigations and from instrumentation installed prior to and during a 2013 field investigation. Pre-2013 water level and temperature instrumentation was installed inside the Brown McDade Pit to record the Pit pond level and groundwater level within the fractured bedrock Pit floor, adjacent to the pond. Other pre-2013 instrumentation records groundwater levels in two monitoring wells constructed north of the Pit, adjacent to the public road. Of these monitoring wells external to the Pit, one has experienced intermittently freezing conditions and the other has experienced permanently freezing conditions. In 2013, a series of additional loggers, thermistors, and vibrating wire pezometers (to measure water level) were installed in newly developed coreholes, primarily in relation to the Brown Mc Dade Pit.

Highly conductive conduits for groundwater movement were not detected during the 2013 packer testing program, although outlier values were recorded. The most conductive result was 10^{-6} m/s (-5.89 log 10 (K)). The hydraulic conductivity of the rock mass forming the Brown McDade Pit area and pit floor can be considered to be at the mid to lower end of the hydraulic conductivity scale, typical for fractured granitoid rocks, although it is not impermeable to groundwater flow over long time periods.

All sensors respond quickly to the onset of freshet with pressure heads at 20 m, 30 m and 40 m increasing on the order of +/- 15 m relative to baseflow conditions (winter levels). In time, recharged water reaches the 60 m depth and pressure heads at this depth begin to rise. At the onset of freshet or the fall rain season, groundwater gradients show a strong downward gradient (i.e., piezometric elevations at surface are greater than those at depth). Eventually, groundwater levels at depth begin to rise, reflecting conditions as fractures in bedrock become completely saturated. The maxima in the Brown McDade Pit pond lags the maxima observed in groundwater levels at 50 and 60 m below ground surface, suggesting that at the pond there is possibly a correlation between bedrock saturation and Pit filling.

During the winter months the Pit pond level and groundwater levels drop with minima's occurring during the month of April. In April, the pressure heads at 20 m, 30 m and 40 m were below their installation depths indicating dry conditions. However, pressure heads at 50 and 60 m depths indicated saturated conditions as levels were above their installation elevation. Baseflow regional groundwater

levels, as experienced during winter low-recharge conditions, occur at about elevation 1,156 m, which is approximately 20 m below the Brown McDade Pit floor.

During freshet, the groundwater piezometric surface across the Site grades from north to south with an elevation of approximately 1,187 m in north to 1,167 m at the southern end. The piezometric surface traverses the Brown McDade Pit floor which ranges in elevation from 1,176 m to 1, 179 m. At present, there is insufficient information to develop a map of the groundwater piezometric surface representative of winter baseflow conditions. Additional deeper bedrock installations surrounding the pit would be required to confirm the seasonal variations of the groundwater piezometric surface beneath.

Vertical groundwater gradients in Dome and Pony creeks were only somewhat consistent with the seepage meter results. The majority of creek stations gave negative (i.e., downward), groundwater directions indicative of losing creek water. This was at variance to the temperature survey and seepage meter findings. Only two stations had positive (i.e., upward), groundwater directions, corresponding to the most upstream station on Dome Creek and one station downstream of the tailings pond. The vertical gradients, therefore, may have been skewed by the onset of freezing conditions that influenced drive-point water levels.

Net groundwater exchange was determined by the residual value remaining after summing net surface water inflow and pond level change. The groundwater component of the Brown McDade Pit pond was variable, with have a net loss over the four year period of studies. The rate of water loss from the Brown McDade Pit pond was quantified as being 0.2 L/s (17.3 m^3/d). The average derived from the three wintertime pond elevation declines is greater than that quantified from water balance methods (0.46 L/s), which contain an unquantified, although previously assumed low, contribution of the Pony Creek seepage. The pit pond decline method of evaluating groundwater outflow is unaffected by the exclusion of Pony Creek seepage and is more selective for quantifying groundwater exchange compared to the water balance method. The 2013 site investigation findings were used to update a documented hydrogeological conceptual site model

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1 Introduction

Yukon Government, Assessment and Abandoned Mines (AAM) is preparing for an assessment of proposed care and maintenance activities at the Mount Nansen Site (the Site), an abandoned gold and silver mine located approximately 45 km (70 km by road) west of Carmacks, Yukon (herein referred to as the Site). The Mount Nansen Care and Maintenance Project (MNCMP) will include site inspections, maintenance, water monitoring, management treatment, as other activities that are conducted to protect human health, safety and the environment at the Mount Nansen Site (the Site). The MNCMP is proposed to have a five year term.

This document forms part of the Care and Maintenance Project Proposal (CMPP) for assessment by the Yukon Environmental and Socio-economic Assessment Board (YESAB). This report describes recent and current hydrogeology conditions at the Mount Nansen Site (the Site). . The results are based on the findings of hydrogeological investigations conducted from 2004 to 2015, including field investigations and information from the existing groundwater monitoring network at the Mount Nansen site. The most recent study, a 2013 field investigation, was designed on the basis of the findings of five hydrogeological summary reports of site investigations during the period 2004 to 2009, inclusive. Details of this 2013 hydrogeological field investigation are summarized in the Site Investigation Data Report (AMEC, 2014a) and the Site Characterization Report (AMEC, 2014b). Groundwater monitoring that occurred from October 2013 to July 2014 are also summarized in the 2014 Site Investigation Report and Site Characterization Update (AMEC Foster Wheeler, 2015).

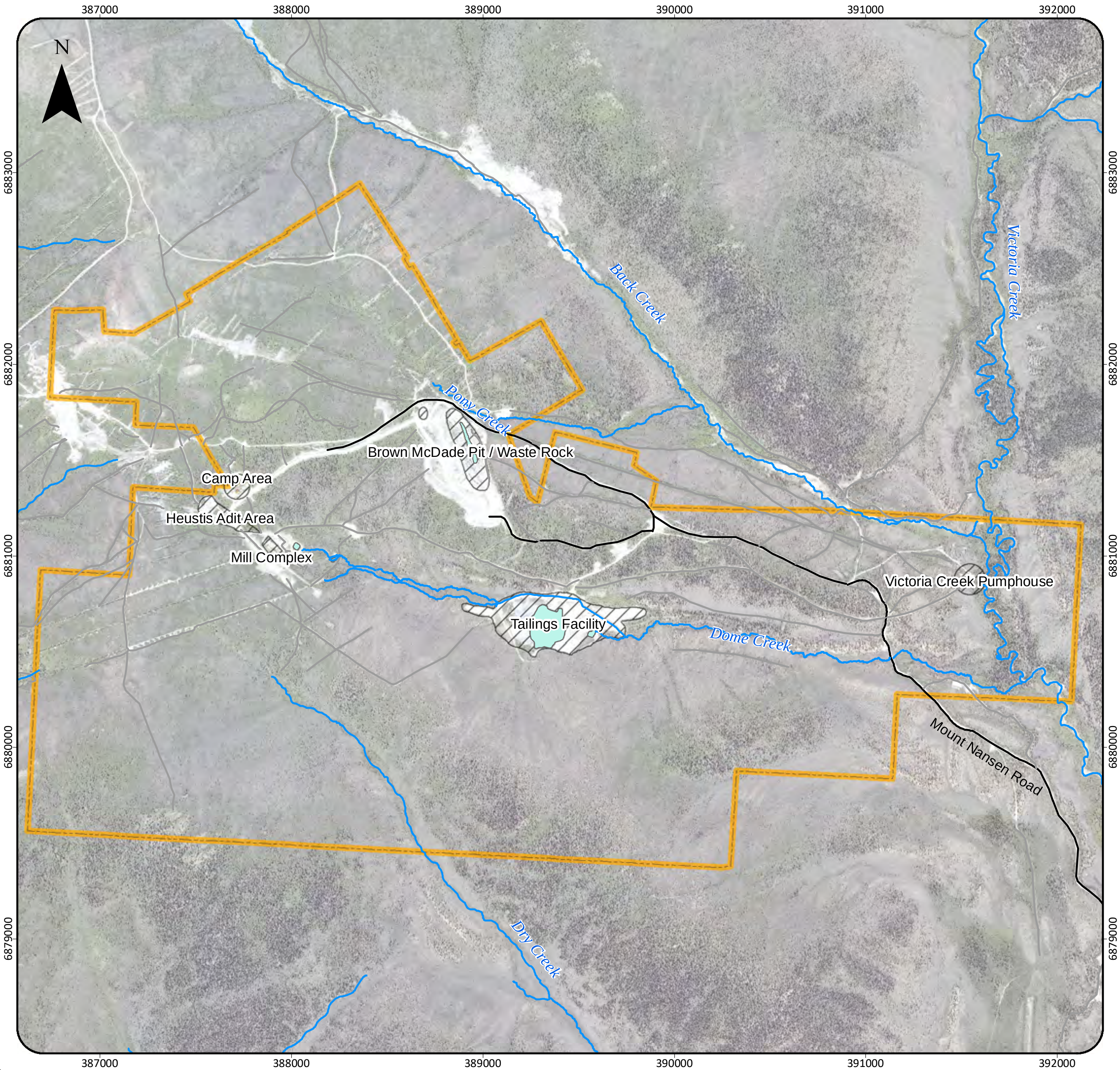
The following sections provide the results of the 2013 hydrogeological field investigation and previous reports using data from the overall existing groundwater monitoring network, hydrostratigraphy at the Site, interpretation and mapping of regional groundwater levels, results of the Dome Creek and Pony Creek groundwater-surface interaction study, a discussion on groundwater and Huestis Adit, the Brown McDade Pit pond groundwater exchange, and the development of the conceptual hydrogeologic model.

2 Study Area

The hydrogeology existing conditions study area is based on the Order in Council (OIC) area, which encompasses the extent of the existing infrastructure at the Site. The primary areas of interest in relation to the MNCMP included the mill area and Huestis Adit, the Brown McDade Pit, the Tailings Storage Facility (TSF), as well as Pony and Dome creeks. A summary of the existing infrastructure areas is presented in Figure 2.0-1.

Mount Nansen Care and Maintenace Project Proposal
Hydrogeology Existing Conditions

Figure 2.0-1
Overview of Existing Infrastructure



Energy, Mines and Resources
Assessment and Abandoned Mines

Watercourses
Trails
Roads
Waterbodies
Site Infrastructure

Local Boundaries

Order In Council Area

Data Source:

1. Site features (e.g., roads, trails, waterbodies, watercourses and infrastructure areas) digitized from imagery.
2. 2008 Quickbird imagery and spatial data provided by Yukon government.

Datum: NAD 1983 CSRS UTM Zone 8N

Scale 1:30,000

Kilometers
0 0.5 1

March 2, 2017

Document Path: M:\Projects\16-249 MN CMPP\Map_Files\Baseline Report Updates\Hydrogeology Report\2017 03 02 Fig 2.0-1 exsiting infrastructure Overview.mxd

3 History of Hydrogeological Investigations

A number of hydrogeological investigations have taken place at the Site from 2004 onwards. These studies have included the installation of a series of groundwater wells, drive points, and related instrumentation, as well as various tests to investigate groundwater conductivity, levels, and flows.

For the purpose of this summary report, previous works have been divided into an initial site characterizations phase that occurred between 2004 and 2009 and a remediation planning phase that occurred in 2013. The latter is based on a data review and data gaps analysis based on all prior results available at the time. Study efforts and purposes are described below.

For hydrogeological characterization purposes, the surficial materials and bedrock at Mount Nansen had been categorized into four hydrogeological media types, namely: overburden, shallow fractured rock, competent rock and tailings.

3.1 Hydrogeological Characterizations: 2004 to 2009

Programs conducted between 2004 and 2009 each involved a components of hydrogeological investigation and characterization. These hydrogeological assessments focused on the Brown McDade Pit, the Tailings Pond and the surface water courses transecting and receiving waters from the Mount Nansen site. The findings from these pre-2013 studies are documented in five reports, as follows:

- Brown McDade Hydrological & Hydrogeological Investigation (Gartner Lee, 2004). This study focused on a Brown-McDade Pit water budget and pit water chemistry to support a long-term pit management strategy and closure planning.
- Brown McDade Pit Summer Monitoring Data Summary Report (Gartner Lee, 2005). Additional field data were collected to refine a water balance of the Brown McDade Pit and water analyzed to characterize pit water and surface water (Pony Creek) at upstream and downstream locations, with respect to the Brown McDade Pit.
- Brown McDade Pit Desktop Hydrogeological Study (Gartner Lee, 2007). Development of a conceptual model continued, with the objective of describing the groundwater and surface water hydraulics of the Brown-McDade Pit together with the potential receiving waters, (i.e. Dome Creek, Pony Creek and Victoria Creek).
- Hydrogeological Site Characterization at Brown McDade Pit (Gartner Lee, 2008). This study refined the conceptual groundwater model with respect to the Brown McDade Pit and provided a preliminary assessment of potential groundwater contaminant transport, in terms of direction and water quality.
- Hydrogeological Field Investigation Summary (AECOM, 2009). During this investigation, 21 new monitoring wells were constructed, sampled and surveyed, along the north side of Brown McDade Pit (Nansen Road) and within the ‘beach’ areas of the Tailings Pond.

3.2 2013 Field Investigation in Support of Remediation Planning

The overarching objective of the 2013 investigation was to continue development of the conceptual site model that had evolved during 2004 to 2009, by adding the level of detail needed to support engineering design for Site remediation. This involved quantifying plausible ranges of hydrogeological influencing parameters associated with various Site areas in order to support current and forecasted surface water quality evaluations. Accordingly, the 2013 field investigation focused primarily on the Brown McDade Pit interior and its surroundings, the Huestis Adit area, as well as Dome and Pony Creeks. The specific objectives for each of these areas were:

- Brown McDade Pit – to evaluate of the rock mass forming the pit floor, pit walls and adjacent rock, to refine hydraulic properties potentially facilitating groundwater movement at and near the pit, as well as to investigate the presence and state of permafrost that is potentially constraining groundwater movement.
- Huestis (4100) Adit – to evaluate the area of this collapsed former portal, which forms the lowest known man-made outlet for mine drainage leaving the Huestis Deposit underground workings, potentially releasing mine water into the upper reaches of Dome Creek.
- Dome Creek and Pony Creek – to evaluate groundwater exchange with surface water, as potential recipients of groundwater moving at and near the Brown McDade Pit.

Detailed findings of the 2013 site investigations are documented in the following report.

- Mount Nansen Remediation Project, Site Characterization Report (AMEC, 2014b).

4 Analysis and Interpretation

4.1 Field Investigation Methods

Several field methods were employed during site investigations and characterizations, as summarized below:

4.1.1 Groundwater Well Installations

Approximately 64 groundwater wells have been installed at the Site from 2004 onwards, most of which have been used for monitoring of groundwater quality, with a subset being used for monitoring of hydrogeological conditions.

The majority of wells were installed in 2007 and 2009, and were shallow to intermediate depth groundwater monitoring wells with the intent of providing information on shallow groundwater elevations and quality. At the time, data objectives were associated with the Brown McDade Pit, Dome Creek, Pony Creek, the Mill and Tailings Pond areas, with shallow well screens installed into overburden and tailings.

4.1.2 Packer Permeability Tests

To estimate the hydraulic conductivity of the bedrock, packer permeability tests were performed from 2004-2009 involving a double-packer system. Packers were lowered down the hole inside the drill rods to the bit and inflating them to create an isolated test zone between the packers and the bottom of the hole. After isolation, a constant pressure head was applied to the test interval and maintained using a pump located at the surface. For each test, three ascending and two descending pressure stages were applied. A flow totalizer was used to record the volume of water that is pumped down the hole during each test over a given time, typically between one and five minutes. The bulk hydraulic conductivity across the test interval was then computed using a formula involving the applied pressure differential, the observed steady-state flow rate, and an empirical shape factor based on the geometry of the test interval.

The 2013 field investigation involved packer testing of the coreholes advanced in the Brown McDade Pit area. Packer testing of the coreholes was conducted to generate estimates of bedrock hydraulic conductivity in the Brown McDade Pit area and also to delineate zones of preferential groundwater flow associated with secondary porosity (fractures/faulting). Details of packer testing methods and results are summarized in the 2013 Site Investigation Data Report, dated March 11, 2014, Appendix A3 of AMEC (2014a).

2013 testing involved single packer equipment, capable of both constant head and falling head type hydraulic conductivity testing, with a lower quantification threshold on the order of 1 x 10-9 m/s, that is, the lowest measurable hydraulic conductivity. For test results at, or less than this threshold, a corresponding 'no flow' comment was noted in the test logs.

In 2013 a total of 32 packer tests were conducted involving sealing 5 m long test intervals of corehole wall. Water was either injected at a constant pressure to measure flow (constant head) or the packer equipment was filled and allowed to drain over time with the pressure change being measured (falling head). Packer testing was not possible in highly weathered and weaker rock portions of coreholes as the packer required competent and intact rock for a sufficient water pressure seal.

4.1.3 Shut-in Pressure Tests

In-situ packer shut-in pressure tests in exploration boreholes are used to characterize in-situ groundwater pressures and gradients. Tests are conducted by positioning the drill rods such that an open section exists between the rods and the bottom of the hole; an inflatable double-packer membrane then is lowered inside the drill rods to the bit and inflated to seal off the interval at the bottom of the hole. After packer inflation, the pressure response in the bottom interval is monitored with an electronic pressure transducer until an equilibrium pressure is attained.

4.1.4 Groundwater Sampling

Groundwater sampling according to industry standard practices has been conducted by several individuals or firms on an ongoing basis, providing data to support both the hydrogeology and groundwater quality disciplines. The general methodology employed for groundwater sampling has included purging at least three well volumes to remove stagnant water from the casing and filter pack prior to collecting groundwater samples, although parameter stabilization methods have also been used more recently. For this latter technique, in-situ parameters including pH, temperature, and electrical conductivity are monitored and purging continued until these parameters stabilize, indicating that stagnant water has been sufficiently removed.

Samples are collected from each well using dedicated tubing or other sampling devices and immediately placed into the appropriate sterile sample containers provided by the laboratory. Samples are filtered and/or preserved as required, and stored in coolers with ice packs at approximately 4°C until they can be transported to a laboratory for analysis under standard chain of custody procedures.

At the time of sampling, the condition of the well and the static water level within the well are also recorded, which provides data to support site hydrogeological calculations.

4.2 Water Balance Model Input and Interpretation

Groundwater data collected was used to determine groundwater recharge and discharge on a month to month basis as is commonly used for hydrologic evaluations. The method provides a simple technique to characterize the interaction of surface water and groundwater components of a flow system, including climate data, streamflow data, snowpack data and groundwater level data. Groundwater recharge was dependant on the water available at ground surface and was adjusted to allow variation in response to effects from surface conditions, soil permeability and available storage capacity.

A linear reservoir model was used characterize the storage and release of groundwater, with water recharged into groundwater storage. The recharged water accumulated within the groundwater compartment was released at a rate determined by the product of the average volume of water in storage and a discharge factor. Month to month storage was allowed, with increasing discharge rate with increasing storage. The volume of water in storage was therefore a sum of the storage in the preceding month plus the volume of water entering the system minus the quantity discharged. Corrections were included to prevent negative storage.

4.3 2013 Dome Creek and Pony Creek Groundwater Interactions Study

Dome Creek and Pony Creek were characterized in terms of identifying losing and gaining reaches and to quantify the rates of groundwater exchanging along these respective creek beds. The timing of the groundwater-surface water interaction study coincided with a period of lower surface water flows (September 2013), shortly before winter freeze-up when relative groundwater contributions to surface water would theoretically be near a maximum, based on commonly-accepted understanding of surface water seasonal flow.

This aspect of the hydrogeology of Mount Nansen was used for the Site-wide water quality modelling, with respect to quantifying the groundwater component contributing to Dome Creek and Pony Creek flows, which is as distinct from surface runoff.

The specific data collection objectives for the creek groundwater-surface water interaction study included:

- Vertical hydraulic gradients - obtained from temporary creek bank drive-points, installed in pairs, shallow (A) to 1.5 m and deep (B) to 3 m below surface.
- Creek bed pore water temperature - obtained from a 0.5 m long probe and pilot hole tool, to obtain creek bed pore water temperature.
- Creek bed groundwater seepage rate (flux) - obtained from three seepage meters, connected to a water storage bag, for water gain or loss measurement, to derive a groundwater flow rate per unit time per unit area.

The vertical gradients were obtained using Solinst drive-point piezometers fitted with 0.15 m long screened tips. The creek bed porewater temperature survey used a Field Scout meter connected to a 0.5 m long temperature probe. Three seepage meters were custom-manufactured for the creek study by Oak Environmental, each consisting of a low-profile, 0.099 m^2 area (14-inch diameter) metal tube, closed at the top, with a side port and tubing connected to a water storage bag. The change in water mass, either collecting in the bag (gaining creek segment) or leaving the bag (losing creek segment), was measured versus elapsed time to give the water mass change per unit time. Three seepage meters were used to enable simultaneous testing at different creek stations.

Fifteen creek study locations, or stations, were selected (ten on Dome Creek and five on Pony Creek), at which vertical gradient, creek bed porewater temperature and seepage meter flow data were collected. The temperature survey included several additional locations between the 15 stations, to increase the survey resolution. One station (DC-04) was deleted from the program due to shallow refusal of the drive-points, later determined to be due to frozen materials.

5 Description of Site Instrumentation

In addition to static measurements taken during groundwater sampling events, there is a network of monitoring wells at the Site that have instrumentation installed to measure groundwater level and/or temperature on an ongoing basis. This network consists of monitoring wells and/or instrumentation from well installations between 2004 and 2009, as well as additional wells and/or instrumentation installed during the 2013 field investigation. The location of Site instrumentation is shown in Figure 5.0-1, and a summary of all instrumentation currently installed for recording Pit water level, fractured bedrock groundwater levels (piezometric elevation) and temperature is provided in Table 5.0-1. This table summarizes the locations, types, configurations, data period and graphical output reference for each of the dataloggers. The most recent field download of instrumentation occurred in February of 2015.

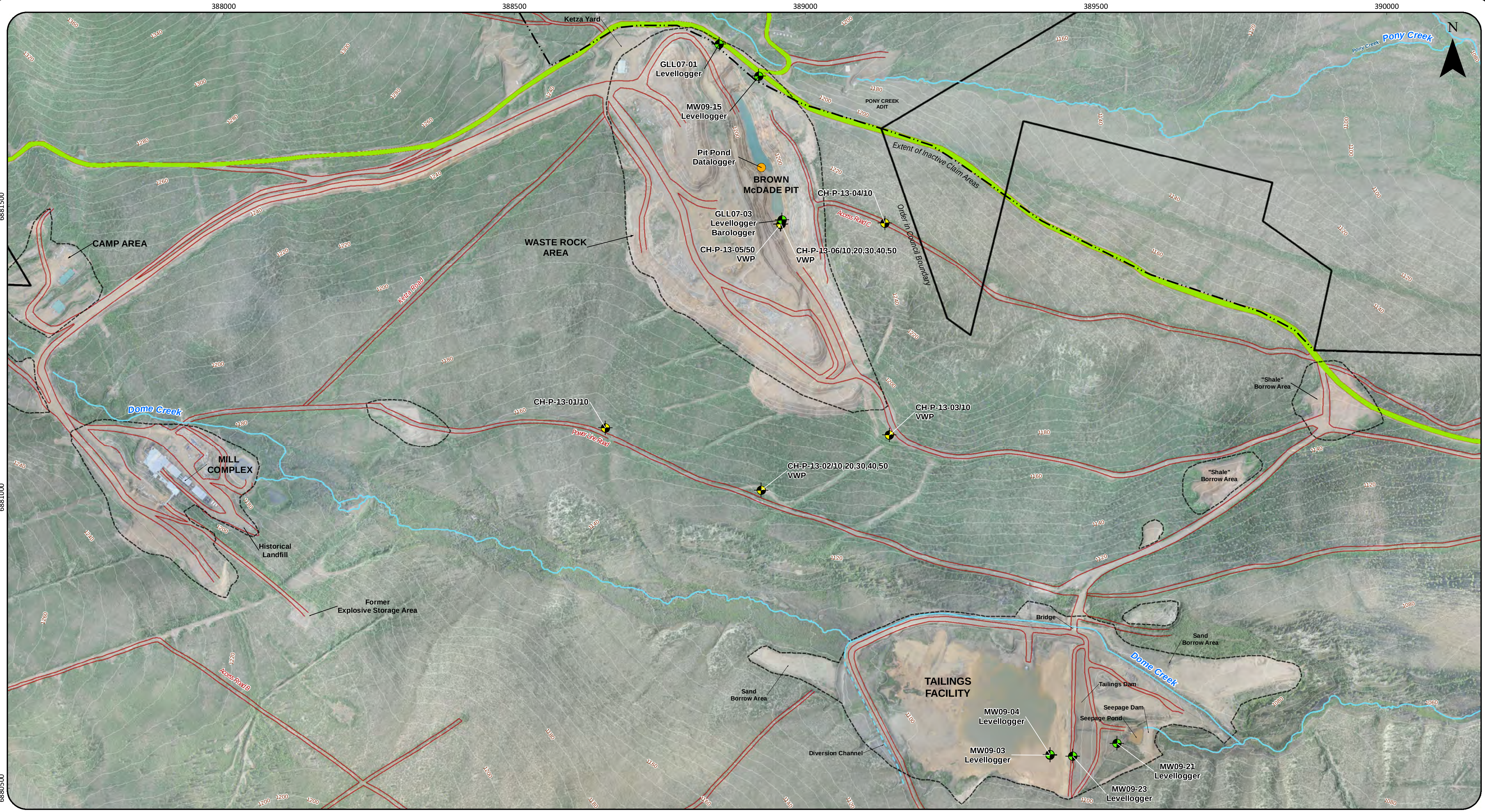
The first water level and temperature instrumentation to be installed at the Site was in and north of the Brown McDade Pit. Dataloggers were installed to record the Pit water level, as well as the groundwater level within the fractured bedrock Pit floor (well GLL07-03) adjacent to the pit pond. The latter was installed in a corehole that was extended to an elevation equivalent to the deepest portion of the Pit pond (El. 1074 m). Dataloggers were also installed in two monitoring wells north of the Pit, adjacent to the public road. Of these, one has experienced intermittently freezing conditions (MW09-15) and the other has experienced permanently freezing conditions (GLL07-01).

In 2013, five vertical coreholes were advanced to a depth of 50 metres below ground surface (mbgs). CH-P-13-05 was drilled inside the Brown McDade Pit and four (CH-P-13-01, CH-P-13-02, CH-P-13-03 and CH-P-13-04) were drilled along the pit periphery. One other corehole (CH-P-13-06) was drilled to a depth of 60 m at a 45° inclination, from the Brown McDade Pit floor (i.e. approximately 42 m vertically) to intercept discontinuities and fracture zones along the Brown McDade Pit east wall associated with geological faulting, as had been mapped during mining activities.

With the exception of the first corehole (CH-P-13-01), vibrating wire piezometers (VWPs) were installed into each corehole on completion and later connected to data loggers to record pressure and temperature readings from each piezometer (detailed in Table 3.2-1). Additionally, adjacent to the four coreholes outside the Brown McDade Pit, a 10 m borehole was drilled into which a PVC monitor well was installed to full borehole depth (e.g. CH-P-13-01/10 see Table 3.2-1). These four 'companion' monitoring wells were fitted with 3 m long intake screens, intended to enable groundwater monitoring in the shallow, active layer.

Two types of dataloggers are currently in service: Leveloggers (Solinst) and vibrating wire piezometers (RST Instruments). One Barologger (Solinst) is located within the Brown McDade Pit, dedicated to recording atmospheric pressure for a Project-wide barometric pressure. Note that loggers for GLL07-01, MW09-15, MW09-21 and MW09-23 appear to have run out of memory prior to the download event in July. All dataloggers were reset by the Government of Yukon – Department of Energy, Mines & Resources – Assessment and Abandoned Mines Branch (AAM) late in 2014 and were downloaded by AAM in December 2014 and February 2015.

During coring of the first corehole (CH-P-13-01), extensive weathering of the bedrock was encountered, as shown in the lowest Solid Core Recovery (SCR) and Rock Quality Designation (RQD) values of all the coreholes. The degree of weathering decreased somewhat after 35 m depth below surface grade. At 40 m depth, flowing artesian conditions were suddenly encountered that necessitated the cessation of coring activities. Using the packer equipment, the flowing artesian condition was measured as being 1.2 L/sec and a shut-in pressure of 110 kPa (16 psi) was measured, equivalent to 11.25 m of water column above a hydrostatic-balanced condition. Corehole CH-P-13-01 was plugged and sealed with cement. Instrumentation was not installed. The occurrence of flowing artesian conditions showed that the Dome Creek valley area surrounding this first corehole appears to be similarly influenced. By addition of the depth that artesian conditions were encountered and the packer shut-in pressure, expressed in metres of water column, the artesian pressure has a piezometric elevation of 1,163 m at corehole CH-P-13-01. On this basis, flowing artesian conditions are likely to be present in the deeper bedrock around corehole CH-P-13-01, wherever the ground surface grade is below elevation 1,163 m.

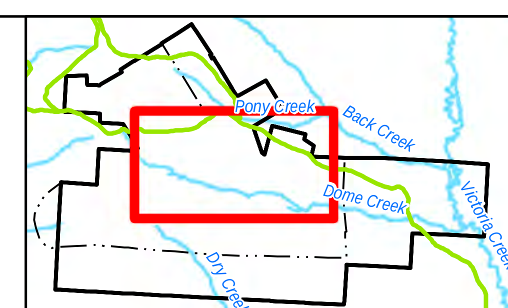


Data Source:
Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 CSRS UTM Zone 8N

Legend
- Order in Council Boundary
- Extent of Inactive Claim Areas
- Public Road
- Road
- Stream
- Diversion Channel
- Contour (20 m)
- Contour (5 m)
- Groundwater Monitoring Installations
- Historic Monitoring Wells
- Dataloggers
- Disturbed Area



Yukon
Energy, Mines and Resources
Assessment and Abandoned Mines

MOUNT NANSEN SITE
FIGURE 5.0-1
CARE AND MAINTENANCE
PROJECT PROPOSAL
SITE DISTRIBUTION OF EXISTING
GROUNDWATER MONITORING LOCATIONS

Scale 1:6,500
Metres
0 130 260

February 22, 2017

S:\PROJECTS\VM00605 - Mount Nansen\GIS\Mapping\Ver2015_RemediationProposal\VM00605_GroundwaterMonitoringLocations_v2.mxd

Table 5.0-1: Summary of Groundwater/Hydrogeologic Datalogger Installations

Mine Element Monitored	Datalogger Identification and Installation Type	Datalogger Sensor Details	Datalogger Data Period	Graph Figures
Brown McDade Pit, interior, pond.	Pit Pond - free water Levelogger.	Pond water suspended.	4/Aug/'10 to 18/Feb/'15.	Figure 6.2-1 - piezometric elevation and temperature. Pit floor inaccessible due to pit wall stability issues in May 2015.
Brown McDade Pit, exterior, northwest.	GLL07-01 - free water Levelogger.	Monitoring well suspended.	2/Sep/'09 to 27/Mar/'14.	Figure 6.2-1 - piezometric elevation showing frozen conditions. Pit floor inaccessible due to pit wall stability issues in May 2015.
Brown McDade Pit, interior, gives Project-wide barometric reference.	GLL07-03 - free air Barologger.	Air suspended.	11/Aug/'10 to 18/Feb/'15.	Not graphed separately. Pit floor inaccessible due to pit wall stability issues in May 2015.
Brown McDade Pit, interior, pit floor.	GLL07-03 - free water Levelogger.	Monitoring well suspended.	11/Aug/'10 to 22/Dec/'15.	Figure 6.2-1 - piezometric elevation. Pit floor inaccessible due to pit wall stability issues in May 2015.
Brown McDade Pit, exterior, northeast.	MW09-15 - free water Levelogger.	Monitoring well suspended.	11/Aug/'10 to 10/Feb/'14.	Figure 6.2-1 - piezometric elevation showing freeze-thaw conditions. Pit floor inaccessible due to pit wall stability issues in May 2015.
Brown McDade Pit, exterior, southwest.	CH-P-13-02 - grouted-in RST vibrating wire.	10 m (El. 1139.1 m), 20 m (El. 1128.7 m), 30 m (El. 1118.3 m), 40 m (El. 1108.6 m), 50 m (El. 1097.9 m).	04/Oct/'13 to 13/May/'16.	Figure 6.2-2A - piezometric elevation (50 m malfunction after Nov 2013); and Figure 6.2-2B - thermistor temperature. Data presented to end of December 2015.
Brown McDade Pit, exterior, south.	CH-P-13-03 - sand pack RST vibrating wire.	50 m (El. 1134.3 m).	14/Nov/'13 to 13/May/'16.	Figure 6.2-3 - piezometric elevation. Non-valid thermistor temperature. Data presented to end of December 2015.
Brown McDade Pit, exterior, east.	CH-P-13-04 - sand pack RST vibrating wire.	35 m (El. 1190.6 m).	31/Oct/'13 to 22/Jul/'14.	Figure 6.2-4 - thermistor temperature. Non-valid piezometric elevation.
Brown McDade Pit, interior, pit floor.	CH-P-13-05 - sand pack RST vibrating wire.	50 m (El. 1135.6 m).	15/Nov/'13 to 22/Jul/'14.	Figure 6.2-5 - thermistor temperature non-valid starting 11/Mar/'14. Non-valid piezometric elevation.
Brown McDade Pit, interior, pit floor and east wall.	CH-P-13-06 - grouted-in RST vibrating wire. Inclined at 45 °.	10 m (El. 1170.7 m), 20 m (El. 1164.3 m), 30 m (El. 1156.6 m), 40 m (El. 1150.1 m), 50 m (El. 1143.4 m).	05/Oct/'13 to 18/Feb/'15.	Figure 6.2-6A - piezometric elevation and Figure 6.2-6B - thermistor temperature.
Tailings Storage Facility (TSF), interior tailings, shallow zone.	MW09-03 – free water Levelogger.	Monitoring well suspended.	17/Oct/'11 to 2/Jun/'12 17/Sep/'13 to 17/Feb/'16.	Figure 6.2-7 - piezometric elevation. Data presented to end of December 2015.
TSF, interior tailings, deeper zone.	MW09-04 – free water Levelogger.	Monitoring well suspended.	17/Oct/'11 to 2/Jun/'12 17/Sep/'13 to 17/Feb/'16.	Figure 6.2-7 - piezometric elevation. Data presented to end of December 2015.
TSF, exterior, dam east face.	MW09-21 – free water Levelogger.	Monitoring well suspended.	17/Oct/'11 to 15/Oct/'12, 4/Dec/'14 to 17/Feb/'16.	Figure 6.2-7 - piezometric elevation. Limited data available.
TSF, exterior, dam crest.	MW09-23 – free water Levelogger.	Monitoring well suspended.	17/Oct/'11 to 17/Feb/'16.	Figure 5.1-7 - piezometric elevation. Data presented to end of December 2015.

6 Results

Recently collected hydrogeology data analysed as part of this report were used to develop an update to previous reports (Gartner Lee 2004, 2005, 2007 and 2008; AECOM 2009 and 2010; AMEC 2014a and 2014b; AMEC Foster Wheeler 2015). This report is not a comprehensive account of the Project area hydrogeological conditions, but is rather should be viewed in conjunction with past reports.

6.1 Hydrostratigraphy

6.1.1 Geology

Corehole logs for the six coreholes completed in September 2013 are provided in Appendix A3 of AMEC (2014). These logs describe the cored rock during recovery, including rock type, fracture type, infill type and thickness, rock strength and weathering. Observations of long-term groundwater movement were also noted in the logs, as iron staining on discontinuity surfaces is indicative of contact with, or submergence by, oxygenated water percolating through the rock mass likely originating as meteoric (surface) water.

The corehole logs describe the majority of the upper 30 to 40 m of bedrock surrounding the Brown McDade Pit as being moderately to highly weathered. The logs also describe the rock as moderately to highly fractured, as quantified by low SCR and RQD values for the recovered core, per core run interval. These deep weathering profile observations are in agreement with the documented geological history of Mount Nansen, which escaped glaciation events that removed much of the weathered bedrock profile in other glaciated areas within the Yukon. Occasional evidence of permafrost was logged, although this was a chance occurrence and not an objective of the corehole logging program. One major rock weakness zone, possibly a geological fault, was encountered east of the Brown McDade Pit (CH-P-13-04), between 35 to 37 m depth (elevation 1,190.5 to 1,188.5 m). This 2 m thick zone was infilled with sand and soft clay with a reddish-brown colour indicative of oxygenated water movement to this depth in the host rock, at some time. This was the only logged encounter of a large-scale rock discontinuity zone. The other logs describe fracturing, mostly with fracture infill materials, on a centimetre or millimetre scale.

6.1.2 Hydraulic Conductivity

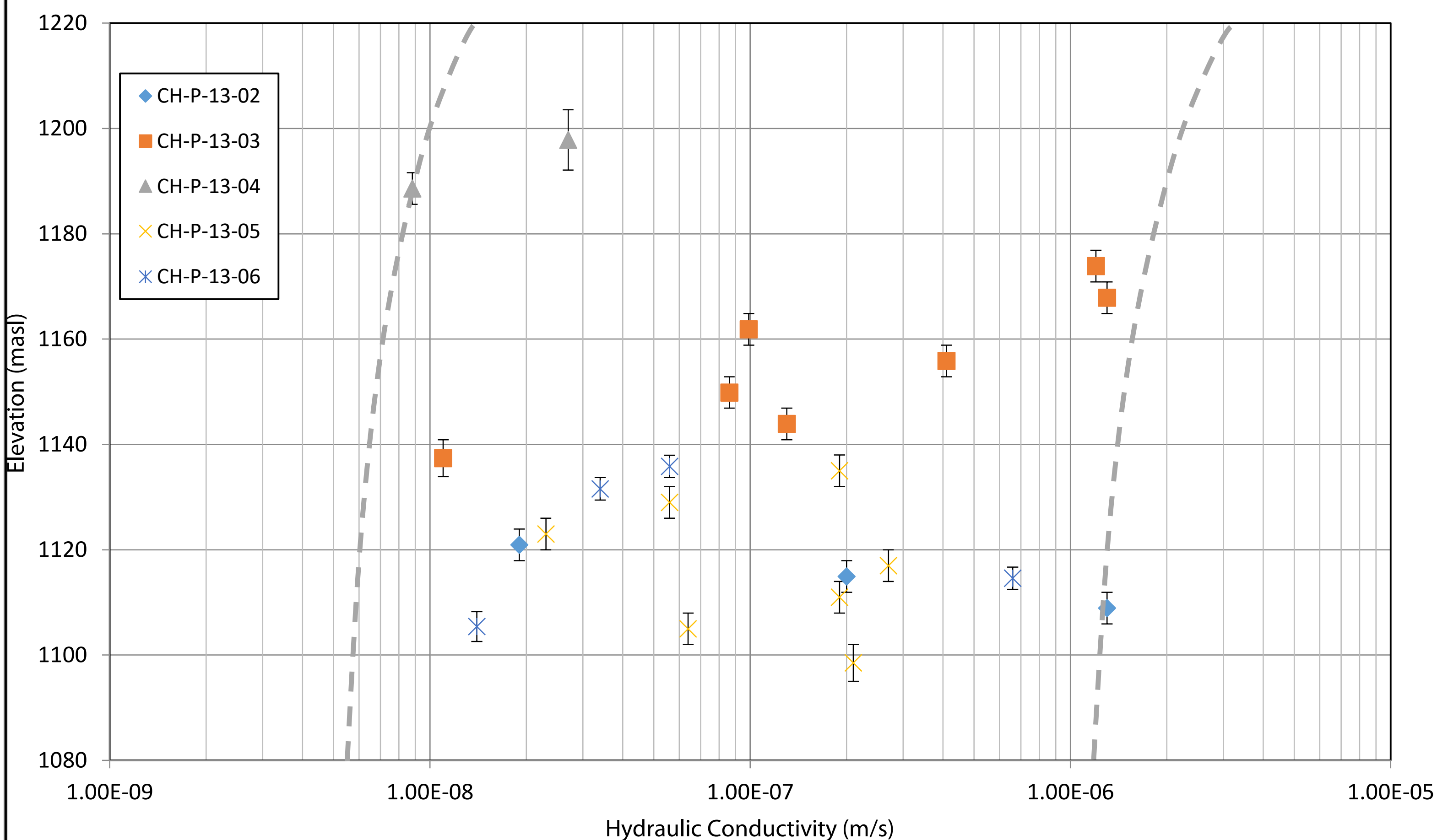
The results of the packer testing are summarized in Table 6.1-1 and also graphed versus elevation in Figure 6.1-1. The test results are shown plotted versus elevation. A moderately-correlating trend is present in the results from corehole CH-P-13-03 (southeast of Brown McDade Pit), with hydraulic conductivity decreasing with depth.

A circular grouping of test results is apparent from corehole CH-P-13-05 (Brown McDade Pit floor), without correlation to elevation, which is considered to be the result of mining disturbance (i.e. blasting). Several test results from lower elevation (i.e. deeper rock mass) stand out as outliers, notably from corehole CH-P-13-02/50 (elevation 1,109 m) and CH-P-13-06/60 (elevation 1,115 m). One interpretation of these occasionally higher values is that the coreholes intersected rock discontinuities with reduced, or absent, weathered rock (clay) infill materials.

Of the 32 tests summarized in Table 6.1-1, nine were recorded as 'no flow' and indicative of either an intact rock mass with minimal conductive fractures, or of permafrost presence, or both. A review of the hydraulic conductivity (K) values, by individual corehole, gave geometric mean values ranging from 1.5 x 10-8 m/s (CH-P-13-04) to 1.9 x 10-7 m/s (CH-P-13-03). The most hydraulically conductive test result was 1.3 x 10-6 m/s, occurring at corehole CH-P-13-03, (13 to 19 m depth, elevation 1,171 to 1165 m; southeast and downhill from the Brown McDade Pit), and at corehole CP-P-13-02 (34 to 40 m depth, elevation 1118 to 1109 m; southwest and downhill from the Brown McDade Pit). Overall, of the 23 hydraulic tests in which packer test flow was measured, a geometric mean K of 1.0 x 10-7 m/s was derived. The packer testing was not successful when rock weathering was greatest as the bladders were ineffective at sealing the corehole. As a result, the dataset for the upper 10 to 20 m portions of bedrock is limited. In the more highly weathered zones, therefore, the hydraulic conductivity is conjectured to approach that of a consolidated soil material which would be greater than in competent rock.

The packer testing in corehole CH-P-13-05, drilled vertically 50 m into the Brown McDade Pit floor, gave an average of 10-7 m/sec for hydraulic conductivity (geometric mean of seven tests). This value is in agreement with earlier hydraulic conductivity analyses conducted on the Brown McDade Pit rock mass (Gartner Lee 2007 and 2008), which analyzed pit pond fluctuations and short pumping tests of a monitoring well constructed into the pit floor to derive an overall hydraulic conductivity of the pit floor rock mass in the order of 10-7 m/s.

Overall, highly conductive conduits for groundwater movement were not detected during the 2013 packer testing program, although outlier values were recorded. The most conductive result was 10-6 m/s.(-5.89 log 10 (K)) The hydraulic conductivity of the rock mass forming the Brown McDade Pit area and pit floor can be considered to be at the mid to lower end of the hydraulic conductivity scale typical for fractured granitoid rocks, although it is not impermeable to groundwater flow over long time periods (i.e., decades).



CLIENT: Yukon Energy, Mines and Resources	DWN BY: MSB	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
	CHK'D BY:		PROJECT No.: VM00605N
	DATUM: -	TITLE: COREHOLES - HYDRAULIC CONDUCTIVITY FIELD RESULTS SUMMARY	REV. No.: A
AMEC Environment & Infrastructure Suite 600 - 4445 Lougheed Highway Burnaby, BC V5C 0E4 Tel. 604-294-3811 Fax 604-294-4664	PROJECTION: -		
	SCALE: NTS		FIGURE No.: 6.1-1

Table 6.1-1: Brown McDade Pit - Hydraulic Conductivity Field Results Summary

CH-P-13-02				CH-P-13-03				CH-P-13-04				CH-P-13-05				CH-P-13-06			
Depth (mbg)	Permeability (m/s)	$Log_{10}(K)$	Test Type (FH/CH)	Depth (mbg)	Permeability (m/s)	$Log_{10}(K)$	Test Type (FH/CH)	Depth (mbg)	Permeability (m/s)	$Log_{10}(K)$	Test Type (FH/CH)	Depth (mbg)	Permeability (m/s)	$Log_{10}(K)$	Test Type (FH/CH)	Depth (mbg)	Permeability (m/s)	$Log_{10}(K)$	Test Type (FH/CH)
No Test due to incompetent rock				7 - 13	1.20E-06	-5.92	CH	10 - 16	-		-	7 - 13	1.90E-07	-6.72	CH	10 - 16	5.60E-08	-7.25	FH
				13 - 19	1.30E-06	-5.89	CH	16 - 22	-		-	13 - 19	5.60E-08	-7.25	FH	16 - 22	3.40E-08	-7.47	FH
22 - 28	1.90E-08	-7.72	FH	19 - 25	9.90E-08	-7.00	FH	22 - 28	-		-	19 - 25	2.30E-08	-7.64	FH	22 - 28	-		-
28 - 34	2.00E-07	-6.70	FH	25 - 31	4.10E-07	-6.39	CH	22 - 33.5	2.70E-08	-7.57	FH	25 - 31	2.70E-07	-6.57	CH	28 - 34	-		-
34 - 40	1.30E-06	-5.89	CH	31 - 37	8.60E-08	-7.07	FH	34 - 40	8.80E-09	-8.06	FH	31 - 37	1.90E-07	-6.72	CH	34 - 40	-		-
40 - 50	-		-	37 - 43	1.30E-07	-6.89	FH	40 - 50	-		-	37 - 43	6.40E-08	-7.19	FH	40 - 46	6.60E-07	-6.18	CH
				43 - 50	1.10E-08	-7.96	FH					43 - 50	2.10E-07	-6.68	CH	46 - 52	-		-
																52 - 60	1.40E-08	-7.85	FH
Geomean	1.70E-07	-6.77		Geomean	1.86E-07	-6.73		Geomean	1.54E-08	-7.81		Geomean	1.08E-07	-6.97		Geomean	6.48E-08	-7.19	
Median	2.00E-07	-6.70		Median	1.30E-07	-6.89		Median	1.79E-08	-7.81		Median	1.90E-07	-6.72		Median	4.50E-08	-7.36	

Overal Values

Mean (K)	1.04E-07	Mean ($Log_{10}K$)	-6.54
Median (K)	9.90E-08	Median (Log10K)	-6.94

Notes:
Packer Testing Results - Permeability Parameters with depth (m/s)
"-" no flow
FH = falling head test; CH = constant head test
Overburden or Heavily Weathered/Fractured Bedrock

6.2 Groundwater Elevations

Data downloaded from site installations are grouped according to mine element location, specifically the Brown McDade Pit and the TSF, as summarized in Table 5.0-1. The data record for each individual installation is also provided in Table 5.0-1 with the latest download occurring in May 2015. The individual outputs from these dataloggers are shown as time-series graphs, Figures 6.2-1 to 6.2-7, inclusive. A summary of each of these seven figures is provided in the following paragraphs.

6.2.1 Brown McDade Pit Pond and Surroundings

Figure 6.2-1 shows Levelogger-derived data for the Brown McDade Pit pond elevation and pond water temperature, together with bedrock groundwater elevations from three bedrock monitoring wells, including: the Pit floor (GLL07-03), the north of the high wall (GLL07-01) and northeast of the high wall (MW09-15). Coinciding with the Pit pond datalogger download event, the pond water elevation was also surveyed, relative to a geodetic benchmark (Underhill UU1981). Sensor download in 2015 was not possible due to pit wall instability and related safety risks.

With the exception of GLL07-01, all monitoring wells show a response to seasonal freshet which is shown by the increase in pit pond level (Figure 6.2-1). Pit pond temperature also show seasonal variations related to freshet with an increase in pit pond temperature; however, it remains above 0°C. Change in pit pond level fluctuations appear to lag the pit pond temperature fluctuations. The changes in water level fluctuation between pit pond and groundwater reflect the dampening effect of large storage available in the pit. The rapid and dramatic increase in water levels within bedrock reflect the limited storage capacity of fractures and their rapid filling; diagnostic of fractured bedrock groundwater systems.

Figure 6.2-1 shows a vertical hydraulic gradient between the Pit pond and the adjacent monitoring well in the Pit floor (GLL07-03), with a 1.8 m long open-hole intake section. Other than two instances of the water level falling below the level of the shallow Pit floor datalogger (flat portions of piezometric elevation for GLL07-03), a downward vertical gradient is consistently present without significant seasonal change or reversal. The observed downward gradient indicates that the Pit pond drains to the underlying groundwater system year round. The other two monitoring wells, in and near the north high wall of the Brown McDade Pit, are influenced by active layer development (MW09-15) and permanently frozen conditions (GLL07-01). By active layer development, it is meant that freezing ground induces pressure build-up and thawing ground induces pressure dissipation, as seen by the peaks over the winter in 2009 and 2011. The sharp rise in piezometric elevation for MW09-15 in March/April of each year is indicative of freshet. Data for GLL07-01 is shown on Figure 5.1-1 for completeness.

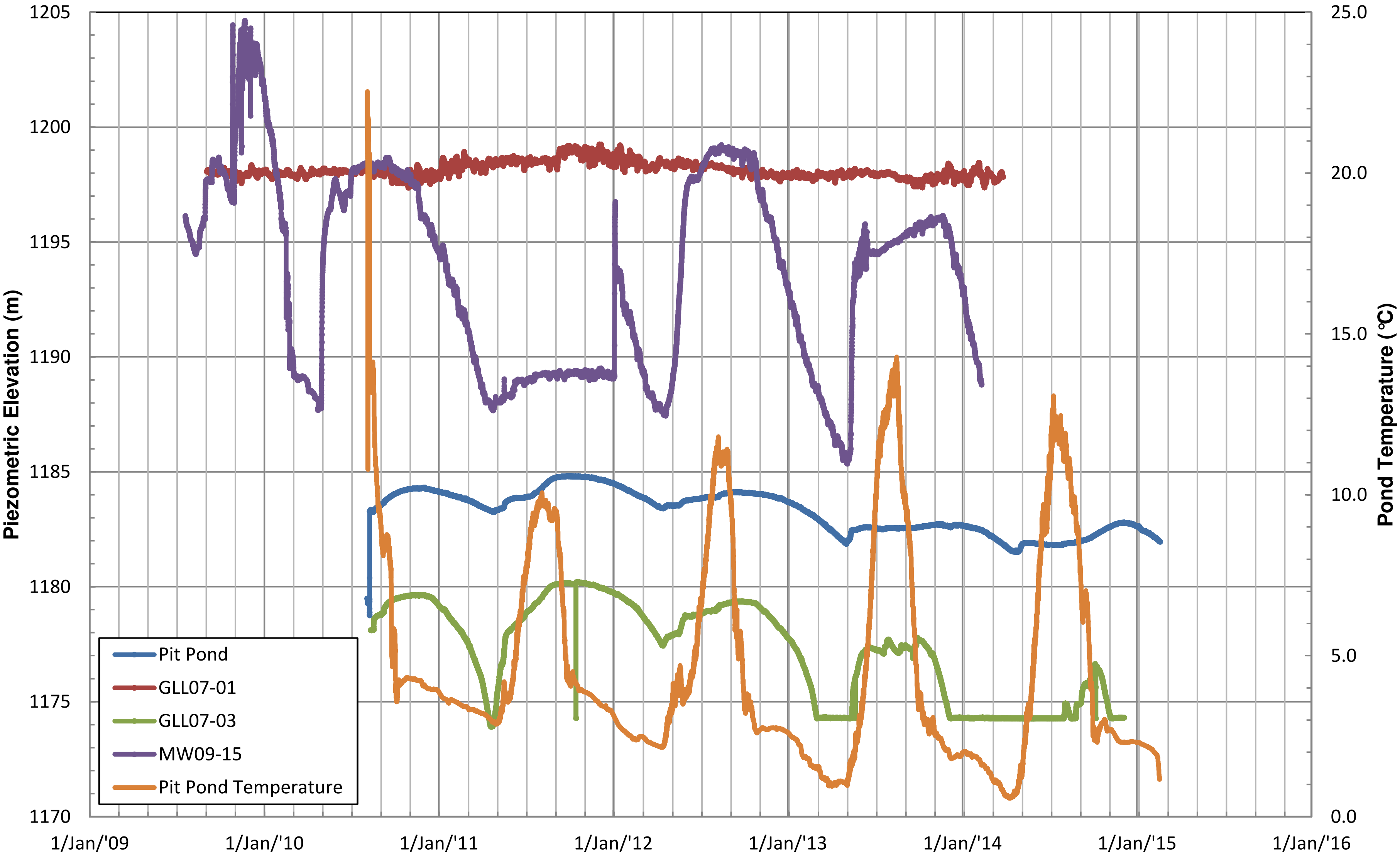
Overall, an upper bound bedrock piezometric elevation on the order of 1,198 m appears to be applicable to these two wells which are screened at elevations 1,191.6 m (GLL07-01) and 1,170.4 m (MW09-15). The latter appears to show some synchronicity and partially mimics the Pit pond, suggesting a degree of hydraulic connectivity exists within the bedrock. If valid, bedrock groundwater movement would be from the north towards the Pit pond.

Figures 6.2-2A and 6.2-2B show vibrating wire piezometer piezometric and temperature data respectively, for corehole location CH-P-13-02, located approximately 550 m southwest of the centre of the Brown McDade Pit. Five VWPs were installed in CH-P-13-02 at depths of 10 m, 20 m, 30 m, 40 m and 50 m, below surface. The data record spans 4 October 2013 to 13 May 2016. The Pit pond elevation and temperature are also shown for reference. The shallowest sensor, at 10 m (elevation 1,139.1 m), shows a piezometric elevation of 1,138 m, relative to surface (elevation 1,145 m). The 20 m sensor indicates a semi-confined condition, with the piezometric elevation greater than that for the 10 m sensor corroborating the upward gradients associated with artesian conditions observed at CH-P-13-01. The 30 m and 40 m sensors indicate a deeper and downward drainage condition. The data from the 50 m sensor is unreliable as it stopped providing meaningful piezometric information in November 2013 before it had stabilized. Note that Figure 6.2-2A shows an initial period of widely varying data while all the frequency sensors stabilize. This is normal for sensors installed in grout.

Water levels at the 10 m and 20 m depths are relatively stable throughout the entire data record. Water levels at 30 m and 40 m depths on the other hand, decrease with time. VWP data at these depths dropped approximately 2 m in 2015. The rate of change appears to be identical and downward gradient is therefore unchanged.

The temperature data at CH-P-13-02 at all depths with the exception of 10 m are relatively constant (Figure 6.2-2B). Overall there is general increase in temperature with depth that may reflect a natural thermal gradient. The temperature at 10 metres below ground surface decreases from approximately 1.5°C to approximately -0.5°C at mid-July 2014 and increases to +0.3°C at mid-November 2014 which likely correlates with seasonal ambient temperature and the increase in pond levels. The time-lag between pit pond temperature and at 10 m below ground surface provides an indication of groundwater travel time and is on the order of four months, which is quite slow. The lack of response at deeper depth would indicate lesser degree of hydraulic connection between deeper groundwater and the Brown McDade Pit.

Figure 6.2-3 shows vibrating wire piezometer piezometric data at CH-P-13-03, approximately 500 m southeast of the Pit centre, with a single sensor at 50 m depth (elevation 1,134.3 m). This sensor shows a fluctuations in piezometric elevation from 1,140 m to 1,135 m for the data period (refer to Table 3.2-1). The piezometric fluctuations appear to lag the fluctuations in pond levels which peak in December 2013 and December 2014. Despite fluctuations, the piezometric correlation to pond levels is indicative of continuous drainage of the bedrock mass. Of interest is an inflection in the piezometric data coinciding with the onset of freshet storage gains to the Pit pond (May 2014). The thermistor associated with this VWP malfunctioned, however, the effect of temperature was accounted for using data from other installations.



CLIENT: Yukon Government	DWN BY: MSB	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
	CHK'D BY:		PROJECT No.: VM00605N
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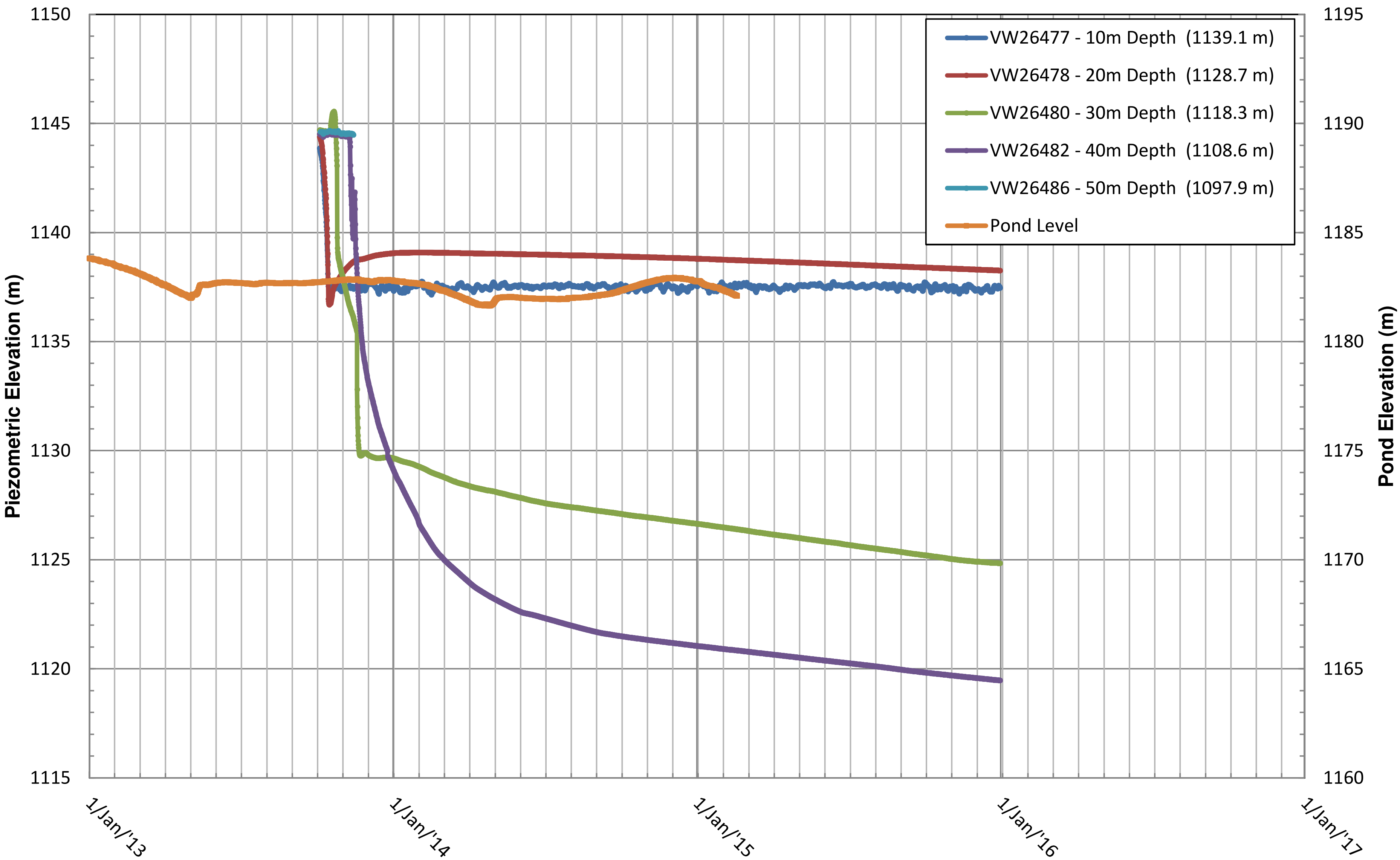
	PROJECTION: -		FIGURE No.: 6.2-1
	SCALE: NTS		



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AMEC Environment & Infrastructure 5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6 PHONE 780-436-2152, FAX 780-435-8425	PROJECTION: -			
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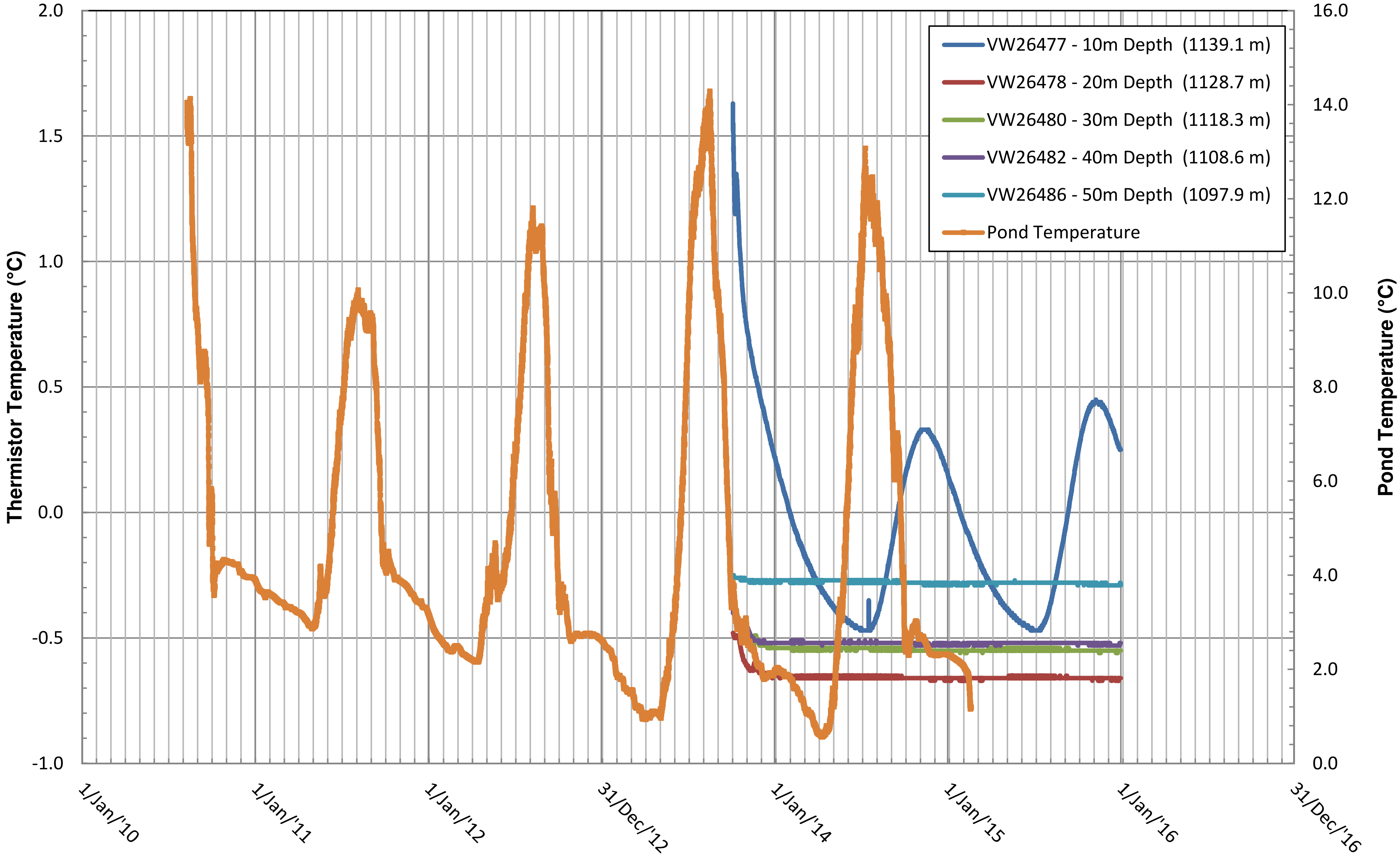

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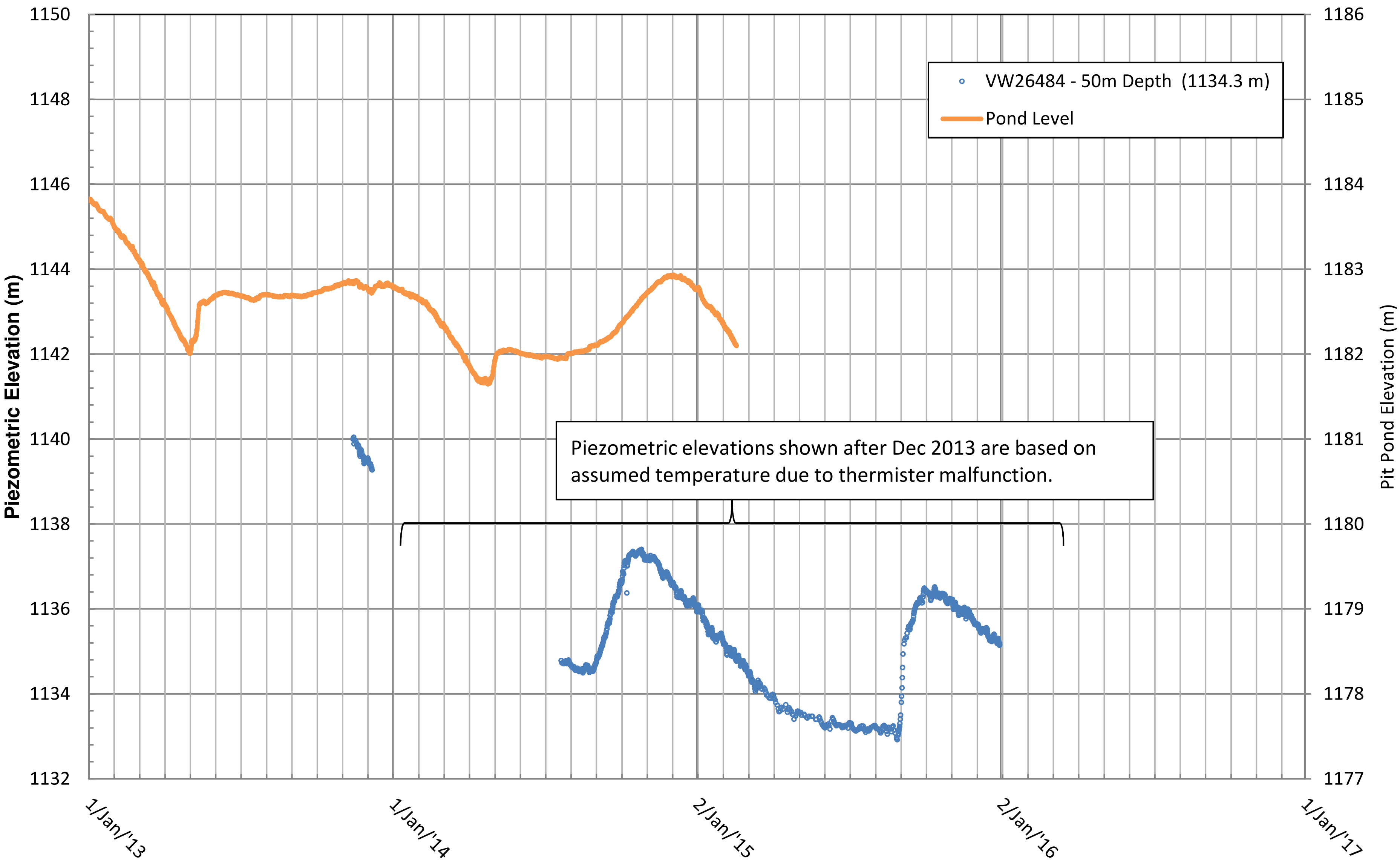
DWN BY: SR
CHK'D BY: MSB
DATUM: -
PROJECTION: -
SCALE: NTS

PROJECT: MOUNT NANSEN SITE

TITLE: TEMPERATURE AT CH-P-13-02

DATE: MAR 2017
PROJECT No.: VM00605N
REV. No.: B
FIGURE No.: 6.2-2B



CLIENT: Yukon Government	DWN BY: SR	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
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AMEC Environment & Infrastructure 5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6 PHONE 780-436-2152, FAX 780-435-8425	DATUM: -	TITLE: PIEZOMETRIC ELEVATIONS AT CH-P-13-03	REV. No.: B
	PROJECTION: -		FIGURE No.: 6.2-3
	SCALE: NTS		

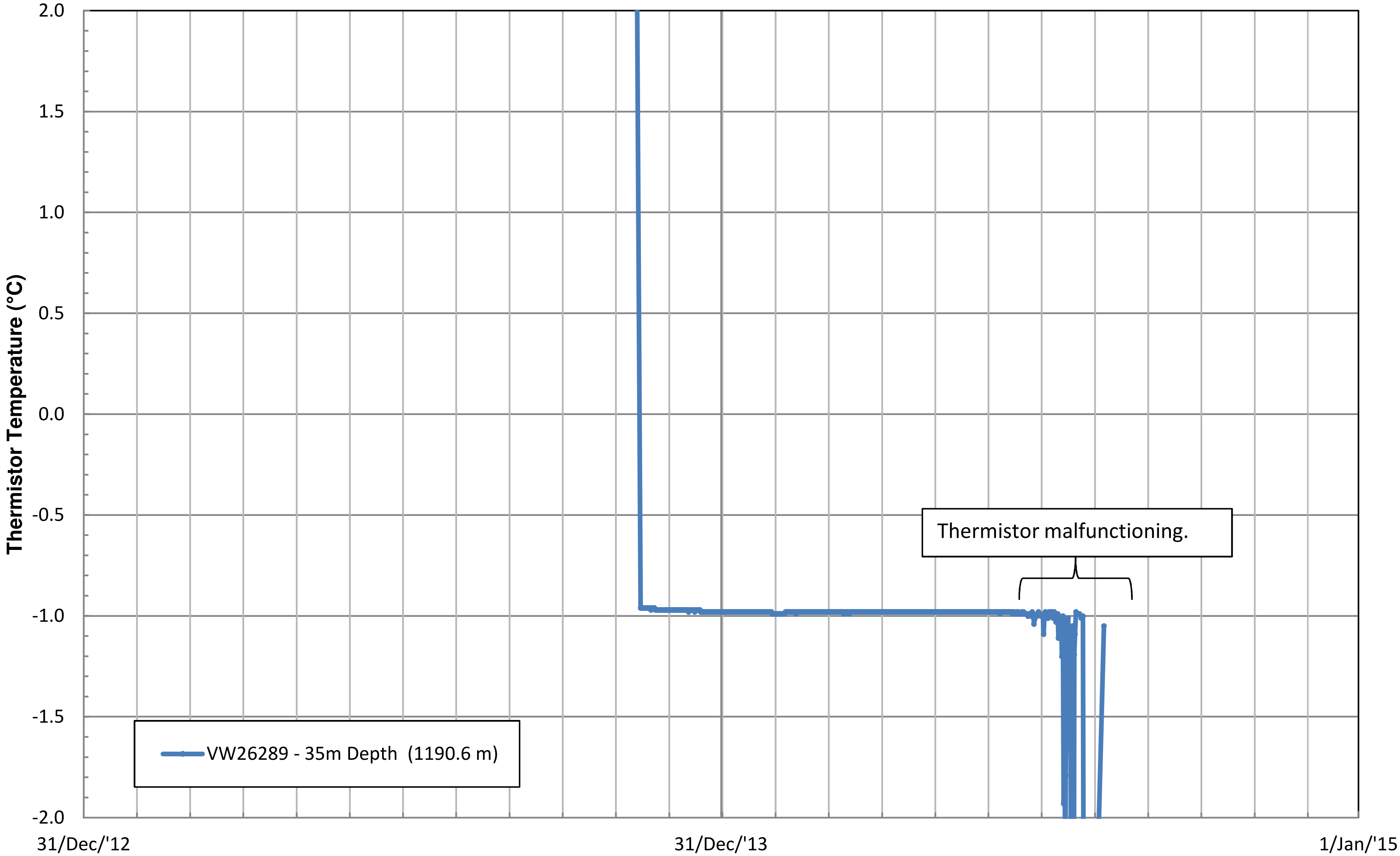
Figure 6.2-4 shows temperature data at CH-P-13-04, approximately 200 m east of the Pit centre, with a single sensor at 35 m depth (elevation 1,190.6 m). The temperature data appears to be valid up to the beginning of July 2014, with the lowest temperature of all the monitored locations (-1.0°C). This is the coldest ground temperature recorded by the instrumentation to date. Data for July 2014 appears to indicate the thermistor is malfunctioning. Data downloaded in December and February confirmed that the thermistor is malfunctioning (data is not plotted).

Figure 6.2-5 shows VWP temperature data at CH-P-13-05, constructed into the Pit floor, with a single sensor at 50 m depth (elevation 1,135.6 m). Other than several apparently erroneous data points, the temperature data from this sensor confirm a talik presence below the Pit pond, with consistently positive temperatures (+0.4°C). Note that data for CH-P-13-05 was downloaded to July 2014, but the thermistor appeared to stop functioning after March 2014 by showing very erroneous temperatures.

Figure 6.2-6A shows pressure head data collected from VWP CH-P-13-06, constructed into the Pit floor at a 45° inclination and 80° azimuth, into which five-sensor instrumentation was installed corresponding to cored depths of 20 m, 30 m, 40 m, 50 m and 60 m. These sensors commence in the Pit floor and progress east and beyond the east Pit wall. For comparison purposes, the Pit pond elevation, rainfall and discharge for Victoria Creek (observed at H-VC-DBC hydrology station in Victoria Creek downstream of the confluence with Pony Creek) is also plotted on Figure 6.2-6A. The data of record spans approximately 1.5 hydrologic cycles capturing two freshet events from the fall of 2013 to the winter of 2014. Due to pit wall instability and related safety issues these sensors were not downloaded in 2015.

The sharp increase in Victoria Creek discharge levels in May 2014 reflects springtime snow melt which relates to rather sharp yet, short-lived increases in pond and groundwater levels to a depth of 60 m below ground surface. The onset of precipitation in the fall (August 2014) lead to a dramatic increase in shallow groundwater levels and a small increase in pit pond level; however, the effect of precipitation was long lived and had a more pronounced effect on groundwater levels than did the spring freshet event.

All sensors respond quickly to the onset of freshet with pressure heads at 20 m, 30 m and 40 m increasing on the order of +/- 15 m relative to baseflow conditions (winter levels). In time, recharged water reaches the 60 m depth and pressure heads at this depth begin to rise. At the onset of freshet or the fall rain season, groundwater gradients show a strong downward gradient (i.e. piezometric elevations at surface are greater than those at depth). Eventually, groundwater levels at depth begin to rise, reflecting conditions as fractures in bedrock become completely saturated. The pressure head at 60 m lags the pressure head peaks at the shallower installations by approximately two months (September to November); slower travel times reflecting lower values of hydraulic conductivity. Interestingly, the maxima in pond level lags the maxima observed in



CLIENT: Yukon Government	DWN BY: DMcL	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
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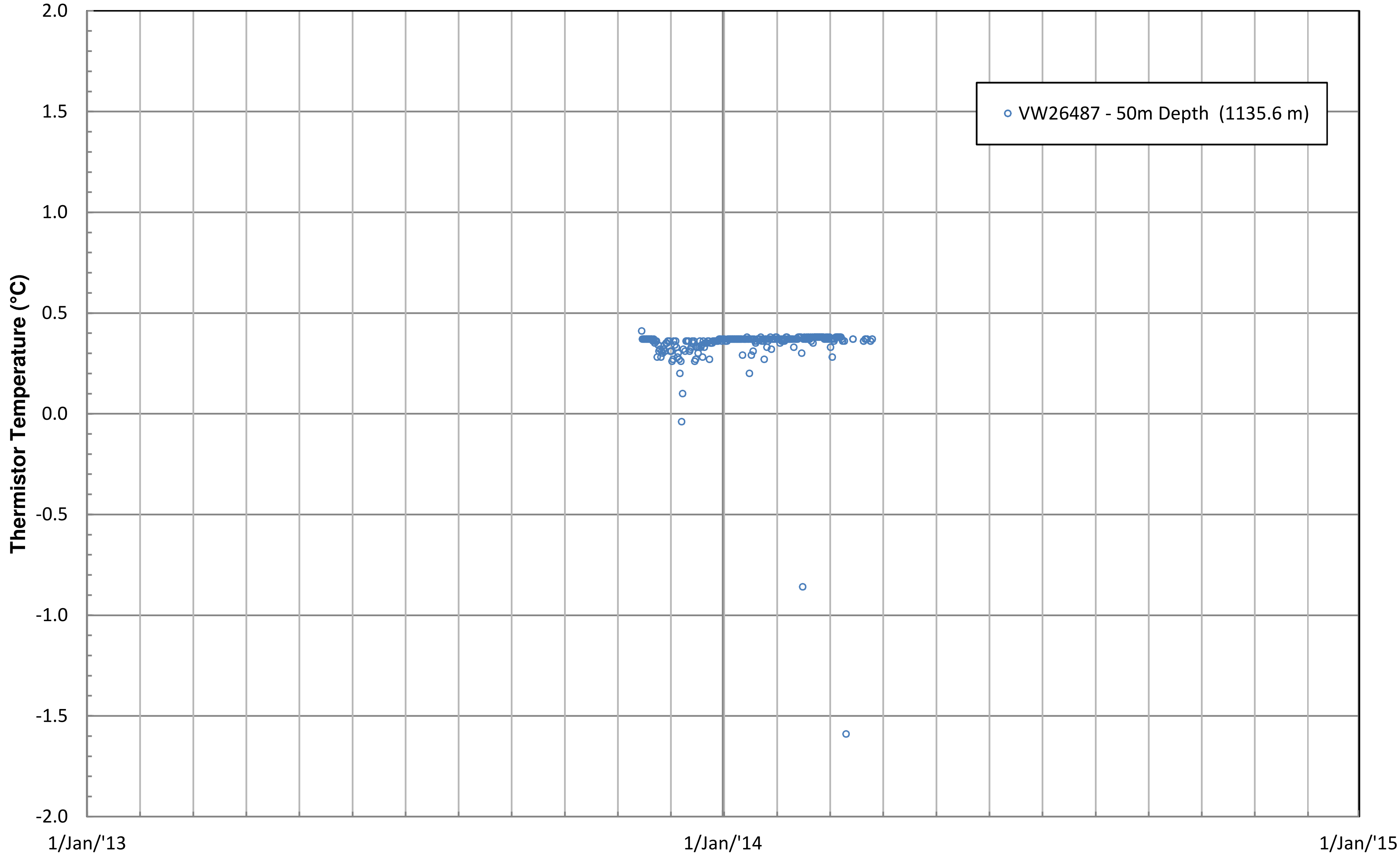
	SCALE: NTS		



CLIENT: Yukon Government	DWN BY: DMcL	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
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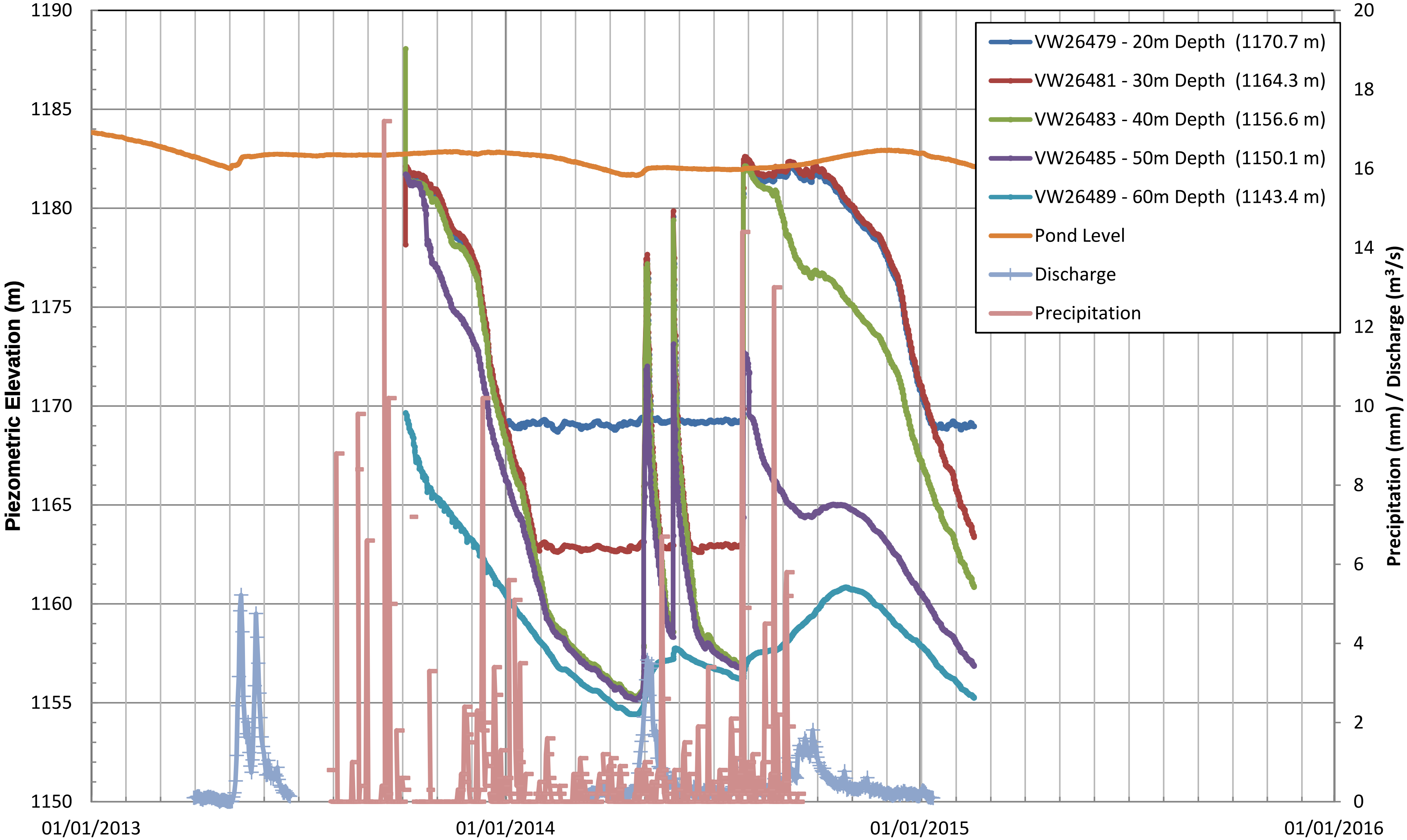

CLIENT: Yukon Government	DWN BY: DMcL	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017
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	PROJECTION: -		FIGURE No.: 6.2-6A
	SCALE: NTS		

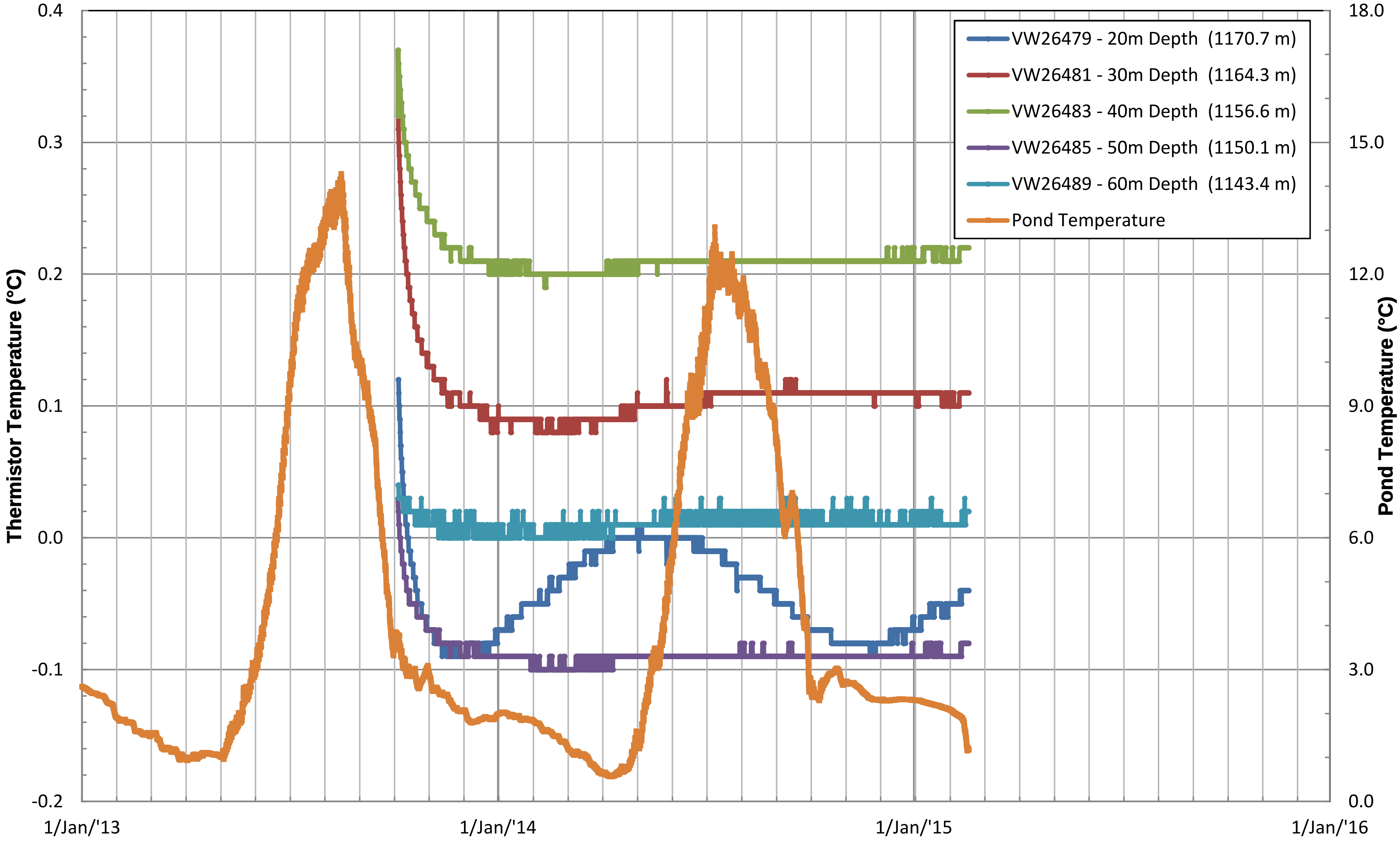
groundwater levels at 50 and 60 m below ground surface, suggesting that at the pond there is possibly a correlation between bedrock saturation and pit filling.

During the winter months the Pit pond level and groundwater levels drop with minima's occurring during the month of April. In April, the pressure heads at 20 m, 30 m and 40 m were below their installation depths indicating dry conditions. Pressure heads at 50 and 60 m depths, however, indicated saturated conditions as levels were above their installation elevation. The data from CH-P-13-06 indicate that baseflow regional groundwater levels, as experienced during winter low-recharge conditions, occur at about elevation 1,156 m, which is approximately 20 m below the Brown McDade Pit floor.

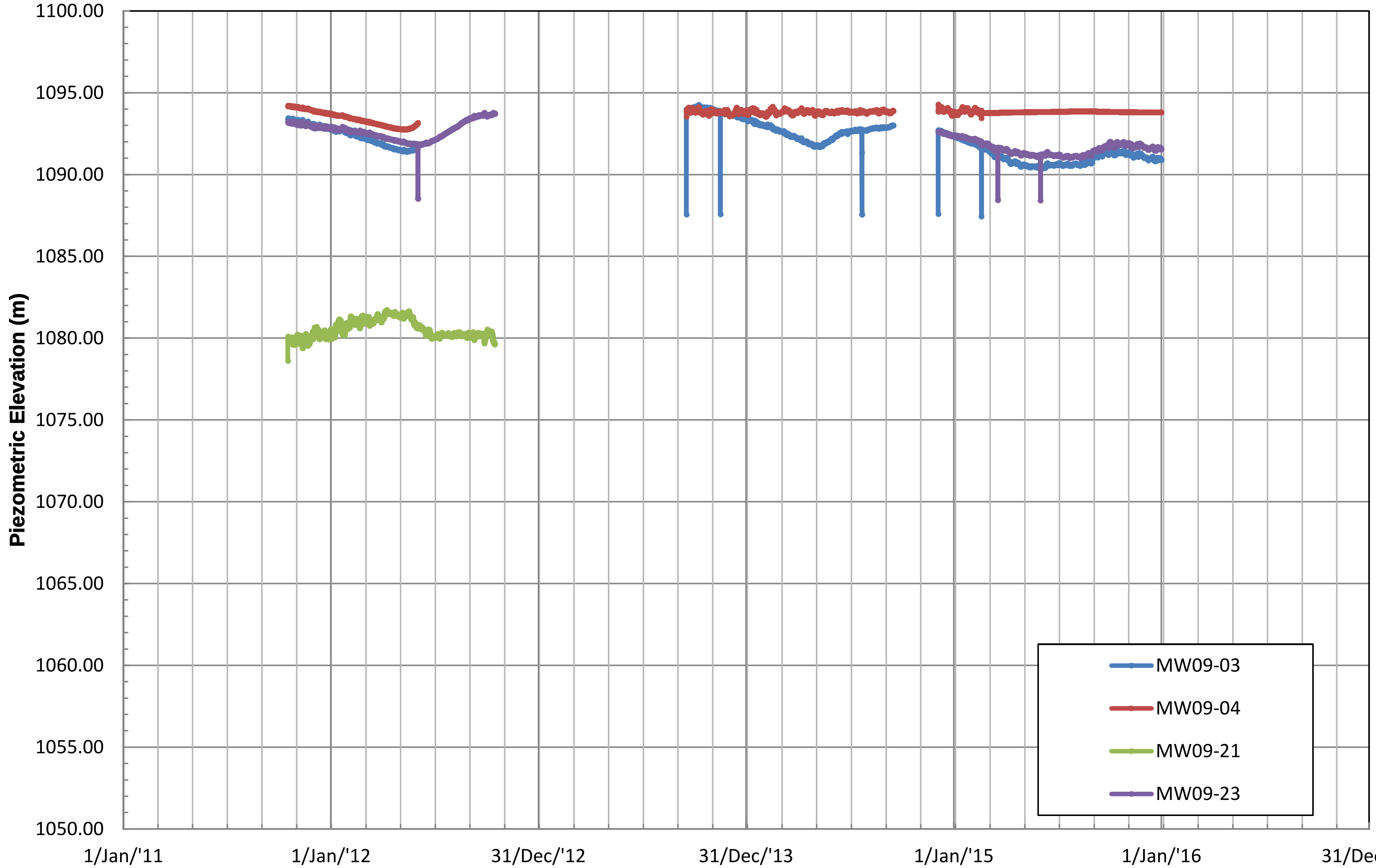
Figure 6.2-6B shows the temperature data for location CH-P-13-06. The increase in Pit pond temperature correlates with freshet. All groundwater temperatures measured by the VWP range from -0.1 to 0.2°C. Temperatures increase, albeit very slightly with depth and with the onset of freshet.

6.2.2 Tailings Storage Facility

Figure 6.2-7 shows a discontinuous data set from October 2011 to the end of December 2015 for four different Levelogger devices in four different monitoring wells, installed at the Tailings Storage Facility. Two of the measuring devices are within the tailings boundary (MW09-03 and 04), one is in the dam crest (MW09-23) and the other is in the downstream dam face (MW09-21). Data downloaded from the sensors in 2015 were barometrically compensated using barometric pressure readings from the site weather station as access to the Barologger® in the Pit was not accessible. This modified method for compensation did not affect the water level data accuracy. Observed water levels in 2015 fall within the range observed in previous years. The two Leveloggers installed inside the tailings were installed October 2011 in paired monitoring wells, with screened intake sections at shallower (MW09-04) and deeper (MW09-03) depths to monitor tailings porewater. Water level data from MW09-03 and MW09-04 decrease throughout the fall and winter of 2011-2012 indicating drainage of the tailings which is followed by freshet and storage increase of the Tailings Storage Facility. The consistent behaviour between the paired monitoring wells in 2011-2012 indicates that the shallow and deep tailings are behaving in the same manner. MW09-04 appears to become non-functional in June 2012 and appears not recover for the remainder of the data record. The other two data loggers have 2012 data that show a seasonal water level decrease at the dam crest monitoring well (MW09-23), and a seasonal level increase in the dam downstream monitoring well (MW09-21). These two dataloggers ceased recording data in 2012, presumably due to exceedance of memory capacity. They were erased and re-started in December 2014. The Levelogger in MW09-21 was observed as being frozen during the February 18, 2015 download and therefore data is not available. Data from MW09-03 and MW09-23 appear to show the same seasonal trends from 2011 through 2015 (i.e. a seasonal decrease over winter). Many of the Leveloggers installed in 2011 are likely reaching their end of their lifespan (typically 4 to 5 years depending on conditions) and replacement for future monitoring activities should be considered.



CLIENT: Yukon Government	DWN BY: DMcL CHK'D BY: MSB DATUM: - PROJECTION: - SCALE: NTS	PROJECT: MOUNT NANSEN SITE	DATE: MAR 2017 PROJECT No.: VM00605N
AMEC Environment & Infrastructure 5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6 PHONE 780-436-2152, FAX 780-435-8425		TITLE: TEMPERATURES AT CH-P-13-06	REV. No.: B FIGURE No.: 6.2-6B



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AMEC Environment & Infrastructure 5681-70 STREET, EDMONTON, ALBERTA, T6B 3P6 PHONE 780-436-2152, FAX 780-435-8425	DATUM: -	TITLE: TAILINGS POND FACILITY AND AREA PIEZOMETRIC ELEVATIONS	REV. No.: B
	PROJECTION: -		FIGURE No.: 6.2-7
	SCALE: NTS		

6.3 Derived Groundwater Conditions Overview

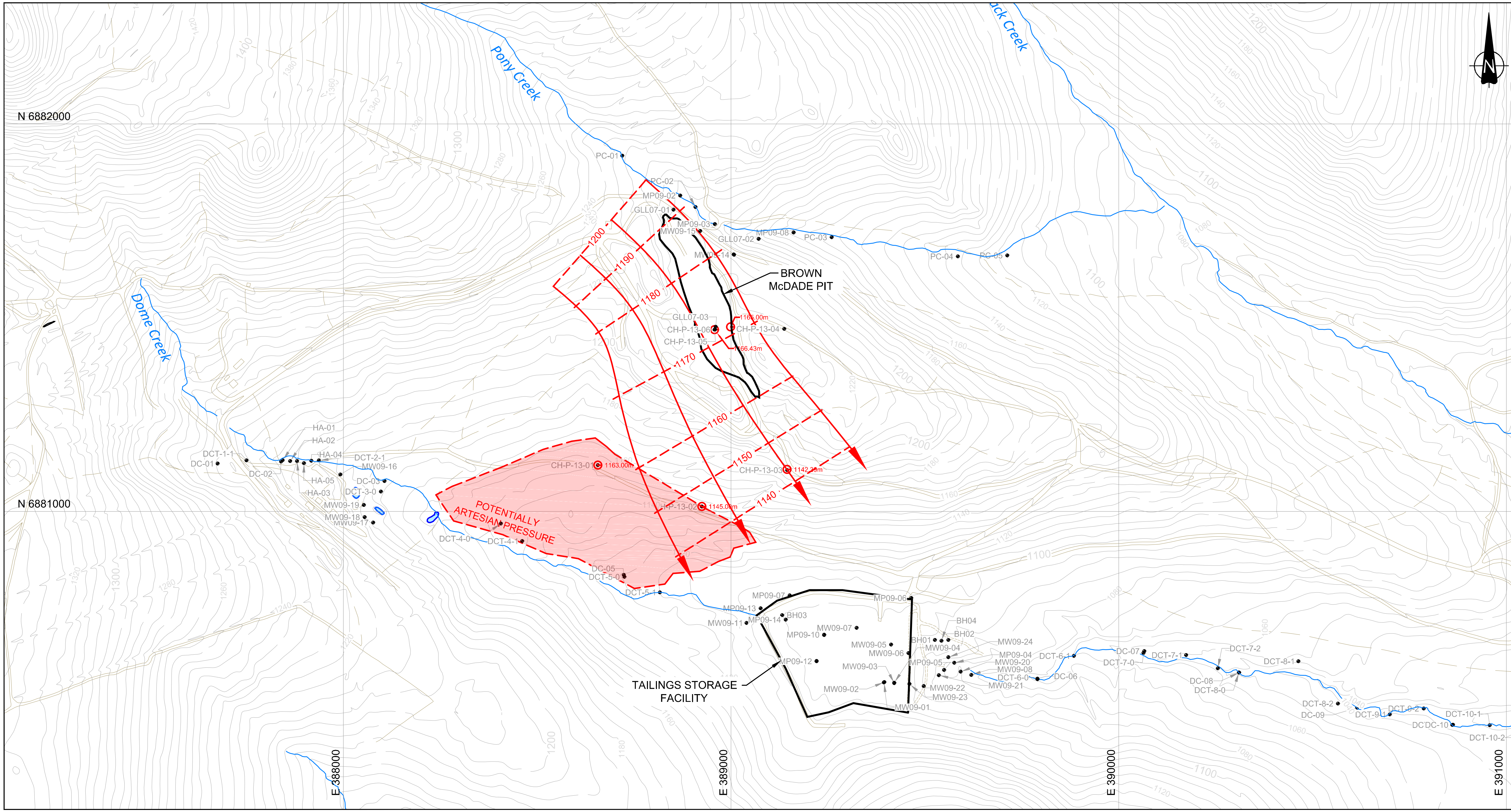
6.3.1 Brown McDade Pit

Figure 6.3-1 represents the piezometric map of the bedrock groundwater system beneath the Brown McDade Pit. This figure represents hydrogeological conditions as observed on October 5, 2013. The map was developed based on data collected from VWPs CH-P-13-01, CH-P-13-02, CH-P-13-03 and CH-P-13-06, as well as water level data from the monitoring wells GLL07-03 and MW09-15.

A detailed summary of the water level data is provided in Appendix F3 of the 2013 Site Investigation Data Report (AMEC 2014). The piezometric map is representative of hydrogeological conditions during freshet conditions in the fall (i.e., September - October) when groundwater and pit pond levels are at their maximum (see Figure 5-7 of that report). Available water level data for 2015 rests within the observed range for 2013 and, as the 2013 data set has more comprehensive spatial coverage, the piezometric map was not updated.

The 2004 to 2009 conceptual site model assigned the regional groundwater piezometric elevation to universally mimic topographic elevation minus 15 to 20 m. This interpretation was updated to include the presence of artesian conditions, across the corehole CH-P-13-01 area, below elevation 1,163 m, in which the regional groundwater piezometric elevation is above surface grade, as shown on Figure 5.1-8. During freshet, the groundwater piezometric surface across the Site grades from north to south with an elevation of approximately 1,187 m in north to 1,167 m at the southern end. The piezometric surface traverses the Brown McDade Pit floor which ranges in elevation from 1,176 m to 1, 179 m.

The winter baseflow groundwater levels observed in April 2013 and April 2014 are substantially lower with groundwater beneath the Brown McDade Pit residing at an elevation of approximately 1,156 m. At present, there is insufficient information to develop a map of the groundwater piezometric surface representative of winter baseflow conditions. Additional deeper bedrock installations surrounding the pit would be required to confirm the seasonal variations of the groundwater piezometric surface beneath.



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Note: Groundwater and Ground Temperature data will be updated in 2014.

0m 100 200 300 400

1 : 10000

Yukon
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Assessment and Abandoned Mines

MOUNT NANSEN SITE
Figure 6.3-1

CARE AND MAINTENANCE PROJECT PROPOSAL

GROUNDWATER ELEVATIONS FOR REGIONAL FLOW

FEBRUARY 2017

C:\Users\yuan.chen\appdata\local\temp\AcPublish_5896\Figure 6.3-1.dwg – FIGURE 16 – Feb. 23, 2017 3:50pm – yuan.chen

6.3.2 Dome Creek and Pony Creek Groundwater

September 2013 creek study data are presented in Figures 6.3-2 and 6.3-3, using colour scales to represent the data magnitude and direction. The signage conventions applied to vertical gradient and seepage flow in these figures, are as follows:

Vertical gradient - positive indicates upwards flow at the creek bed; and

- negative indicates downwards flow at the creek bed.

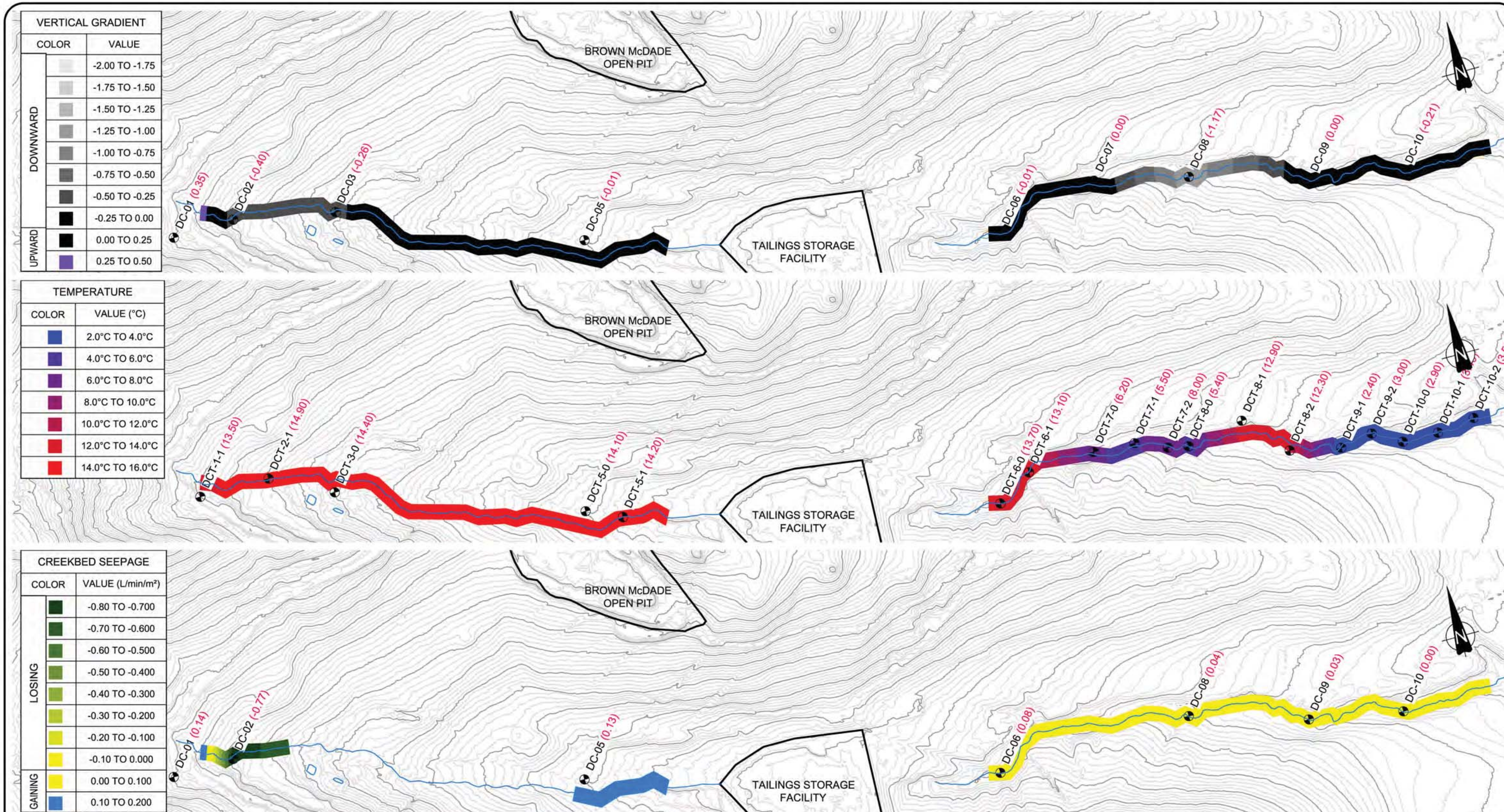
Seepage flow - positive indicates groundwater entering creek; and

- negative indicates groundwater leaving creek.

The September 2013 temperature survey indicated that the segments of Dome Creek upstream of the tailings pond and segments of Pony Creek upstream and adjacent to the Brown McDade Pit possessed relatively warm creek bed porewater, denoted in red on Figures 6.3-2 and 6.3-3, respectively. Downstream of the tailings pond, Dome Creek porewater became cooler and downstream of the Brown McDade Pit, Pony Creek porewater also became cooler, denoted in blue on both figures.

The seepage meter tests provided a direct measure of groundwater exchange in the creek bed, indicating gaining or losing creek segments. For Dome Creek, these data showed a pattern of low, positive seepage rates and indicated gaining creek segments, with one notable exception near Huestis Adit (DC-02), which had the most negative seepage rate and loss from Dome Creek. For Pony Creek, the seepage meter data showed a pattern of low, positive seepage and gaining creek segments. Overall, the seepage meter data indicated that groundwater contributes to Dome Creek and Pony Creek at low rates.

Vertical groundwater gradients, derived from the dual drive-point piezometers, were only somewhat consistent with the seepage meter results. The majority of creek stations gave negative (i.e. downward), groundwater directions indicative of losing creek water. This was at variance to the temperature survey and seepage meter findings. Only two stations had positive (i.e., upward), groundwater directions, corresponding to the most upstream station on Dome Creek (DC-01) and one station downstream of the tailings pond (DC-07). The vertical gradients, therefore, may have been skewed by the onset of freezing conditions that influenced drive-point water levels.



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Comments:

Vertical gradient - positive indicates upwards flow at the creek bed; and
- negative indicates downwards flow at the creek bed.

Seepage flow - positive indicates groundwater entering creek; and
- negative indicates groundwater leaving creek

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Figure 6.3-2

CARE AND MAINTENANCEPROJECT PROPOSAL

DOME CREEK - GROUNDWATER-SURFACE WATER INTERACTION

0m 100 200 300 400
1 : 10,000

March 2017

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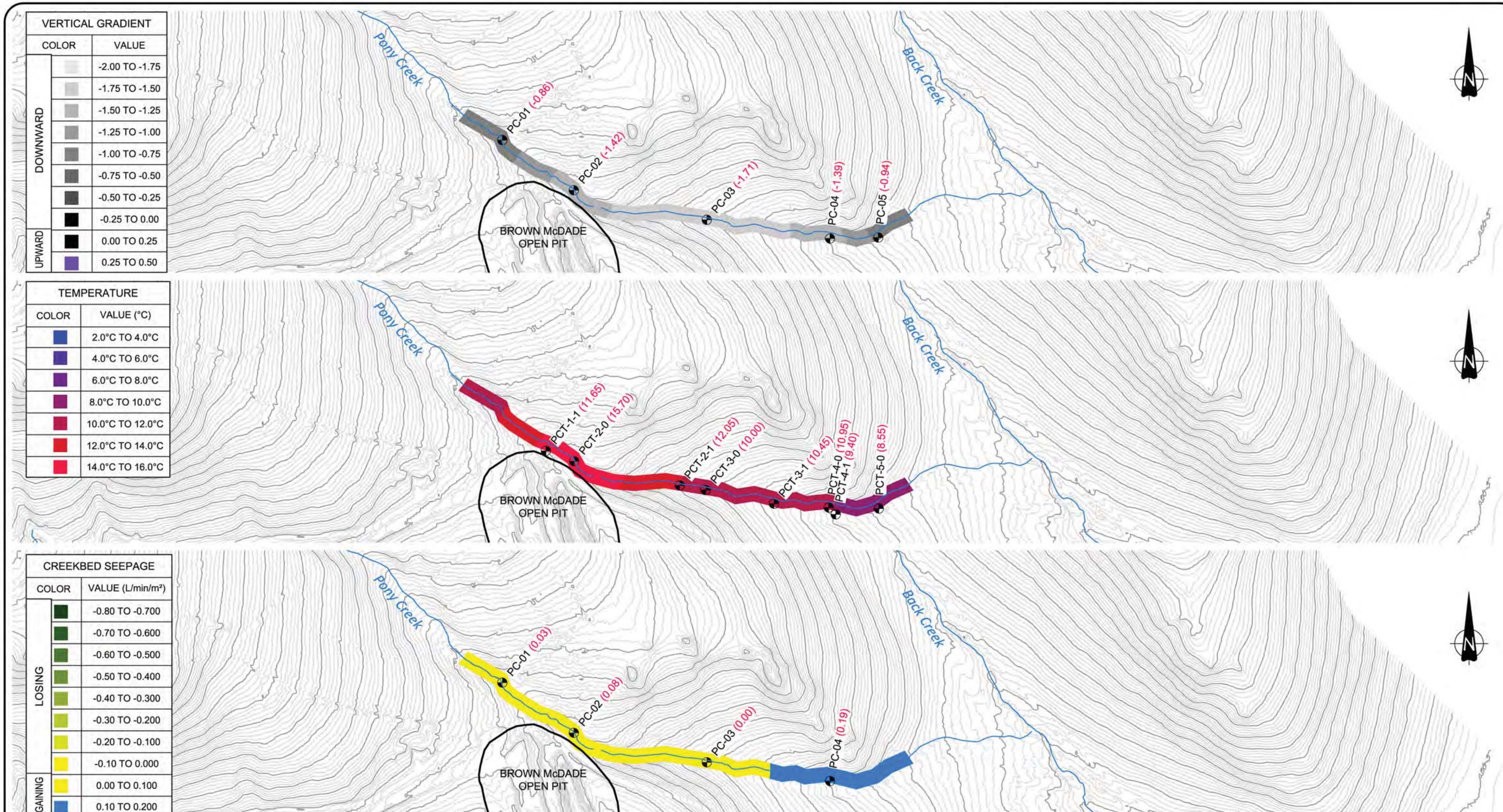

Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

Comments:

Vertical gradient - positive indicates upwards flow at the creek bed; and
- negative indicates downwards flow at the creek bed.

Seepage flow - positive indicates groundwater entering creek; and
- negative indicates groundwater leaving creek

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Figure 6.3-3
CARE AND MAINTENANCE PROJECT PROPOSAL

PONY CREEK - GROUNDWATER-SURFACE WATER INTERACTION

0m 100 200 300 400
1 : 10,000

March 2017

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6.3.3 Groundwater and Huestis Adit

A preliminary groundwater flow plan was developed for the northwest portion of the mill area within proximity to Huestis Adit. This part of the former mine was investigated in 2013 to detect shallow groundwater potentially leaving the underground workings via the Huestis '4100 Level' Adit. This Adit is the lowest known man-made outlet for mine drainage leaving the Huestis Deposit underground workings (Huestis and Webber Zones, Feasibility Study - Normand Lecuyer, 1997). It could potentially release mine water to surface, in the proximity of upper Dome Creek.

Five drive-point piezometers were installed close to the determined location for this collapsed, former portal and lowest point of drainage from the Huestis underground workings. Groundwater elevations from the five drive-points provided an indication of the shallow water table depth from which some extrapolation was possible, based on topographic mapping and depth to the shallow water table. Using this approach, groundwater contours and flow direction were interpreted, as shown on Figure 6.3-4. Observed groundwater levels along Dome Creek in the vicinity of the Huestis Adit follow topography, and the contours drawn tangential to Dome Creek are therefore interpreted as such. The groundwater contours indicate convergence about the creek with the creek serving as a likely groundwater discharge zone.

6.3.4 Brown McDade Pit Pond Groundwater Exchange

Water Balance Method

A water balance was conducted based on water accounting, to derive groundwater exchanging (entering or leaving) with the Brown McDade Pit pond. The water balance accounts for quantifiable inflow and outflow volumes for the pit pond, to derive the groundwater as a remainder from the accounting process. The period of data used for the water balance was from August 4, 2010 to June 14, 2013, inclusive, and was conducted to update an earlier water balance for the Brown McDade Pit (Gartner Lee, 2007).

Daily data were available for the Brown McDade Pit pond level, and monthly data for the other parameters for the water balance analysis. The water balance parameters were as follows:

- Surface Water Inflow:
  - direct precipitation, within the pit perimeter, P; and
  - surface runoff (factored for sublimation), entering as pit wall runoff, R.
- Surface Water Outflow:
  - evaporation, E (assumed to be the only surface water outflow).
- Net Surface Water Inflow:
  - P + R - E.
- Pond Level Change:

  - pond water level change, factored for area, giving pit volume change, PV.
- Net Groundwater Exchange:
  - P + R - E - PV.

Daily values for Net Groundwater Exchange were determined by the residual value remaining after summing Net Surface Water Inflow and Pond Level Change. Figure 6.3-5 shows the groundwater component of the Brown McDade Pit pond to be variable, with a net loss over time (i.e. water predominantly leaves as groundwater) during the period of these studies. A dry year in 2012 followed by a delayed freshet in 2013 prevented groundwater recharge. The rate of water loss from the Brown McDade Pit pond was quantified as being 0.2 L/s (17.3 m3/d).

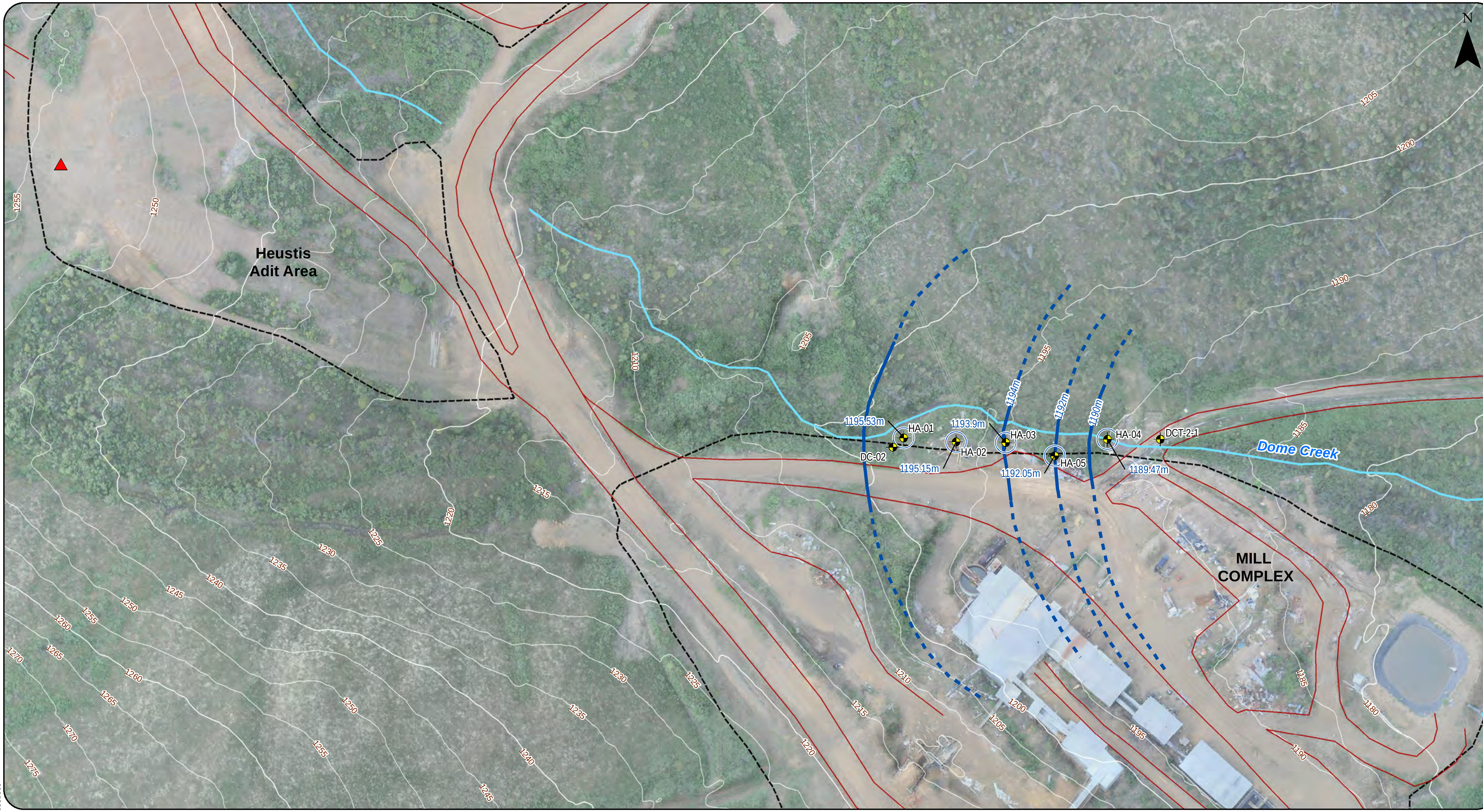
Winter Recession Curve Method

Pit pond level data, as recorded by the in-pond data logger, captured three wintertime periods and was used to generate pond level recession curves. These pond level data were analyzed to identify the following:

The pond elevation relationship to groundwater inflow/outflow daily rates, as derived from water balance (i.e., the pond water ‘head’ dependency), if any; and

The time relationship to groundwater inflow/outflow daily rates, as derived from water balance (i.e., seasonal dependency), if any.

The currently-calibrated pond elevation and pond water temperature data for August 4, 2010 to June 14, 2013, inclusive, are shown on Figure 6.3-6, as variables compared to calculated daily groundwater inflow (positive values) and daily groundwater outflow (negative values).



Data Source:

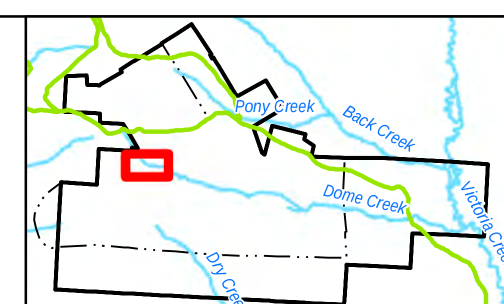
Roads, trails, streams, waterbodies, watercourses and infrastructure areas digitized using 2008 Quickbird imagery (courtesy of Yukon Geomatics) and spatial data provided by Yukon government.

Heli LIDAR Data Survey and Imagery, 2012

Datum: NAD 1983 CSRS UTM Zone 8N

Legend

- Road
- Stream
- Contour (20 m)
- Contour (5 m)
- Disturbed Area
- Adit Location
- Groundwater Monitoring Locations
- Groundwater Depth
- Groundwater Flow Huestis and Mill Area



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MOUNT NANSEN SITE
FIGURE 6.3-4
CARE AND MAINTENANCE
PROJECT PROPOSAL

GROUNDWATER FLOW
HUESTIS ADIT AND MILL AREA

Scale 1:1,400
Metres
0 30 60

February 22, 2017

S:\PROJECTS\VM00605 - Mount Nansen\GIS\Mapping\Ver2015_RemediationProposal\VM00605_GroundwaterFlowHeustis_v2.mxd

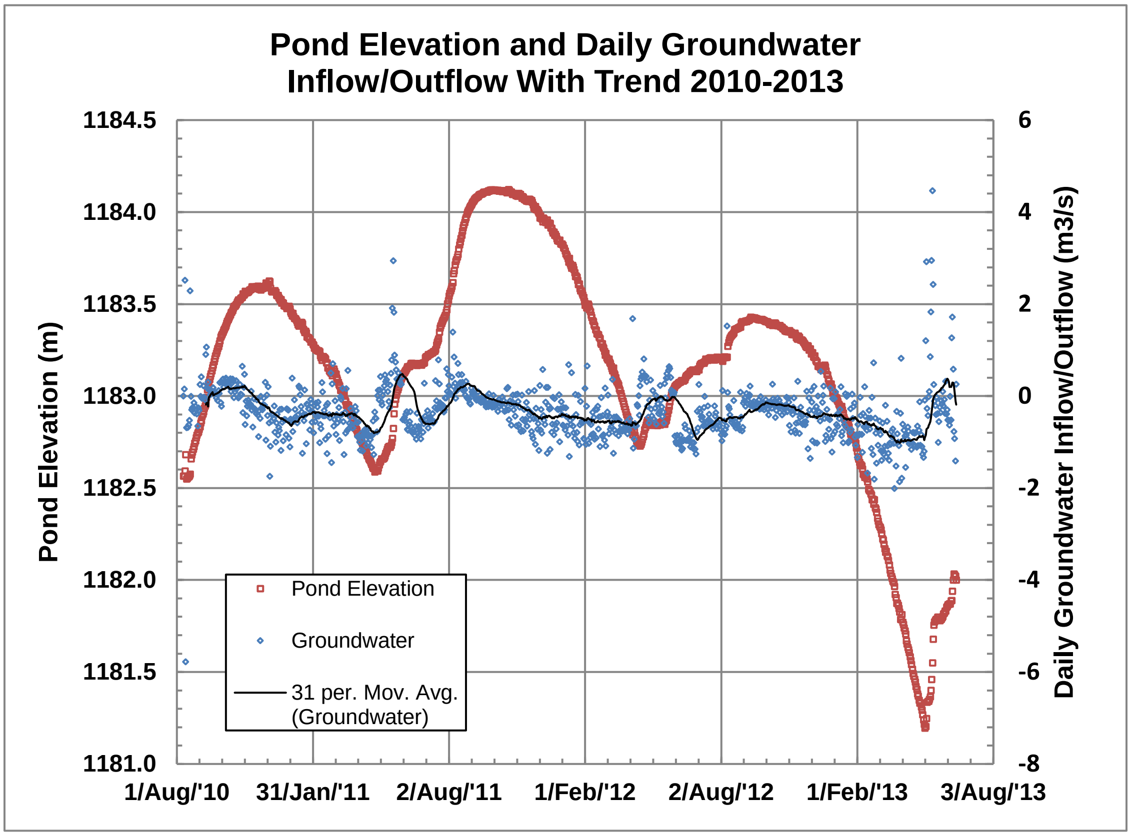


Figure 6.3-5: Pond Elevation and Daily Groundwater Inflow/Outflow with Trend 2010-2013

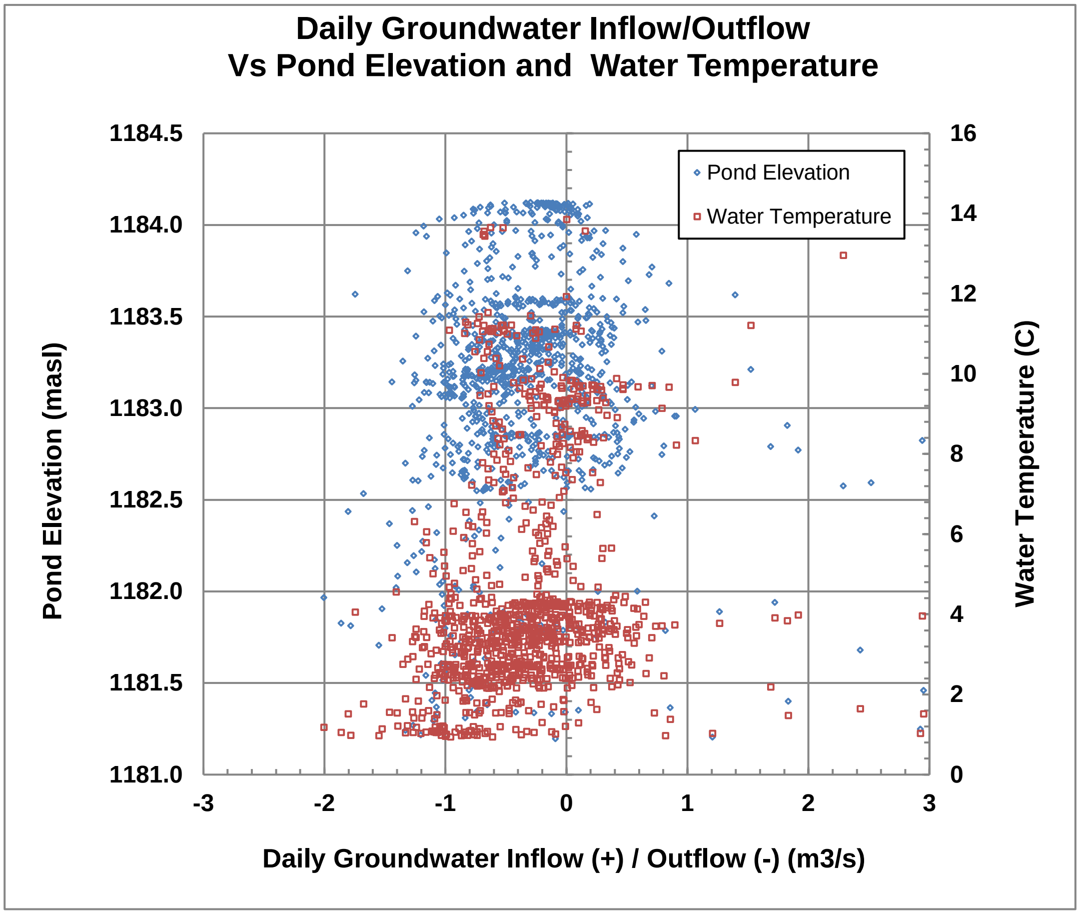


Figure 6.3-6: Daily Groundwater Inflow/Outflow vs. Pond Elevation and Water Temperature

Figure 6.3-6 indicates the following:

- A correlation between the pond elevation and groundwater inflow/outflow values is not apparent, inferring that the groundwater exchange with the Brown McDade Pit pond is not strongly controlled by pond elevation within the range of recorded pond level data, that is, pond elevations 1,181 to 1,184 m; and
- A cluster of groundwater outflow points is associated with cooler water temperatures, inferring that the daily groundwater inflow/outflow component is more discernible in the wintertime data.

The annual periodicity of pond storage increases from the addition of water from freshet, direct precipitation and runoff within the Brown McDade Pit catchment area, as shown on Figure 8.1-1, which shows pond elevation and daily groundwater inflow/outflow data for the 2010 to 2013 data period.

Annual pond elevation peaks occurred from September to December followed by pond elevation declines with high linearity, through winter until the commencement of the following annual freshet and other surface sources. As the pit pond does not freeze to bottom, daily water levels were recorded for the four year data period.

One additional water source that has a bearing on the water balance but that has not been quantified to date is groundwater originating from Pony Creek that moves, via shallow rock, into the Brown McDade Pit. This was first documented in 2004, observed as wintertime icing on the north pit wall above the pond level. This Pony Creek seepage water discharges into the pit through the north pit wall and potentially skews (positively) the derived groundwater inflow/outflow parameter (i.e. introducing an additional surface input that decreases the apparent groundwater outflow).

The linear declines in wintertime pond elevation, when the pit walls were frozen and no surface water input was possible, were used to more selectively quantify groundwater leaving the Brown McDade Pit pond. Figure 5.1-1 shows pond elevation and water temperature and the near-linear decline in wintertime pond elevation.

Data points were picked for each of the linear pond elevation declines, corresponding to the winters of 2010/2011, 2011/2012 and 2012/2013. These gradient values were factored for pond area and time to derive rates for groundwater loss, as shown in Table 6.3-1.

Table 6.3-1: Wintertime Pit Pond Groundwater Outflow Rates

Data Period	Groundwater Outflow Volumes and Rates		
	m3	m3/day	L/s
February 25, 2011 to April 24, 2011	1,627	28.0	0.32
January 30, 2012 to April 11, 2012	2,603	36.2	0.42
February 10, 2013 to May 3, 2013	4,555	55.5	0.64
Average 0.46 L/s			

The average derived from the three wintertime pond elevation declines is greater than that quantified from water balance methods (0.2 L/s), which contain an unquantified, although previously assumed low, contribution of the Pony Creek seepage. The pit pond decline method of evaluating groundwater outflow is unaffected by this exclusion of the Pony Creek seepage and is also more selective for quantifying groundwater exchange, compared to the water balance method, arising from the different measurement scales (i.e., metres of pit pond elevation range versus millimetre summations of surface water inputs and evaporative losses).

7 Hydrogeological Conceptual Site Model

The 2013 site investigation findings were used to update a documented hydrogeological conceptual site model (Gartner Lee and AECOM, 2004 to 2009), as follows.

1. *Dome Creek groundwater exchange:*

    a. Dome Creek shows a pattern of low, positive seepage rates and gaining creek segments, with one notable exception near Huestis Adit (DC-02), which had the most negative seepage rate and loss from Dome Creek. The most upstream station on Dome Creek (DC-01) and one station downstream of the tailings pond (DC-07) had positive (i.e., upward), groundwater directions.

    b. Downstream of the tailings pond, Dome Creek porewater became cooler.

2. *Pony Creek groundwater exchange:*

    a. The September 2013 creek data suggests that, in its upper reaches, Pony Creek is either a slightly losing or gaining stream, as the amount of groundwater exchanged was very low. The amount of creek bed groundwater exchange is likely more pronounced when greater hydraulic heads are present during freshet and heavy rainfall. Surface water ponds, created by exploration trenches, may increase infiltration to shallow groundwater.

    b. Pony Creek, adjacent to the Brown McDade Pit, is documented as losing stream water to shallow groundwater, some of which reports to the Brown McDade Pit via the north pit wall.

    c. In September 2013, the Pony Creek reach upstream of the confluence with Back Creek had the greatest groundwater gains, indicating it to be a considerable discharge area for groundwater to surface water.

3. *Brown McDade Pit groundwater exchange:*

    a. Several faults have been mapped through the Brown McDade Pit, extending north and south of the Brown McDade Pit footprint. These features have been described as low conductive, groundwater zones and barriers to flow and may also be directing some water from Pony Creek into the pit. The 2013 vibrating wire piezometer temperature data indicate that permafrost is present east and southeast of the Brown McDade Pit, as also verified by freeze-back observations of the groundwater monitoring wells constructed in the 2013 coreholes. Permafrost, therefore, currently appears to be the greater constraint against deep groundwater moving east and southeast from the Brown McDade Pit area.

b. *Brown McDade Pit rock mass:* The Brown McDade Pit rock mass has a hydraulic conductivity in the order of 10-7 m/s, as quantified by hydraulic packer testing of two coreholes into the Brown McDade Pit floor and east wall. This value agrees with documented analyses of rock mass permeability that used pond level fluctuation and short-duration pumping tests (Gartner Lee, 2007 and 2008).

c. *Brown McDade Pit pond groundwater exchange:* The pond was documented as a possible perched water feature. From 2010 to 2013, climatic and pit pond levels and piezometric elevation data for the underlying rock mass shows the pond to be a surface water retention feature, with saturated hydraulic connection to the deep groundwater system (i.e. a leaky retention feature).

d. *Brown McDade Pit initial climatic water balance:* Using precipitation, runoff, evaporation and pond level change data, the rate of water exchange between the pond and groundwater was calculated and an average seepage rate out of the Brown McDade Pit initially was determined to be 0.2 L/s (Gartner Lee, 2007).

e. *Brown McDade Pit wintertime pond level recession curves:* The pond level data for August 2010 to June 2013, inclusive, included three wintertime pond level decline curves (2010-2011, 2011-2012 and 2012-2013). These occur when climatic surface water inputs to the pond are not possible and Pony Creek north seepage inputs are negligible. As the pit pond does not freeze to bottom and water continues to leave as groundwater, the latter was quantified in a more selective manner compared to water balance. This method quantified the pond water outflow rate as being in the 0.3 to 0.6 L/s range during the winter season.

f. *Brown McDade Pit pond annual relationship to groundwater:* It has been concluded that the pond behaves as a leaky surface water retention feature, with a seasonally intermittent saturated hydraulic connection to deep groundwater. Water leaves the pit pond, as groundwater, at an average rate of 0.46 L/s (rounded), based on the winter recession curve method, all year, applicable to a pond elevation range between 1,181 and 1,184 m, as recorded by the pond data logger from August 2010 to June 2013, inclusively.

g. *Brown McDade Pit underlying rock piezometric elevation range:* The underlying rock piezometric elevation is a key part in controlling the equilibrium condition between the Brown McDade Pit pond and the surrounding and underlying deep groundwater. (i.e., the long-term groundwater elevation in the Brown McDade Pit starting from an empty pit condition, with negligible climatic inputs and negligible Pony Creek water reporting to the north pit wall). An upper bound value for the piezometric range, within the deeper rock mass underlying the Brown McDade Pit, was derived from pond elevation wintertime minima of five winters, each exhibiting a linear decline. Elevation 1,181 m is currently interpreted as the upper bound value for the piezometric range, within the deeper rock mass underlying the Brown McDade Pit, applicable to the period of minimum pond storage in April-May each year. However, data from VWP CH-P-13-06 (see Figure 6.2-6A) reveals that groundwater levels in bedrock beneath the pit fall to about 1,156 m in the month of April and that fractures in bedrock beneath the pit appear to become unsaturated. The regional minima can also be as high as 1,166 m during the months of October/November (observed initially following drilling CH-P-13-05). The lower bound value for the piezometric range beneath the Brown McDade Pit ranges from 1,156 to 1,166 m.

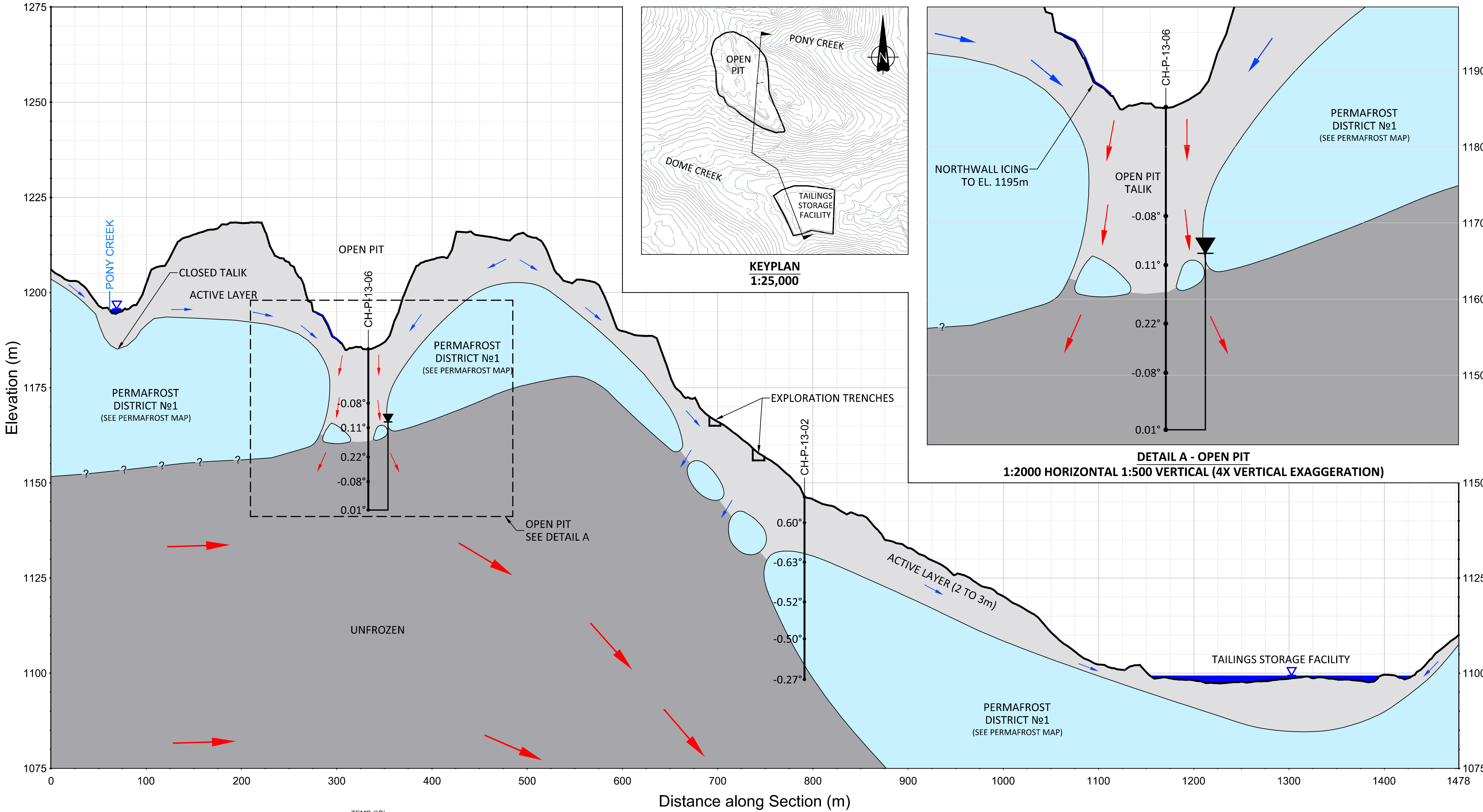
4. *Deep groundwater:*

   a. Deep groundwater in the vicinity of the Brown McDade Pit appears to be recharging unconsolidated overburden in the central and lower reaches of Dome Creek and, to a lesser extent, the lower reaches of Pony Creek.

   b. Deep groundwater discharging to shallow groundwater within Dome Creek and Pony Creek overburden, ultimately to surface water, is currently influenced by relict permafrost surrounding the Brown McDade Pit.

A cross-section extending from Pony Creek, through the Brown McDade Pit, down to the Tailings Pond, is shown as Figure 7.0-1. In that Figure, Pony Creek is depicted adjacent to the Brown McDade Pit with a closed talik that currently limits groundwater-surface water exchange when an active layer is absent. Permafrost is currently limiting water gains to Pony Creek upstream of the Brown McDade Pit for some distance uphill to the northwest. Adjacent to the Brown McDade Pit, Pony Creek appears to be a losing stream with a component of creek water reporting to the Brown McDade Pit, observed in late fall as icing ‘layers’ along the north wall. This surface water contribution to the Brown McDade Pit will tend to increase in the long-term, as the closed talik degrades allowing Pony Creek water to recharge the overburden and deep groundwater adjacent to the Brown McDade Pit.

Figure 7.0-1 shows the Brown McDade Pit pond with its current pond level range of 1,181 to 1,184 m that loses water as groundwater, at an average rate of 0.46 L/s, all year. The Brown McDade Pit is considered to act as a leaky surface water retention feature, with a saturated hydraulic connection to underlying deep groundwater. The current equilibrium elevation between the Brown McDade Pit pond and deep groundwater (i.e. the pond level corresponding to zero climatic and north pit wall seepage inputs) is currently interpreted to be between elevation 1,156 and 1,181 m.



Data Source:
Datum: NAD 1983 CSRS UTM Zone 8N

LEGEND
ACTIVE LAYER FLOW
DEEP GROUNDWATER FLOW

Note: Groundwater and Ground Temperature data will be updated in 2014.

NOTES:
1. FIGURE IS CONCEPTUAL. ALL ELEVATIONS ARE APPROXIMATE.
2. THE PIT FLOOR ELEVATION VARIES, MINIMUM ELEVATION IS 1176m.
3. GROUND SURFACE AT CH-P-13-06 IS 1184m, THE CROSS SECTION ON THE FIGURE INTERSECTS THE PIT AT THE CH-P-13-06 LOCATION, AND NOT AT THE MINIMUM PIT FLOOR ELEVATION.

0m 40 80 120 160
1 : 4000 HORIZONTAL
0m 10 20 30 40
1 : 1000 VERTICAL (4x EXAGGERATION)

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MOUNT NANSEN SITE
Figure 7.0-1

CARE AND MAINTENANCE PROJECT PROPOSAL

CONCEPTUAL HYDROGEOLOGICAL MODEL GROUNDWATER FLOW AND PERMAFROST

FEBRUARY 2017

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