Mount Nansen Site
Hydrologic Monitoring
2011-2012

Prepared for:

Yukon
Energy Mines and Resources
Assessment and Abandoned Mines

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2012 ENVIRONMENTAL EMPLOYER OF THE YEAR

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ENVIRONMENTAL DYNAMICS INC.

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EXECUTIVE SUMMARY

Assessment and Abandoned Mines (AAM) is preparing a project proposal for remediation of the Mount Nansen site. AAM retained EDI Environmental Dynamics Inc. (EDI) to conduct hydrologic monitoring in watersheds at the site in 2011 and 2012 for the purpose of extending and enhancing the existing baseline hydrologic data record.

Hydrometric monitoring at the Mount Nansen site was conducted during the open water season (May-September) and the winter season (October – March). During the open water season, the gauge sites were visited bi-weekly and discharge measurements were collected; in the winter season the gauges were visited on a monthly basis and discharge measurements were collected where appropriate gauging conditions existed. As of March 2012, the hydrometric monitoring program included 18 hydrometric stations and 3 atmospheric stations.

Between May, 2011 and October, 2011, ten hydrometric sites were instrumented with continuous water level loggers installed in stilling wells with staff gauges; three of these data loggers were winterized and left in over the winter. Discharge and stage measurements (where ice conditions permitted) were obtained at all sites including the un-instrumented sites throughout the winter or until the channel was frozen to the substrate.

The 2011/2012 hydrometric monitoring program was successful at capturing a large number of discharge measurements throughout the year in a dense hydrometric network for the study area size. Discharge data were collected using a variety of hydrometric measurement methods and instrumentation including continuous water level loggers, the velocity area mid-section method, salt tracers, a v-notch weir, volumetric and float measurements. The methods were adapted for channel conditions during each visit at each discharge gauging location. The velocity area method was most useful on Victoria Creek and Back Creek whereas, volumetric, weir and salt tracers were found to the most effective means of measurement for all other stations due to smaller channel sizes. Winter discharge measurements provided estimates of streamflow recession to baseflow levels for all channels that continued to convey flow under the ice; however these measurements are considered less accurate than open water measurements. AAM's site meteorologic station malfunctioned during the majority of the monitoring period and as a result updates to the regional climate relationships could not be completed. Instead regional and site climate estimates were obtained from a climate model for western North America based on site location, elevation and climate normals from the period 1971-2000.

AUTHORSHIP

This report was prepared by the EDI Environmental Dynamics Inc. EDI staff who contributed to this project include:

Jane Bachman, B.Sc. .... Primary Author

Dave Bean, M.Sc., E.P. .... Technical Reviewer

Pat Tobler, R.P.Bio., CPESC .... Project Manager

EDI field staff that conducted the 2011/2012 hydrologic monitoring program included Jane Bachman, Meghan Marjanovic, Laura Grieve, Lori Carter, Matt Power and Ben Schonewille. Little Salmon First Nation Assistants were present on all field visits except one; Danny Skookum was the primary field assistant; Shelley Buyck, a Carmacks student assistant, assisted on several visits.

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1 INTRODUCTION

Assessment and Abandoned Mines (AAM) is preparing a project proposal for remediation of the Mount Nansen site. AAM retained EDI Environmental Dynamics Inc. (EDI) to conduct hydrologic monitoring in watersheds at the site in 2011 and 2012 for the purpose of extending and enhancing the existing baseline hydrologic data record. In the future, data from this monitoring report will be compiled with other baseline hydrologic data and be used to support remediation design and the project proposal submission to the Yukon Environmental and Socio-Economic Assessment Board (YESAB).

There are five watercourses in the immediate project area; Pony Creek, Dome Creek, Back Creek and Minnesota Creek drain into Victoria Creek which is a tributary to the Nisling River. The Mount Nansen site is located within the Pony Creek and Dome Creek watersheds.

Prior to the 2011-2012 hydrometric monitoring program, data were collected during the open water season (May to early September) in the Pony Creek, Back Creek, Dome Creek and Victoria Creek watersheds since 2009(AECOM 2010a; 2011). The 2009-2010 data was collected at seven hydrometric stations, and included continuous water level data from data loggers and a monthly stream gauge and stage measurements (AECOM 2010a; 2011).

The 2011-2012 hydrologic monitoring program was designed to achieve the following:

- Continue monitoring at the existing gauging stations in the watersheds noted above;
- Establish additional gauging stations where gaps in the hydrologic understanding of the site were determined through discussions with AAM;
- Address site specific problems with the gauges encountered in previous monitoring years (i.e., sedimentation);
- Improve measurement quality in the smaller creeks where traditional gauging techniques (i.e., the mid-section method) are not feasible at all stages;
- Obtain monthly winter measurements at gauges where additional base flow data was recommended by the 2011 Project Team (Lorax Environmental 2011).
- Produce a quality controlled hydrometric database (MS Access) for raw and corrected data;
- Update the regional precipitation and temperature analysis.

The resulting hydrometric monitoring network in 2011/2012 was expanded as follows:

- Three sites were identified in May 2011 as important locations for additional stations to correlate with water quality monitoring locations in the Dome Creek and Victoria Creek watersheds.
- Seven additional sites were recommended in November 2011 to obtain water quantity data for correlation with water quality sites during low-flow conditions (Lorax Environmental 2011). These sites were located in the Dome Creek, Victoria Creek and Minnesota Creek watersheds.

1.1 PROJECT LOCATION

The Mount Nansen site is located approximately 45 km east of Carmacks, in the Yukon Territory (Figure 1). The site is part of the Klondike Plateau ecoregion characterized by warm summers and very cold winters; precipitation amounts are between 300-500 mm with the majority of rainfall occurring between June and August. The mean annual temperature is -5°C; average January temperatures range between -23°C and -32°C; and average July temperatures range from 10°C to 15°C. On a regional scale the site is part of the extensive discontinuous permafrost zone (50-90% coverage). The Klondike Plateau is part of the Beringia region where the last glaciations occurred approximately 3 Ma. As a result, bedrock in the site area is highly weathered and fractured (Smith et al. 2004).

The Mount Nansen site lies within the Nisling River drainage basin. The Nisling River flows into the Donjek River, a tributary of the White River which in turn flows into the Yukon River upstream of Dawson City (Figure 1). There are five main watercourses flowing through or near the Mount Nansen site. These are Pony Creek, Dome Creek, Back Creek, Minnesota Creek and Victoria Creek (Figure 2).

The small Pony Creek watershed is on the north side of the site and flows into Back Creek, a tributary of Victoria Creek. Dome Creek is the main watershed that overlaps with the Mount Nansen site footprint and confluences with Victoria Creek approximately 8.4 km upstream of the confluence with the Nisling River (Figure 2). The Mount Nansen Road crosses Victoria Creek approximately 6.4 km upstream of the confluence with the Nisling River. Further details on each of these watersheds are found in the 2011/2012 monitoring network description (Section 3).

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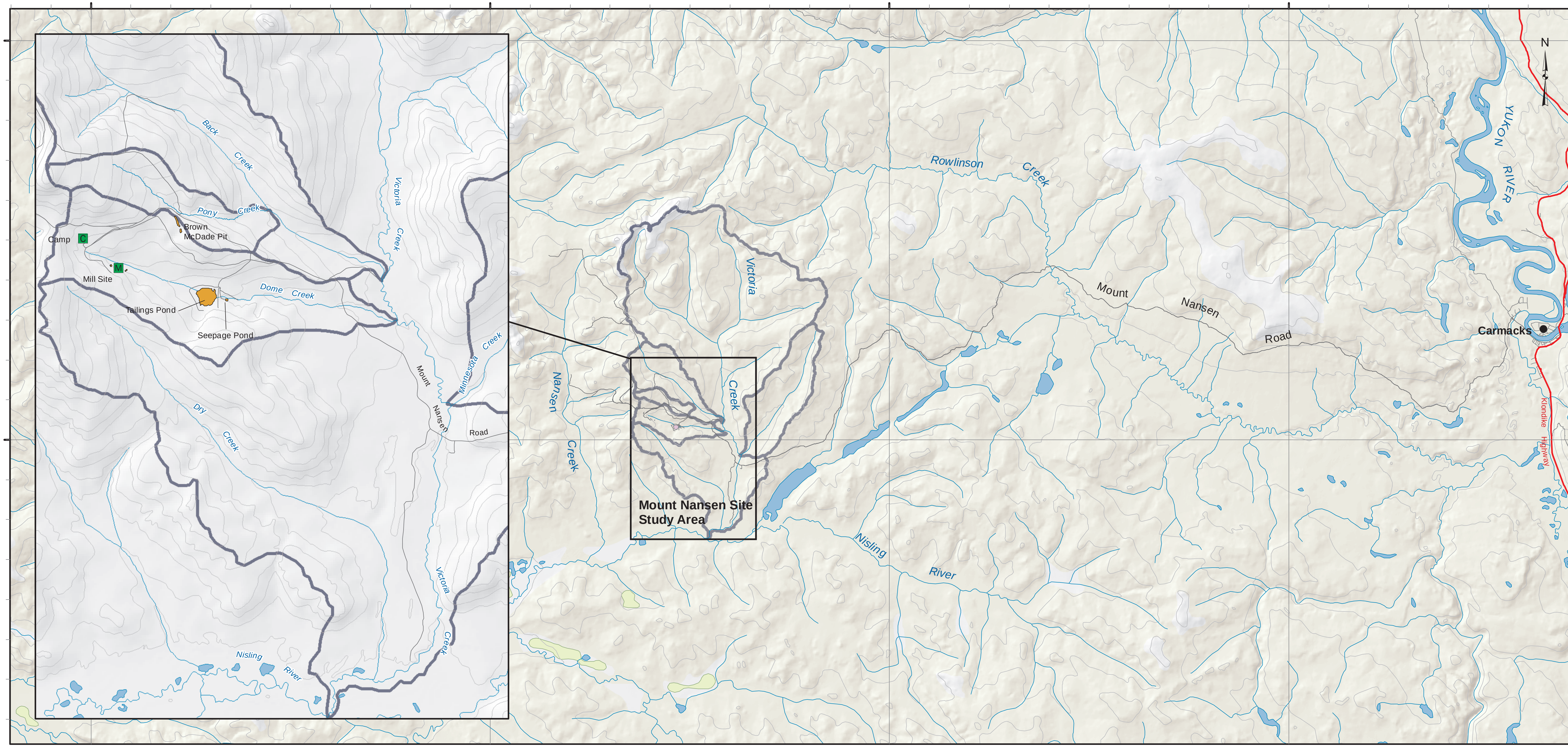

Regional Overview Map of Mount Nansen Site Area

Legend

- Unpaved Road/Access
- Highway
- Topographic Contour
- Watercourse
- Waterbody
- Wetland Area
- Drainage Areas (Local)

1:250,000 and 1,000,000 Topographic Spatial Data provided by Natural Resources Canada via online source geogratis.cgdi.gc.ca.

Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2011) was obtained using Garmin GPS technology.

This document is not an official land survey and the spatial data presented is subject to change.

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Map Projection: North American Datum 1983 UTM Zone 8N

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MP	JB / MM	FIGURE 1	Date: 4/5/2012

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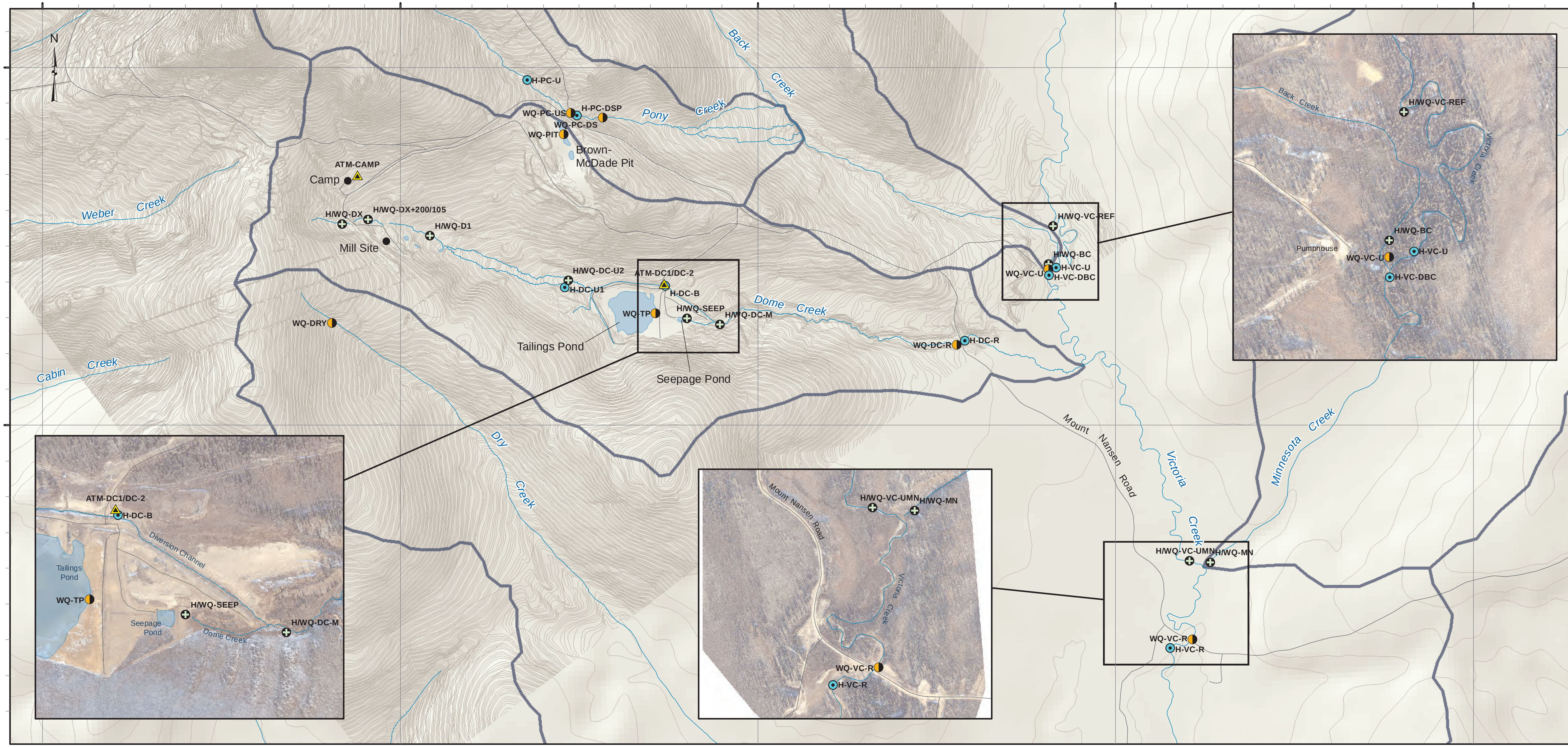

Mount Nansen Site: Hydrometric and Water Quality Stations

Legend

- Atmospheric Station (label ex: ATM-DC-1)
- Hydrometric and Water Quality Station (label ex: H/WQ-DC-U2)
- Hydrometric Station (label ex: H-VC-R)
- Water Quality Station (label ex: WQ-PC-US)
- Unpaved Road/Access
- Contours (1 m where contours are shown in detail)
- Contours
- Drainage Areas (Local)

1:250,000 and 1,000,000 Topographic Spatial Data provided by Natural Resources Canada via online source geogratis.cgdi.gc.ca.

Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2011) was obtained using Garmin GPS technology.

Contours (1 metre) were provided by Yukon Government Department of Energy, Mines and Resources (2012).

This document is not an official land survey and the spatial data presented is subject to change.

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metres

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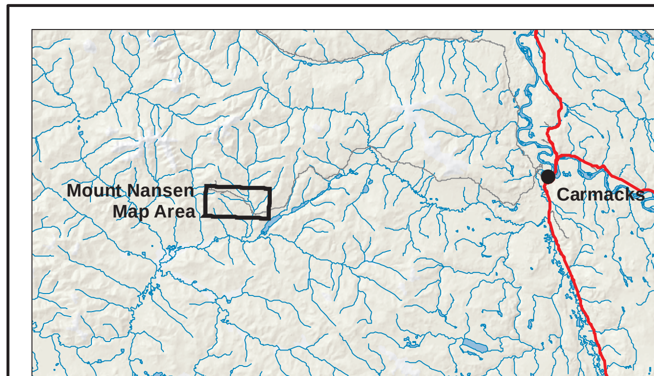

Yukon EDI

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2 MONITORING METHODS

Hydrometric monitoring at the Mount Nansen site was conducted during the open water season (May-September) and the winter season (October – March). The start and end of the open water season varied among sites depending on the thickness of ice present in the channel in the spring, air temperatures and channel size. During the open water season, the gauge sites were visited bi-weekly and discharge measurements were collected; in the winter season the gauges were visited on a monthly basis and discharge measurements were collected where appropriate gauging conditions existed.

2.1 DISCHARGE MEASUREMENT TECHNIQUES

Discharge measurements at the Mount Nansen site were obtained during both the open water and winter seasons. Varying conditions such as extreme low flows, vegetation in the channel and the presence of ice required a combination of discharge measurement techniques throughout the year. Many of the creek are small channels which are either too shallow, too narrow or have too much vegetation present in the channel for accurate measurements using the conventional velocity-area technique. In total, six different methods of discharge measurement were used and at most sites, data was obtained using at least two methods if the velocity-area method was not employed. The selection of discharge measurement methods were prioritized according to relative measurement accuracies and were prioritized in this order during each site visit. The following list and proceeding sections are in order of relative accuracy (most to least accurate):

1. Volumetric
2. V-notch weir
3. Velocity-area
4. Salt tracer
5. Float

2.1.1 Volumetric

The volumetric method for measuring discharge was used at four sites where a culvert, pipe or a weir was present. Volumetric measurements are considered to be one of the most accurate methods because all the streamflow is captured in a bucket of a known volume at a confined outlet or constriction. The channel constrictions created by the culverts, pipe and weir provided an opportunity to measure the streamflow by measuring the time to fill a bucket of known volume. Typically the bucket size was 19 L and five measurements were made and averaged to reduce measurement error with the timer. The estimated measurement accuracy is +/- 10%.

2.1.2 V- Notch Weir

A 90° thin plate v-notch weir was installed in the upper Pony Creek watershed approximately 15 m upstream of the H-PC-U gauging site at an existing channel constriction (Figure 3). Head over the weir crest was measured during each site visit as a secondary measurement method at the site (the primary measurement technique was using salt slug tracers). Discharge from the weir was calculated using a standardized rating structure equation for a fully contracted v-notch weir where:

$$Q = 1.370\ h^{25}$$

Where Q is discharge in m^3/s, and h is the height of water above the v-notch (head) (RISC 2009).

The operating limits for thin plate v-notch weir structures are summarized in Table 1. Low flow discharge values outside of the operation limits are noted.

Table 1. Design operating limits for v-notch weirs (from Table 6, RISC, 2009) and H-PC-U as-built design parameters and measurement ranges.

	Device Type	Device Size	Max. h_1(m)	Max. Q (m^3/s)	Min. h (m)	Min. Q (m^3/s)	Debris Capacity	Sediment Capacity	h/p
Design	V-Notch	90°	0.60	0.390	0.05	0.0008	Very Poor	Very Poor	≤1.2
As-built/ 2011 Measured Values	V-Notch	90°	0.14	0.016	0.035*	0.0003*	No Debris Issues	No Sedimentation Issues	1.2

Notes:

* Minimum discharge measured at the weir is outside the rating structure accuracy range.

p = Depth of approach channel below the crest of the upstream side of the weir.

Figure 3. V-notch weir installation in the upper Pony Creek watershed (H-PC-U).

2.1.3 Velocity-Area

The mid-section velocity-area method (RISC 2009) was used to calculate discharge in streams where flow depths were greater than 10 cm and the channel was wide enough to obtain at least 20 measurements. At all hydrometric gauging locations the water depth was less than 0.75 m. Specific measurement sites were chosen where the velocity profile was expected to be as laminar as possible such the velocity at 60% of the depth represented the average velocity in the water column (RISC 2009). Using the discharge ($\boldsymbol{Q}$) relationship with velocity ($\boldsymbol{v}$) and ($\boldsymbol{A}$): $\boldsymbol{Q = v \cdot A}$, the cross-section panel width and depth were multiplied by the velocity averaged over 40 seconds to obtain an instantaneous discharge measurement.

Discharge was calculated using the mid-section method and the following equation was used for each panel:

$$q = v_n d_n \frac{(b_{n+1} - b_{n-1})}{2}$$

Where q is the discharge (m^3/s) in the panel, v is the velocity (m/s), d is the depth (m) and n is the panel number. The discharges for the first and last panels were calculated using half the distance from the edge to the first and last verticals. The discharges for each panel were summed to obtain the total discharge at the cross-section.

The current meters used to collect the velocity measurements were a Swoffer current velocity meter (Model 2100) and a Price Type Pygmy current velocity meter. Measurement accuracies for these instruments are +/- 1% and were checked for calibration before each trip. During the March 2012 site visit, a Sontek ADV Flow-Tracker was used on site, however extreme low flows and ice conditions produced poor quality measurements.

2.1.4 Salt Tracer

Salt tracers (or salt dilution gauging) were used at hydrometric sites where the channel conditions were not suitable for using a current meter. During the winter this was often the only feasible method of discharge measurement due to ice. Every site was gauged using salt dilution methods at least once during the monitoring period (with the exception of SEEP). The methodology was adapted to the site based on guidelines presented in Kite (1994), Laberge Environmental Services (1999) and Moore (2005). Site channel and temperature conditions required some adaptations to the methodology presented in Moore 2005 therefore methods employed at Mount Nansen followed the Laberge Environmental Services (1999) technical report which tested and validated the salt slug injection method in the Yukon Territory. The authors tested salt slug tracers at various locations including a high background conductivity stream located on an abandoned mine site. The formula used to calculate discharge was:

$$Q = \frac{1000 M_s \Gamma_{g,25}}{\tau \sum (EC_m - EC_o)}$$

Where Q is discharge (m^3/s), M_s is the mass of salt (kg), Γ_{g25} is the gram conductivity assumed to be 2.01 µS/cm/m^3 (Laberge Environmental Services 1999), τ is the time interval in seconds and EC_o and EC_m are the background conductivity and measured conductivity, respectively. A typical salt tracer curve is shown in

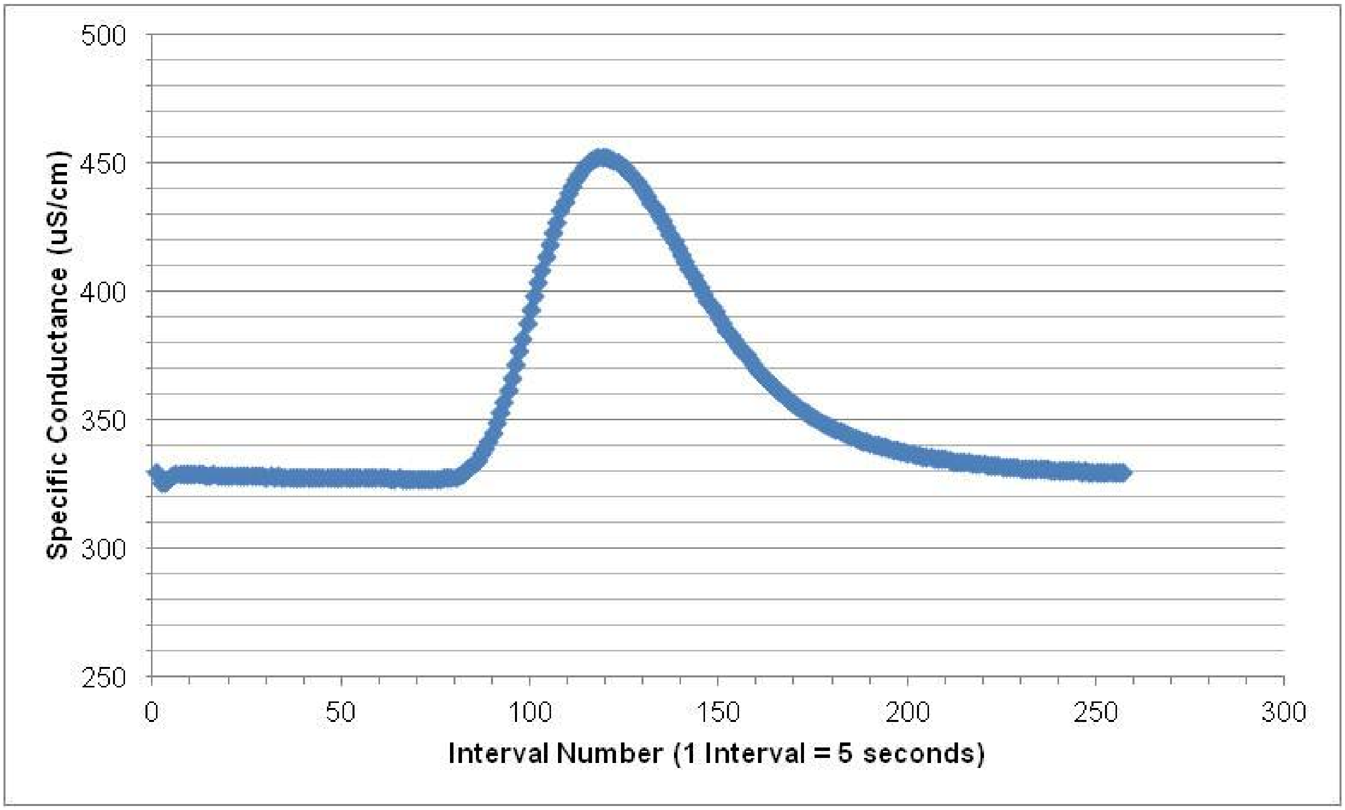

Figure 4. Typical salt slug tracer specific conductance curve.

Background specific conductance at the hydrometric sites range from between 1015 µS/cm (DC-M) and 119 µS/cm (MN) with an average of 639 µS/cm. These conductivities are below the high conductivity range validated in the Yukon (Laberge Environmental Services 1999). The assumption for gram conductivity was checked at several locations at the Mount Nansen site confirming that the gram conductivity, 2.01 µS/cm/m^3 =+/- 10%, was valid. Typically the target maximum specific conductance measured during the trials was between 50% and 150% of the background specific conductivity.

Bags of salt were pre-weighted to the nearest milligram using a laboratory balance. The known volume of water and mass of salt are mixed in a 19L plastic bucket until the salt was fully dissolved. Salt injection sites were selected to traverse the gauging station site and preferentially located upstream of constrictions (e.g., culverts) to facilitate full mixing. A conductivity meter recorded specific conductance approximately 30 m downstream for the smaller creeks and 30 m to 90 m for Victoria Creek, depending on channel conditions.

For each salt tracer measurement, a minimum of two trials were conducted and the resulting discharge values were averaged. Specific conductivity was measured or logged using a calibrated YSI Professional Plus or YSI 556 MPS multi-meter (Figure 5). Efforts were also made to obtain a secondary measurement using an alternative gauging method such as a volumetric measurement in order to validate salt tracer measurements.

Figure 5. **Salt tracer conductivity meter set-up. Salt input site was 90 m upstream of the conductivity meter.**

Testing was done to determine how volumetric measurements varied from salt gauging. Salt gauging and volumetric measurements at H-PC-DSP were both regularly conducted at each site visit and the salt slug injection point at the upstream end of a road culvert ensures good mixing in the channel downstream. Figure 6 shows that salt slug tracers tended to overestimate the volumetric measurements by 20-40%. While over-estimate is specific to H-PC-DSP, the conservativeness of the salt tracer method is assumed similar at other hydrometric gauges.

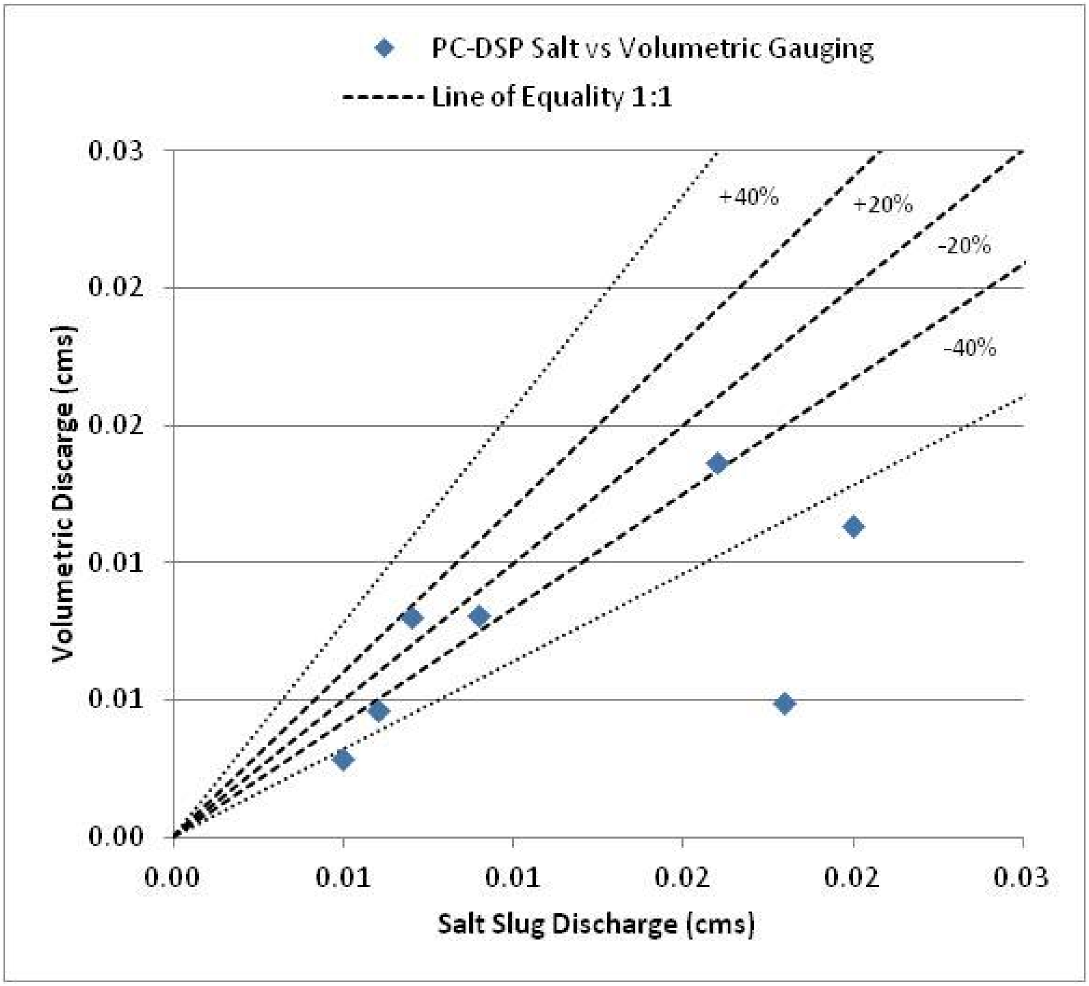

Figure 6. **Volumetric Vs. Salt Slug Tracer Discharge Measurements**

2.1.5 Float

This method involves launching a float in the channel thalweg (typically a small orange or stick) and recording the time it takes to travel a given distance. This method was predominantly used on the small creeks (i.e., not Victoria Creek) as a redundant measurement for other methods. Typically a travel distance of 5 m was used and flows depths were shallow (ie. too shallow for a current meter). However, certain site or hydraulic conditions required shorter distances and were adjusted accordingly. Five measurements were collected and the average velocity in the reach calculated. Average width and depth measurements over the measurement reach were obtained for a velocity-area calculation using the float velocity.

The float method is relatively simple and does not provide a high level of accuracy therefore it was only used when no other method was possible, or as a back-up method for the salt tracer measurements. The measurements made using this method are generally of the same order of magnitude as other more accurate methods, but the float measurements were not used to develop stage-discharge rating curves.

2.2 WINTER HYDROMETRICS

Measuring discharge during the winter months at the Mount Nansen site required several different measurement techniques. All creeks were ice covered during the winter therefore each winter visit required checking for flow beneath the ice using an ice auger or axe (depending on ice thickness). If flowing water was found to be present, one of two discharge measurement techniques were used depending on channel geometry beneath the ice. These methods were salt tracers and current meters. In Victoria Creek, a current meter was used with substantial attention to flow conditions and the condition of the instrument. To use the current meter, no frazil ice could be present; flow depths were required to be sufficient for the current meter to operate without obstruction; and the current meter could move freely (i.e., no icing on moving parts). Typically, cold air temperatures required the current meter to be kept in flowing water throughout the measurement so that the parts would not freeze. If these channel conditions were present, then the ice was cut across the channel for the cross-section and current meter measurements were obtained at 50% of the flow depth (RISC 2009).

If these channel conditions were not present in Victoria Creek, then the salt tracer discharge method was used with the same method as open water conditions. Discharge measurements at all other locations throughout the site were collected using salt tracers (or volumetric at applicable sites). Ice augers were used to drill holes in the ice for the conductivity meter in the same locations used during open water conditions.

Figure 7. Winter velocity measurements using a current meter on Victoria Creek.

2.3 RATING CURVE DEVELOPMENT

Rating curves are based on open channel hydraulic relationships between stage (water level) and discharge. The y-axis represents the recorded stage level at the gauge and the x-axis the discharge. The rating curve equation represents the hydraulic reaction of a smoothly varying channel with increasing stage (or a constant control point at all stages) (Maidment 1992). The rating curve equation has the form:

$$Q = C(h + a)^N$$

Where Q is discharge in m^3/s, C is similar to the channel width, (h+a) represents the depth of water above the minimum control height (channel bed) and the value of N is a function of the channel geometry (Maidment 1992). If the pressure transducer is below the point of zero flow, the value of is negative; conversely a positive value indicates that it is above. Typically as the stage increases, the hydraulic control shifts from low flow hydraulic control to channel friction control or to ice related controls and as such, multiple rating curves are often required to accurately represent the full range of flows in the stream.

By taking the log of both sides of the rating curve equation,

$$\log Q = logC + N log(h + a)$$

the rating curve equation takes the linear form y=mx+b and can be fit to the discharge calibration points as a straight line. Rating curves may be developed using several different methods including fitting the calibration points by eye and the maximum likelihood solution. Given the small size of the channels at the Mount Nansen site, and the small range of change in stage, and channel instabilities, the rating curves were developed by fitting by eye in the Aquarius Time Series Software environment (Aquarius Informatics Inc.). Rating curves were developed for the 10 hydrometric gauging stations that had a continuous water level logger.

2.4 CONTINUOUS STAGE RECORDS

Continuous stage level data loggers were established at ten sites, in four watersheds at the Mount Nansen site in 2011. Seven of these sites were at the same locations as the loggers installed in 2009 and 2010. The data loggers were non-vented HOBO U20-001-04 pressure transducers with a 0-4 m range (± 3 mm or 0.43kPa). The pressure transducers record water temperature and pressure. Several gaps in the data logger records (described in Section 2.5) existed and it was found that the HOBO software could not handle gap filling, and signal joining satisfactorily and caused problems with time stamps therefore the raw HOBO pressure and temperature data was exported to Aquarius Time-Series software and the following calculations were made manually:

The water pressure was compensated for atmospheric pressure recorded from a barometric pressure logger (i.e., $P_{H\text{-}PC\text{-}U} - P_{ATM\text{-}DC2}$). Water depth was found using the following relationship from the Euler/Bernoulli equations where:

$$H = \frac{P}{\gamma} + z$$

Hydraulic head (H) or water depth, hydrostatic pressure (P) in Pa, the specific weight of water $\gamma = pg$ where p is the density of water at a given temperature (kg.m^{-3}), g is acceleration due to gravity (m.s^{-2}) and z is elevation above a datum. Density of water varies with temperature and given the wide range in stream temperatures throughout the year, the density was computed using the Thiesen-Scheel–Diesselhorst equation (Maidment 1992):

$$\rho = 1000\left[1 - \frac{t + 288.94}{508929.2(t + 68.12963)}(t - 3.9863)^2\right]$$

Stage records were obtained at 5 minute intervals during the open water season and 15 minute intervals in the latter portion of the winter (January 2012 to March 2012). Measurements required re-sampling at 30 minute intervals for data analysis due to a limiting dataset used for filling gaps (see Section 2.5).

Continuous discharge was calculated using the stage discharge rating curve for each site.

2.5 GAP FILLING

There were several instances in the continuous data logger records where gaps were present due to data downloading errors or equipment malfunction. The majority of the gaps were short in duration (i.e., less than 30 minutes) and associated with the downloading process overlapping with a logging interval. These short duration gaps were linearly interpolated at 5 minute intervals. In some cases these gaps could be filled using simple interpolation techniques or surrogate signals from other stations where strong relationships were observed (i.e., for barometric logger gaps).

The following is a list of logger data gaps, causes and gap filling techniques employed:

- July 20 and August 3, 2011 – this occurred at all barometric and water level loggers except H-PC-DSP during data retrieval on August 3, 2011.
    - The water level logger data gaps were not filled because no appropriate surrogate signal existed; Hydrologic responses at H-PC-DSP do not reflect responses at other sites.
    - The ATM-CAMP data (30 minute intervals) were used to fill data gaps at ATM-DC1(5 minute intervals)
- The ATM-DC1 data logger became encased in ice between October and November site visits and was subsequently unrecoverable. The ATM-DC1 record stops on October 12, 2011. ATM-CAMP was used to fill the data gap until a new logger (ATM-DC2) was installed at the site in January, 2012.
- The HOBO weather station that logged meteorologic parameters (i.e., rainfall, temperature, wind speed and direction) located near the camp kitchen was in place before the 2011/2012 monitoring program began. The station malfunctioned on June 8, 2011 two days after the last data download. The reason for the malfunction could not be determined by the manufacturer and the weather station could not be repaired. AAM installed a new weather station on October 19, 2011 in a new location (similar elevation). The resulting data gap for rainfall, wind speed and wind direction occurred between the dates noted above. Temperature and barometric data continued to be collected by the ATM-CAMP barometric logger (separate instrument from weather station) as a back-up for ATM-DC2.

It should be noted that the meteorologic data obtained from AAM for the period prior to the 2011/2012 monitoring period has major quality control issues that were outside of the scope of this workplan to address.

2.6 DISCHARGE UNCERTAINTY

All instruments used to measure velocity, specific conductivity for discharge measurements were maintained and calibrated regularly. The measurement uncertainties associated with these instruments are noted in Section 2.1, and individual measurement data flags are found in the database.

Five additional sources of discharge measurement uncertainty associated with poor environmental or channel conditions were noted on site:

- Vegetated channels
- Braided Channels
- Channel instability and siltation
- Groundwater discharge to streams
- Winter streamflow measurements obtained under ice

While efforts were made to follow guidelines for the selection of high quality sites for hydrometric stream gauging (following RISC 2009), the Mount Nansen site offers few stable sites to establish permanent dataloggers. All sites except those in Victoria Creek were characterized by fine grained beds and banks influenced by ground ice and permafrost that caused some degree of instability in the channel during the summer. Most of the smaller channels are influenced by vegetation in the channel providing resistance to flow. In addition, storm events in summer produced pulses of fine sediment in the diversion channel that required excavation. Higher than normal winter baseflows in Dome Creek produced large aufeis (ice developed from groundwater seepage) dams near the diversion channel bridge that had to be regularly excavated to ensure the stability of the bridge. As a result, the continuous discharge measurements at H-DC-B have a higher degree of uncertainty than other sites.

While winter measurements are valuable indicators of baseflow, discharge measurements in ice affected channels are considered less accurate than during open water conditions due to the backwater effect of ice in (e.g. frazil ice, anchor ice) or on the channel. Winter measurements flagged with the letter B (similar to the Water Survey of Canada) indicate ice conditions were present during measurements.

2.7 HYDROMETRIC GAUGE REPAIRS AND ONGOING MAINTENANCE

Prior to the EDI 2011 monitoring program, the last site visit to the seven existing hydrometric gauging stations was early September 2010. Solinst data loggers were left in over winter and numerous repairs to the benchmarks, stilling wells and staff gauges were required prior to commencing the monitoring program in May, 2011. The data loggers left over winter were recovered and replaced. The 2010/2011 winter pressure transducer data was recovered from the loggers, but given that there were no 2010/2011 winter streamflow measurements, the stage data could not be converted to discharge nor could the condition of the gauge with respect to ice conditions be confirmed.

Throughout the 2011/2012 monitoring program regular site visits enabled monitoring of the hydrometric stations for sedimentation and channel stability. Every site visit included a hydrometric level survey to ensure stability of benchmark pins, staff gauge and stilling well. Checks for sedimentation inside the stilling well were also conducted. In general, if 1 cm of sediment or less had accumulated inside the stilling well, the accumulation measurements were noted, the data logger checked to ensure it was not buried in fine sediment and the stilling well was left alone. However if greater than 1 cm of sediment accumulation in the well was present, the wells were cleaned out and re-surveyed. At several sites prone to instability and sedimentation (e.g., DC-B, DC-U2, DC-R, and VC-R) the stilling wells were found to be filled with fine sediment and required cleaning on several occasions.

Benchmarks were established at each site with a continuous data logger to survey in water levels and monitor for shifts in the installation. The gauging stations were surveyed at least once per month throughout the year to monitor channel and benchmark stability. If channel changes such as scour or sedimentation occurred, they were quantified with the surveys and the level logger data were corrected if required.

The operating temperature range for HOBO U20 Level Loggers is -20°C to 50°C (sensors calibration 0°C-40°C). Since the site is regularly subjected to lower temperatures throughout the winter, in the case that the loggers were dewatered or iced into the wells, the data loggers were 'winterized' to protect the pressure transducer sensors from the cold temperatures and ice build-up. The data logger sensors were covered in a condom, filled with non-toxic glycol and sealed with pipe clamps prior to freeze-up in September, 2011 (Figure 8).

Figure 8. A winterized HOBO U20-001-04 water level logger.

2.8 HYDROMETRIC DATA MANAGEMENT

A database was developed in MS Access to hold the 2011-2012 hydrometric monitoring data and related regional data. This enabled efficient QA/QC processing and will facilitate easy data transfer to AAM and the Project Design Team in the future. The hydrometric database was designed to hold raw field data transferred from hardcopy field sheets and data loggers. Data are reviewed through a QA/QC process and data issues are flagged, corrected and changes tracked. Discharge measurement data are extracted from the database for calculations in external software (Aquarius Workstation, MS Excel). Once computations are made in external software, the results are added back to the databases in summary tables (e.g., compensated water level logger data, stage-discharge rating tables).

2.9 MOUNT NANSEN SITE METEOROLOGIC DATA

There have been three meteorological stations recording barometric data for various time periods since 2009. The HOBO Weather station (ATM-CAMP AAM) that was operating in May 2011 at the start of the 2011 monitoring program, ceased to operate due to instrument malfunctions on June 8, 2011. The only instrument that continues to operate at the ATM-CAMP AAM station is a HOBO logger which records barometric pressure and air temperature. Looking back at the record for this station there is also a data gap between July 22, 2010 and July 10, 2011 however this may be related to the QA/QC required for this historical data noted in Section 2.5.

In October 2011, a new meteorologic station (ATM-ROAD AAM) was installed near the camp adjacent to the Mount Nansen access road at a similar elevation as ATM-CAMP AAM. The ATM-CAMP AAM meteorological station instrument malfunction produced a gap in rainfall data collection between June 8, 2011 and October 19, 2011; the air temperature record for this station is complete. A short term monitoring station was set up by Yukon Government (YG) Energy Mines and Resources (EMR) Client Services on Victoria Creek near the Mount Nansen Road crossing and provided some information on rainfall during the summer of 2011.

3 2011/2012 HYDROMETRIC MONITORING PROGRAM

As of March 2012, the hydrometric monitoring program included 18 hydrometric stations and 3 atmospheric stations. Seven of the hydrometric stations were originally established with continuous data loggers in 2009 and were monitored until September 2010 (AECOM 2010a, 2011).

In May 2011, EDI began monitoring surface water quantities on a bi-weekly basis throughout the open water season and monthly throughout the winter until March 2012. Streamflow monitoring in the beginning of May included site reconnaissance at the gauge sites, repair of winter damage and the re-establishment of the 7 existing hydrometric stations with new water level loggers and benchmarks (where required) and discharge measurements. Throughout the 2011/2012 program, an additional 11 hydrometric stations were added to the network, however only three of these additional sites were instrumented with continuous water level loggers. The remaining sites were established for low flow monitoring objectives in November, 2011 which was too late in the year for the installation of continuous loggers before winter.

Between May, 2011 and October, 2011, ten hydrometric sites were instrumented with continuous water level loggers installed in stilling wells with staff gauges; three of these data loggers were winterized and left in over the winter. Discharge and stage measurements (where ice conditions permitted) were obtained at all sites including the un-instrumented sites throughout the winter or until the channel was frozen to the substrate.

The reporting period for this monitoring report is May 12, 2011 to March 8, 2012.

Table 2. Summary of 2011/2012 Field Visits

Visit #	Date From	Date To	Key Monitoring Events[1]
1	12-May-11	12-May-11	Gauge site reconnaissance; Discharge measurements
2	25-May-11	25-May-11	Gauge site repairs; Discharge measurements
3	06-Jun-11	07-Jun-11	Water level loggers installed at all sites except DC-R; Discharge measurements
4	22-Jun-11	23-Jun-11	Second Upper Dome site added (DC-U2), logger installed; DC-R logger installed; Discharge measurements
5	06-Jul-11	07-Jul-11	Discharge measurements
6	20-Jul-11	21-Jul-11	Discharge measurements
7	03-Aug-11	04-Aug-11	Discharge measurements
8	17-Aug-11	18-Aug-11	Discharge measurements
9	30-Aug-11	31-Aug-11	Discharge measurements
10	14-Sep-11	14-Sep-11	Discharge measurements
11	27-Sep-11	28-Sep-11	All water level loggers winterized; Discharge measurements
12	11-Oct-11	12-Oct-11	All stream data loggers removed except DC-M, VC-U, VC-R; Discharge measurements
13	16-Nov-11	17-Nov-11	7 new winter low flow gauge sites added; Discharge measurements
14	14-Dec-11	15-Dec-11	Discharge measurements
15	09-Jan-12	12-Jan-12	Discharge measurements

Visit #	Date From	Date To	Key Monitoring Events[1]
16	30-Jan-12	01-Feb-12	All winter loggers dewatered/frozen to bed; Discharge measurements
17	05-Mar-12	06-Mar-12	New winter submerged loggers installed; Discharge measurements

Note: All site IDs in Table 1 are described in Section 3.1.

3.1 HYDROMETRIC MONITORING NETWORK

The hydrometric gauge sites are labeled according to their location in the. Most of the site names of the existing stations from 2009 and 2010 have remained the same, however all sites have been assigned a Hydrometric ID (HID) for ease of reference in the database and on maps (Figure 2). The HID takes the form:

H-XX-YYY

Where **H** refers the hydrometric monitoring program, **X** refers to the watershed and **Y** annotates the location within the watershed. Similarly, since most water quality sampling sites are coincident with the hydrometric stations, the water quality sites are labeled **WQ-XX-YYY**.

A typical hydrometric gauging station (Figure 9) with a continuous data logger includes the following items:

- Staff gauge (1.0 m);
- Anchored stilling well (ABS pipe with holes drilled along one side);
- Continuous water level logger (HOBO U20-001, accuracy ±3 mm);
- Benchmarks (rebar, unless otherwise noted);
- Set locations for mid-section method cross-sections and salt tracer input/output locations.

The hydrometric stations are located in five watersheds that either flow out of the Mount Nansen site footprint or confluence with creeks that flow from the site (Figure 2). These watersheds are Pony Creek, Dome Creek, Back Creek, Minnesota Creek and Victoria Creek.

The proceeding sections summarize the gauging station locations and site specific installation details and discharge measurement methods. Appendix A contains sketches and photos of the hydrometric gauging stations, including benchmarks and access trails.

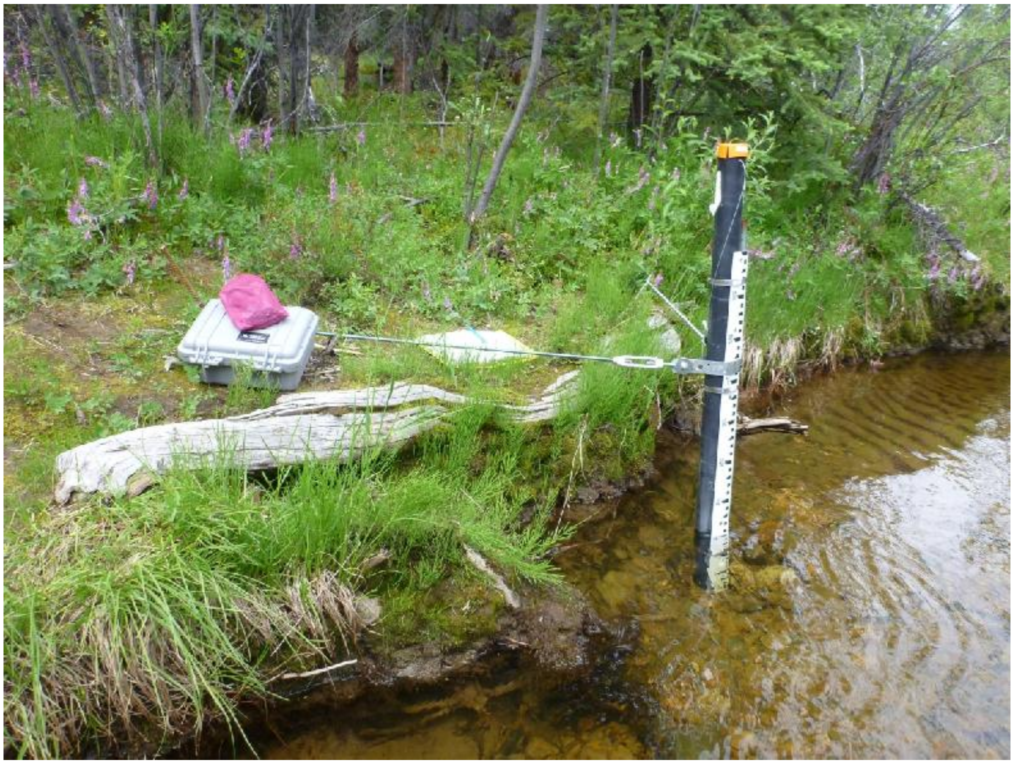

Figure 9. Hydrometric gauging station installation for a continuous data logger on Victoria Creek.

3.1.1 Pony Creek Watershed

Pony Creek is a small, ephemeral stream that flows southeast past the north end of the mine pit (Figure 2). The total drainage area (A_D) is 1.7 km^2. There are a number of locations along the length of the channel where flow is sub-surface and re-surfaces downstream. Channel dissection and infiltration to ground appears to occur in the fan area upstream of the Back Creek confluence (see Figure 2). Pony Creek empties into Back Creek near the southeast corner of the mine site via a poorly defined channel. While there is a deep regional groundwater divide between Pony Creek and the pit, it is suspected that there is shallow groundwater hydraulic connectivity via fractured bedrock (AECOM 2010b). Evidence of these hydraulic pathways has been observed during two periods of the year; late fall and early winter in response to rainfall events, and the months of May and June in response to snowmelt and freshet in Pony Creek (AECOM 2010b).

The Pony Creek channel was affected by the construction of an access road with a culvert (Back Creek watershed access road), the deposition of waste rock piles into the stream during active mining and trenching in the upper watershed. The trenching activity resulted in earth berms changing the course of the channel and caused pooling in some areas. Several placer claims are still active in the upper watershed and evidence of recent excavation activity was observed in 2011.

There are two hydrometric gauging stations located in the Pony Creek watershed (Figure 2). Details of the gauging station installation are located in Table 3.

Table 3. Pony Creek watershed hydrometric monitoring stations.

Hydrometric ID	Hydrometric Station Name	Location	Easting	Northing	Drainage Area (km^2)	Installation Details	Logger Serial #	Start Date	End Date	Winter Data Logger
H-PC-U	Upper Pony Creek	Upper Pony Creek watershed	6881930	388708	0.84	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks; V-Notch weir located 15 m upstream of data logger at constriction	9896521	06-Jun-11	12-Oct-11	No
H-PC-DSP	Pony Creek Downstream of Pit	15 m downstream of Back Creek access road and culvert	6881734	388986	1.0	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Stable Rock Weir; Benchmarks	9896522	07-Jun-11	12-Oct-11	No

[1] – NAD 83, UTM Zone 8

3.1.2 Dome Creek Watershed

The Dome Creek watershed has a total drainage area of 4.78 km^2 and contains the majority of the abandoned mine site footprint. The upper portion of the watershed lies upstream of the mill site (Figure 2), the middle portion of the watershed contains the tailings pond where the channel is constrained to a diversion channel around the north side of the tailings pond. The lower portion of the Dome Creek watershed receives flow from both the diversion channel and the seepage pond outflow (water pumped from the seepage pond) and is thus influenced by pumping rates. Lower Dome Creek is also intersected by the Mount Nansen access road where streamflow is routed through a culvert. The accumulation of large amounts of snow and aufeis (overflow ice) throughout the Dome Creek Valley is an indication that while the watercourse typically (not in 2011/2012) freezes to the substrate through the winter season, groundwater discharge continues. At the road crossing this accumulation of aufeis often leads to ice blockage in the culvert and build-up on the road. The melt of the aufeis typically leads to high flows in mid to late June.

There are nine hydrometric gauging stations located in the Dome Creek watershed including the outflow pipe from the seepage pond (Table 4).

Table 4. Dome Creek watershed hydrometric monitoring stations.

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
H-DX	DX Dome Creek Headwaters	6881127	387674	0.21	None; Discharge measurements only	-	-	-	No
H-DX+200/105	DX+ 200 m Seep (+105 in Winter)	6881150	387819	0.52	None; Discharge measurements only	-	-	-	No
H-D1	D1 Dome Creek Headwaters	6881059	388166	0.91	None; Discharge measurements only		17-Nov-11	12-Oct-11	No
H-DC-U1	Upper Dome Creek 1	6880772	388919	2.05	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9896528	07-Jun-11	12-Oct-11	No
H-DC-U2	Upper Dome Creek 2	6880812	388938.3	2.05	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908128	22-Jun-11	12-Oct-11	No
H-DC-B	Diversion Channel at Bridge	6880780	389479	3.02	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks; Rock Weir	9896533	06-Jun-11	12-Oct-11	No
H-SEEP	Seepage Pond Outflow	6880598	389603	n/a	None; Discharge measurements only	-	-	-	No

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
H-DC-M	Middle Dome Creek	6880565	389788	3.26	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908153	23-Jun-11	07-Mar-12	Yes
H-DC-M Winter	Middle Dome Creek Temporary Submerged Winter Logger	6880565	389788	3.26	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908153	06-Mar-12	Ongoing	Yes
H-DC-R	Dome Creek at Road	6880475	391156	4.48	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908152	22-Jun-11	12-Oct-11	No

[1] – NAD 83, UTM Zone 8

3.1.3 Back Creek Watershed

Back Creek is a small watercourse with a total drainage area of 10.4 km^2. It originates north of the Mount Nansen site (Figure 2) where it flows southeast of to the eastern edge of the mine site and into Victoria Creek just upstream of the pumphouse (artesian well water source). The middle and upper areas of the Back Creek watershed have active placer mining operations that use water from the creek for processing and may regulate the streamflow regime. While there are sedimentation ponds associated with this placer activity, turbidity in the creek is often very high during the summer when the operation is active. Back Creek is generally one of the first sites to freeze to substrate typically from mid-October until early May. The highest flows in Back Creek are associated with spring snowmelt. When precipitation is low in June and July, Back Creek exhibits low flows. Past observations of streamflow indicate that storm events in August do not typically increase flows in Back Creek substantially.

There is one hydrometric gauging station located in the Back Creek watershed upstream of the confluence with Victoria Creek (Table 5).

Table 5. Back Creek hydrometric monitoring station.

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
H-BC	Back Creek	6880901	391625	10.4	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9896527	07-Jun-11	12-Oct-11	No

[1] – NAD 83, UTM Zone 8

3.1.4 Minnesota Creek Watershed

The Minnesota Creek watershed is located east of Victoria Creek and the Mount Nansen site. While the 12.7 km^2 watershed does not overlap with the site, Minnesota Creek discharges to Victoria Creek upstream of the Mount Nansen Road crossing and contributes to streamflow and water quality measured at the hydrometric station/water quality site on Victoria Creek near the road. The 2011/2012 winter season was the first time that discharge in Minnesota Creek was monitored. There is one hydrometric gauging station located in the Minnesota Creek watershed (Table 6).

Table 6. Minnesota Creek hydrometric monitoring station.

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
H-MN	Minnesota Creek	6879235	392530	12.7	None; Discharge measurements only	-	-	-	No

[1] – NAD 83, UTM Zone 8

3.1.5 Victoria Creek Watershed

Victoria Creek is the largest watercourse on the Mount Nansen site (Figure 2) draining a total area of 112.0 km^2 into the Nisling River. Back Creek, Dome Creek and Minnesota Creek all contribute to Victoria Creek in the vicinity of the site. Peak flows typically occur in late May corresponding with ice and snowmelt in the valley. Midsummer flows are low, corresponding with low precipitation, but the winter period may be lower in certain reaches where baseflow contributions maintain flow beneath the ice, with numerous sections of open water throughout the winter season. Increased precipitation in the fall typically has little effect on the discharge of Victoria Creek.

There were five hydrometric sites established on Victoria Creek in order to quantify contributions from tributaries in the vicinity of the Mount Nansen site (Table 1).Two stations on Victoria Creek had continuous data loggers installed, and both were left in place over the winter.

Table 1. Victoria Creek Watershed hydrometric monitoring stations.

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
H-VC-REF	Victoria Creek Reference Site	6881113	391650	64.0	None; Discharge measurements only	-	-	-	No
H-VC-U	Upper Victoria Creek	6880882	391666	64.6	HOBO Water Level Logger HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9896531	07-Jun-11	07-Mar-12	Yes
H-VC-U Winter	Upper Victoria Creek - Temporary Winter Logger	6880882	391666	64.6	HOBO Water Level Logger HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908152	06-Mar-12	Ongoing	Yes
H-VC-DBC	Victoria Creek Downstream of Back Creek	6880840	391627	75.0	None; Discharge measurements only	-	-	-	No
H-VC-UMN	Victoria Creek Upstream of Minnesota Creek	6879244	392413	83.4	None; Discharge measurements only	-	-	-	No
H-VC-R	Victoria Creek at Road	6878755	392304	97.7	HOBO Water Level Logger U20-001; Staff Gauge; Stilling Well; Benchmarks	9908154	22-Jun-11	07-Mar-12	Yes
H-VC-R Winter	Victoria Creek at Road - Temporary	6878755	392304	97.7	HOBO Water Level Logger U20-001; Staff	9896522	07-Mar-12	Ongoing	Yes

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Drainage Area (km^2)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
	Winter Logger				Gauge; Stilling Well; Benchmarks				

[1] – NAD 83, UTM Zone 8

3.1.6 Barometric Compensation Data Loggers

Three barometric loggers were used throughout the 2011/2012 hydrometric monitoring program to compensate for atmospheric pressure in the data recorded by the water level loggers at gauge sites. The primary barometric logger (ATM-DC1) was located downstream of the bridge over the diversion channel at the H-DC-B hydrometric station (el. 1099 metres above sea level [masl]). This location was the same location as previous years and is located at approximately the median elevation in the watershed such that the data collected could be reasonably applied to water level loggers at all hydrometric stations.

In November 2011, ice accumulated several metres above the streambed and overtopped the location of the ATM-DC1 logger attached to the DC-B stilling well. The atmospheric data logger was replaced in December, 2011 and renamed ATM-DC2. The ATM-DC2 logger was installed approximately 4 m higher in elevation (el. 1103 masl) than ATM-DC1. This difference in elevation was assumed negligible and therefore the two barometric signals were joined without elevation adjustments.

A third barometric logger located outside the camp kitchen (ATM-CAMP AAM). The linear regression model used for filling gaps in the barometric compensation data had a mean absolute error of +/- 0.31 kPa and was based on the relationship between ATM-CAMP AAM (el. 1241 masl) and ATM-DC1 which was:

$$ATMDC1 = 4.8 + 0.96(ATMCAMP\ AAM)$$

Table 2. Atmospheric data loggers used for hydrometric data logger compensation and site meteorologic data.

Hydrometric ID	Hydrometric Station Name	Easting[1]	Northing	Elevation (masl)	Installation Details	Serial #	Start Date	End Date	Winter Data Logger
ATM-CAMP AAM	Barometric Logger at Camp (Mt. Nansen Air Logger)	6881399	387759	1241	HOBO Level Logger (Installed by AECOM)	853567	28-Mar-09	Ongoing	Yes
ATM-DC1	Barometric Logger at Diversion Channel (1)	6880792	389475.5	1099	HOBO Level Logger U20-001	9858715	06-Jun-11	17-Nov-11	Yes
ATM-DC2	Barometric Logger at Diversion Channel (2)	6880792	6880792	1103	HOBO Level Logger U20-001	9896533	14-Dec-11	Ongoing	Yes

[1] – NAD 83, UTM Zone 8

4 RESULTS

In total there were 200 discharge hydrometric measurements obtained between May 2011 and March 2012 (17 field visits) at 18 hydrometric gauges throughout the site. A summary of the key hydrologic observations from each site visit are found in Table 7 and discharge measurements and stage levels for each station is located in Table B.1, Appendix B.

Table 7. Chronological record of hydrologic observations during site visits at the Mount Nansen site.

Visit #	Date From	Date To	Key Observations
1	12-May-11	12-May-11	Ice free in Back Creek and Victoria Creek
2	25-May-11	25-May-11	Ice free in Pony Creek and lower Dome Creek
3	06-Jun-11	07-Jun-11	All sites ice and snow free.
4	22-Jun-11	23-Jun-11	
5	06-Jul-11	07-Jul-11	
6	20-Jul-11	21-Jul-11	
7	03-Aug-11	04-Aug-11	
8	17-Aug-11	18-Aug-11	
9	30-Aug-11	31-Aug-11	
10	14-Sep-11	14-Sep-11	
11	27-Sep-11	28-Sep-11	
12	11-Oct-11	12-Oct-11	
13	16-Nov-11	17-Nov-11	H-PC-U, H-PC-DSP, BC, DC-U1 frozen to substrate
14	14-Dec-11	15-Dec-11	
15	09-Jan-12	12-Jan-12	MN frozen to substrate
16	30-Jan-12	01-Feb-12	Minnesota and Dome Creek aufeis
17	05-Mar-12	06-Mar-12	Victoria Creek and Dome Creek aufeis

The following sections briefly describe the key results of the hydrologic monitoring at each gauging station. A copy of the hydrometric database containing all raw and processed data is found in Appendix C.

4.1 PONY CREEK WATERSHED

4.1.1 Upper Pony Creek (H-PC-U)

Upper Pony Creek (H-PC-U) was originally established in 2009 to supplement the hydrogeologic investigations on the site (AECOM 2010a). The gauging station is located in the upper watershed draining an area (A_D = 0.84 km^2) that has been disturbed by mining activity in the past. Remnant landscape features (berms) from trenching are visible at and upstream of the H-PC-U gauging site and constrains the channel. While the channel is relatively well defined near the station, there are grasses and shrubs growing in and at the banks that likely influence streamflow conveyance. The sand and fine gravel bed channel in the vicinity of the gauge is between 0.07 m and 0.32 m deep and between 0.24 m and 0.74 m wide. Extremely low-flows in 2009 were observed at the H-PC-U station and the creek went dry several times throughout the summer.

The small channel size and influence of vegetation caused challenges with standard discharge measurement techniques (i.e., mid-section method) such that the channel was too small to obtain accurate measurements with the current meter. Alternative gauging techniques were used including salt gauging, the installation of a v-notch weir and volumetric measurements.

An existing constriction in the channel approximately 15 m upstream of the stilling well and staff gauge was utilized to construct a thin plate 90° v-notch weir (See 2.1.2). The discharge measurements calculated using the weir equation was plotted against the stage read at the staff gauge (15 m downstream at the stilling well) is plotted in Figure 10. In addition to the weir, discharge measurements were obtained using salt tracers, float techniques and volumetric techniques once the weir was installed.

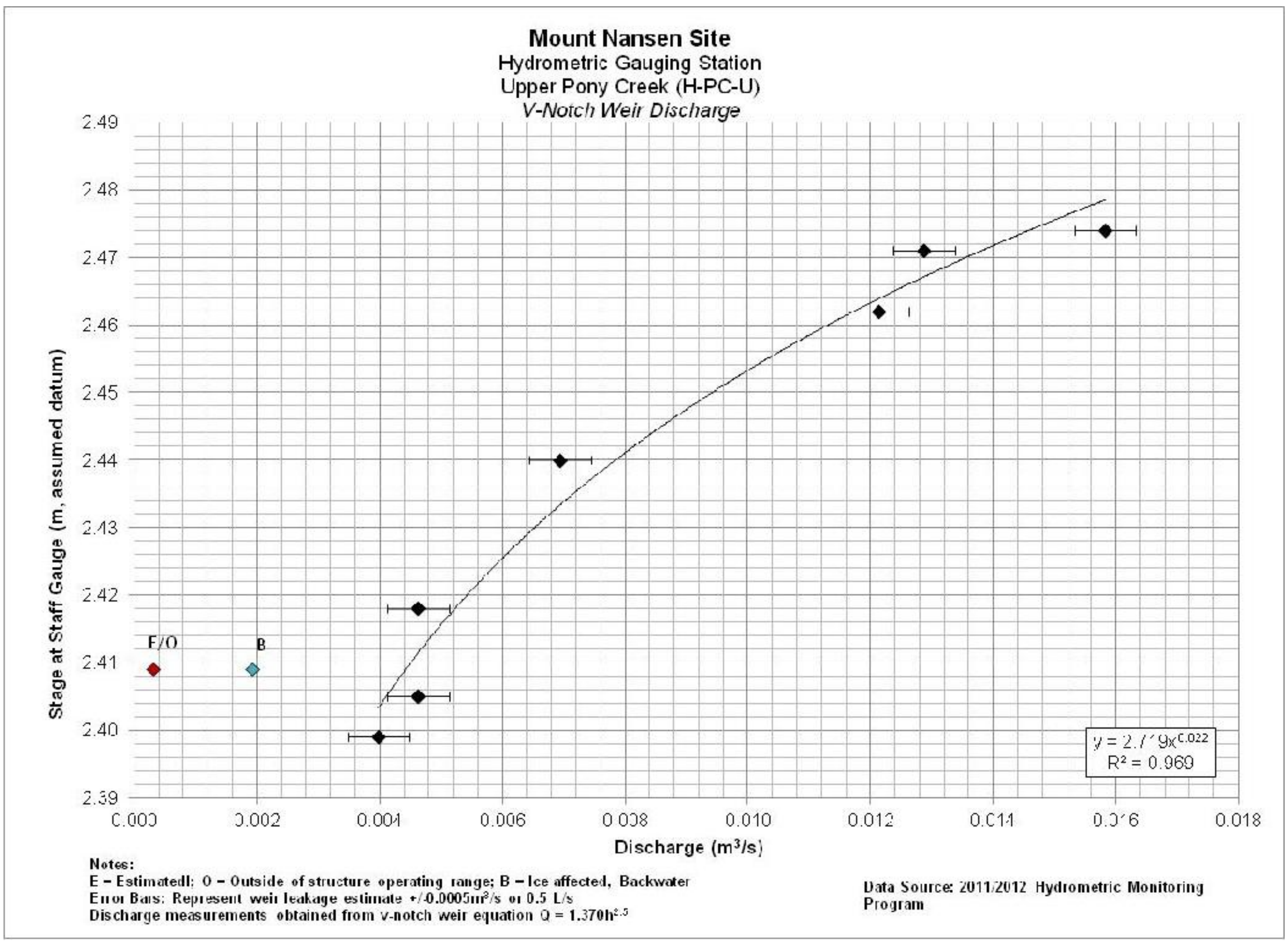

Figure 10. **Upper Pony Creek Weir Rating Curve, 2011 Hydrometric Monitoring Program.**

Streamflow was observed at the H-PC-U gauging station during each site visit however extreme low flows may have occurred between site visits as indicated in the hydrograph (Appendix B). Discharge measurements ranged from 0.000 m^3/s to 0.019 m^3/s between May 12 and October 13, 2011.The highest measured discharges occurred in late summer while the lowest flows occurred in early spring before the upper watershed snowpack fully melted and in the late fall as flows receded to baseflow.

The general trend of discharge recession to baseflow in the autumn is apparent in the hydrographs; if the data is viewed on an hourly time-step, diurnal discharge patterns may be observed. The continuous water level logger began recording a diurnal discharge fluctuation starting on September 29, 2011 which roughly corresponds with when air temperatures begin to drop below 0°C on a daily basis (September 25, 2011).

Photos and a site sketch are found in Appendix A. The rating curve and hydrograph with continuous and discharge measurements are located in Appendix B.

4.1.2 Pony Creek Downstream of the Pit (H-PC-DSP)

A second hydrometric station on Pony Creek named Pony Creek downstream of the Pit (H-PC-DSP)(A_D = 1.0 km^2) was located downstream of the Back Creek access road culvert, adjacent to the open pit. The legacy name for this site is Pony Creek Downstream of the Pit (H-PC-DSP). Despite its namesake, the surface water collected at this site is upstream of the pit adit and it is uncertain how much, if any, of the water at this site includes contributions from the open pit via shallow groundwater connectivity. Similar to H-PC-U, H-PC-DSP was a challenging site to measure discharge using traditional methods due to the small channel size and a current meter could not be used. Volumetric measurements were obtained at the culvert approximately 20 m upstream of the staff gauge and salt tracer techniques were used. The salt tracer was input on the upstream side of the culvert to ensure full mixing. Scour was observed in the vicinity of the stilling well (approximately 1-3 cm).

Streamflow was observed at the H-PC-U gauging station during each site visit however extreme low flows may have occurred between site visits as indicated in the hydrograph (Appendix B). Discharge measurements ranged from 0.001 m^3/s to 0.039 m^3/s between May 12 and October 12, 2011. The highest measured discharges occurred in late summer while the lowest flows occurred in early spring before the upper watershed snowpack fully melted and in the late fall as flows receded to baseflow.

Discharge at H-PC-DSP was greater than the discharges recorded at H-PC-U throughout the year with little to no lag time between signals. H-PC-DSP was the only continuous logger that did not lose data between July 20 and August 3, 2011 (See Gap Filling Section 2.5 for discussion).

Photos and a site sketch are found in Appendix A. The hydrograph with continuous and discharge measurements is located in Appendix B.

4.2 DOME CREEK WATERSHED

4.2.1 H-DX

H-DX is the highest elevation hydrometric site in the watershed; established originally for water quality testing as a site upstream of the mine site footprint with a very small contributing basin. The drainage area (A_D) is 0.21 km^2. The channel is very poorly defined in open channel conditions and braids through willow shrub. This site was established as a hydrometric site in November, 2011 and was frozen to substrate before a measurement could be obtained however rough estimates of flow during water quality sampling earlier in the year indicate that discharge is approximately 0.001 m^3/s (1.0 L/s). This site is assumed to be predominantly fed by groundwater. The site was checked periodically throughout the winter but no flow was observed.

Photos and a site sketch are found in Appendix A.

4.2.2 H-DX+200 (105)

H-DX-200 was established 200 m downstream of H-DX in the upper Dome Creek watershed (A_D = 0.52 km^2) in November, 2011 and similar to H-DX, was frozen to substrate before a measurement could be obtained. The site was checked periodically throughout the winter to ensure that no baseflow conditions existed at the site. A groundwater seep near the mill site appears to the main contributor to flow at this site. During the winter a location 105 m downstream of H-DX was located where open water was present year-round and named H-DX+105. The channel at H-DX+105 is a poorly defined sand bed channel kept open by a seep that appears to originate from under the road bed. The channel is approximately 0.05 m deep and 0.10 m wide. Although flow in the channel was shallow and slow throughout the winter, salt tracers tests were successful the winter and required relatively short mixing lengths. Discharge measurements using salt tracers ranged between 0.001 m^3/s and 0.009 m^3/s.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.2.3 H-D1

H-D1 is a poorly defined channel braiding through willow shrub. At the gauging site in open water conditions the channel is relatively confined however during the winter, flow spreads out across the area. This site was established in November, 2011 and only one measurement (December 15, 2012) was obtained using the float discharge measurement method before the channel was frozen to substrate. The discharge was estimated to be 0.023 m^3/s. Substantial baseflow and aufeis production lower in the Dome Creek watershed was observed throughout the winter upstream of the vicinity of H-DC-U1 and H-DC-U2 therefore it was suspected that flow could restart in this area therefore the site was checked periodically throughout the winter. In March, 2012, there was wet ice and snow observed in the vicinity of the channel but a free flowing channel beneath the ice could not be located and no discharge measurements could be obtained using any of the available methods.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.2.4 Upper Dome Creek 1 (H-DC-U1)

Upper Dome Creek 1 was established as a gauging site in 2009, and the installation (staff gauge and stilling well) fared well through the 2010/2011 winter; the only repair required at this site was the re-establishment of benchmarks. The channel lies on the south side of the flat Dome Creek valley upstream of the tailing pond and appears to receive flow from seeps and surface water channelized by old exploration trenches on the south side of the valley. The channel is well defined and stable with a relatively low width to depth ratio in most sections in the vicinity of the gauge. On average the channel is < 0.50 m wide and < 0.25 m deep. A continuous water level logger was installed at this site for the open water season and removed at the start of freeze-up in mid-October. Discharge measurements obtained at H-DC-U1 ranged from 0.002 m^3/s to 0.036 m^3/s and were collected predominantly using salt tracers. H-DC-U1 contributes flow to the upstream end of the diversion channel that is routed around the tailings pond.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.2.5 Upper Dome Creek 2 (H-DC-U2)

Upper Dome Creek 2 was one of the three new gauging sites with a continuous data logger. This channel is located directly north of H-DC-U2 and was discovered when investigating the discrepancy between the magnitude of discharge in the diversion channel and H-DC-U1; the diversion channel appeared to convey substantially more water than was observed at H-DC-U1. The channel near the station appeared somewhat stable when installation occurred, but as the open water season developed and rain storms occurred, the ground ice melted, banks destabilized and sediment washed into the channel. The remainder of the season was spent excavating the stilling well and data logger from silty organic sediments. This site was not stable, and the continuous data from the water level logger should be interpreted with extreme caution. The discharge measurements due to the size of the channel and were conducted predominantly with salt tracers, ranged between 0.049 m^3/s and 0.007 m^3/s and are considered to be within the acceptable range of accuracy.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.2.6 Diversion Channel at the Bridge (H-DC-B)

The Mount Nansen diversion channel conveys water from Upper Dome Creek along the north side of the tailings pond. The H-DC-B is small, straight and shallow gravel/sand bed channel. After review of the siltation problems that occurred at the site in the past, it was decided to build a small, stable boulder weir downstream of the stilling well to produce a pool. The diversion channel has been excavated several times throughout the monitoring to maintain a stable channel and conveyance under the diversion channel bridge. Excavations of silt were required after the bridge abutments shifted during the summer causing some siltation at H-DC-B approximately 15 m downstream of the bridge. During the winter, the channel filled with aufeis leaving little clearance between the bridge and the ice. The ice was excavated numerous times throughout the winter and as a result a pulse of water that was dammed up behind the ice was released down the channel. While H-DC-B was not monitored during the winter, the pulses of water may have affected downstream gauge locations at H-DC-M and H-DC-R.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.2.7 Seepage Pond Outlet Pipe (H-SEEP)

Water is pumped from the tailings pond year round into the seepage pond on the downstream side of the tailings dam. Records of seepage pump rates were recorded daily by the facility operator and were compared to measurements taken at the seepage pond outlet pipe and H-DC-M located approximately 300 m downstream. Pumping rate records indicate that the required rate has increased over time, and show that the rate of pumping is substantially higher than measured outflows from the seepage pond outlet pipe.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.2.8 Middle Dome Creek (H-DC-M)

Middle Dome Creek was one of the three new gauging sites with a continuous data logger installed. It is located downstream of the confluence of the diversion channel and the seepage pond pipe outflow; subsequently the flow is regulated in part by pumping rates and activity upstream in the diversion channel. The channel is small, but moderately well defined in fine grained sediment. The channel is typically < 0.50 m wide and 0.15 m deep therefore a combination of salt tracers and current meter measurements were used to measure discharge. The discharge measurements ranged from 0.002 m^3/s to 0.175 m^3/s. The highest flows were associated with snowmelt in June and rainfall in August. A continuous logger was left in over winter at this site and collected data until mid January when the well was dewatered and frozen to substrate. A new logger was submerged in the channel in March, but it is uncertain how measurements will be affected by anchor ice.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.2.9 Dome Creek at the Road (H-DC-R)

Dome Creek at the Road gauging station is a legacy station located downstream of the Mount Nansen Road culvert in a broad, flat valley bottom. The small channel is vegetated with grasses and provided some challenging gauging conditions. Typically salt tracers were used at this site and injected on the upstream side of the culvert, however, the flow depth was occasionally deep enough to use a current meter. The discharge measurements obtained at this site ranged from 0.026 m^3/s to 0.232 m^3/s. Near the end of the open water season in September, 2011, a large pulse of sediment travelled down the channel and filled the pool where the stilling well was located. This sediment pulse will represent a shift in the rating curve and in the 2012 open water season the gauge will have to be re-located. In the winter, the continuous data logger was removed since large aufeis development occurs at the site; excavation of the road and valley bottom occurred several times throughout the winter and the melt of the aufeis in spring may extend the duration of high flows to the channel downstream.

Photos and a site sketch are found in Appendix A. The rating curve, and hydrograph with continuous and discharge measurements are located in Appendix B.

4.3 BACK CREEK WATERSHED

4.3.1 Back Creek (H-BC)

The Back Creek station was stable throughout the monitoring period (May 12 to October 12, 2011). Typically discharge measurements were obtained using a current meter and the mid-section method (See Section 2.1.3), however, due to the relatively narrow and deep geometry of the channel typically only about 16 panels were measured in the cross-section. The discharge measurements ranged from 0.004 m^3/s to 0.339 m^3/s, however due to the placer activity upstream of this site it is difficult to discern hydrologic responses to rain events. This channel is not considered to have natural flow due to placer activity effectively regulating the regime by attenuating flow in sedimentation ponds. Back Creek was frozen to substrate in mid-October and no winter measurements could be obtained from the creek.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.4 MINNESOTA CREEK WATERSHED

4.4.1 Minnesota Creek (H-MN)

Minnesota Creek was not observed during open water conditions therefore the condition of the channel is not known. A winter discharge measurement was obtained on Minnesota Creek on December 14, 2011 using a salt tracer in a slow, shallow stream of water flowing beneath thick ice. The discharge was 0.015 m^3/s. On subsequent visits the creek was frozen to bed. It is uncertain whether the creek would have frozen to bed if flows had not been exposed to surface air temperatures.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.5 VICTORIA CREEK WATERSHED

4.5.1 Victoria Creek Reference (H-VC-REF)

The Victoria Reference site was originally established for water quality sampling and was added to the hydrometric program in November, 2011. The site is located upstream of the Back Creek confluence with Victoria Creek and represents reference channel conditions unaffected by the Mount Nansen site. Three winter low flow measurements were obtained at this site using salt tracers. At the start of the winter the ice was relatively thin in the area and groundwater flux to the channel may be present. The range of discharge measured between 0.003 m^3/s and 0.043 m^3/s. The ice at this site became progressively thicker through the winter until March 2012 when a substantial deposit of aufeis inhibited discharge measurement.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.5.2 Upper Victoria Creek (H-VC-U)

Upper Victoria Creek is a legacy gauging location at a stable channel location approximately 65 m upstream of the Back Creek confluence. This site is known to be an area of groundwater contributions, as thin ice and open water are observed annually here. The channel is approximately 5 m wide, on average, it is 0.35 m and 0.16 m deep in the open water and winter seasons respectively.

Discharge measurements were generally obtained using a current meter at this site, however several salt tracer tests were also used. Discharge measurements ranged from 0.059 m^3/s to 2.600 m^3/s with the highest flows occurring in late May (snowmelt) and August (rain events). Similarly the continuous logger recorded discharge peaks in mid-June, early and mid-July and multiple peaks in August (See Appendix B hydrograph). The flow recession towards baseflow began in mid to late August. A continuous logger was left in over winter at this site, however the influence of ice in the channel is visible in the signal in early October. The ice affected continuous water levels and inferred discharges should be used cautiously; some recession curve smoothing may be required.

By mid January the well was dewatered and frozen to substrate. The data logger could not be retrieved during the February 2012 site visit due to ice in the stilling well therefore continuous data is only available until February 2, 2012. A new logger was submerged in the channel in March, but it is uncertain how measurements will be affected by anchor ice.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.5.3 Victoria Creek Downstream of Back Creek (H-VC-DBC)

The Victoria Creek downstream of Back Creek was added to both the hydrometric and water quality programs in November, 2011. The site is located upstream of the Back Creek confluence with Victoria Creek. Four winter low flow measurements were obtained at this site using salt tracers and a current meter. At the start of the winter the ice was relatively thin in the area and groundwater flux to the channel may be present. The range of discharge measured between 0.002 m^3/s and 0.554 m^3/s. The mixing length for the salt tracer tests is approximately 90 m.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.5.4 Victoria Creek Upstream of Minnesota Creek (H-VC-UMN)

The Victoria Creek Upstream of Minnesota was added to both the hydrometric and water quality programs in November, 2011. The site is located in a straight reach upstream of the Minnesota Creek confluence with Victoria Creek. Five winter low flow measurements were obtained at this site using salt tracers and a current meter. The ice was relatively thin in the reach and groundwater flux to the channel may be present. The range of discharge measured between 0.005 m^3/s and 0.262 m^3/s. The mixing length for the salt tracer tests is approximately 60 m. It is recommended to re-evaluate the location of this gauge site in the open water season as numerous riffles in the reach posed challenges for measuring winter low flows with a current meter.

Photos and a site sketch are found in Appendix A. The discharge measurements are located in Appendix B.

4.5.5 Victoria Creek at the Road (H-VC-R)

Victoria Creek at the Road was one of the three new gauging sites with a continuous data logger installed in 2011. It is located approximately 90 m downstream of the Mount Nansen Road culvert in a meandering section of the channel. The channel is composed of cobbles, gravel and sand, approximately 8-9 m wide with depths up to 0.66 m at the right bank where the continuous level logger is located. The discharge measurements ranged from 0.043 m^3/s to 3.670 m^3/s. The highest flows were associated with snowmelt in June and rainfall in August. Similarly the continuous logger recorded discharge peaks in mid-June, early and mid-July and multiple peaks in August (See Appendix B hydrograph). The flow recession towards baseflow began in mid to late August. A continuous logger was left in over winter at this site, however the influence of ice in the channel is visible in the signal in early October. A break point was included in the rating curve at approximately 2.0 m (above the site datum) to describe the low flow stage relationship, however a separate winter rating curve may be considered for this site because the majority of the calibration points below this stage are associated with winter (ice affected) channel conditions. A separate winter curve was not computed because of general agreement of ice affected calibration points with autumn recession curve points. The ice affected continuous water levels and inferred discharges should be used cautiously; some recession curve smoothing may be required.

A continuous logger was left in over winter at this site and collected data until mid-January when the well was dewatered and frozen to substrate. A new logger was submerged in the channel in March, but it is uncertain how measurements will be affected by anchor ice.

Photos and a site sketch are found in Appendix A. The rating curve, hydrograph with continuous and discharge measurements are located in Appendix B.

4.6 SITE & REGIONAL METEOROLOGY

There are several sources of meteorological data available for the Mount Nansen Site for air temperature, barometric pressure, rainfall, snowfall, wind and radiation. For the purposes of this hydrologic monitoring report, only precipitation and temperature will be discussed as these two parameters (aside from snowpack) are the key atmospheric variables influencing surface water flow. This section will also briefly discuss air temperature and rainfall at the Mount Nansen compared to available regional as outlined in the original scope, however a different regional approach will be taken compared to past analysis due the paucity of regional precipitation data. Discussion on the snowpack and wind data can be found in the Mount Nansen 2011/2012 Snow Survey Report (in preparation, EDI 2012).

Figure 11 shows the variation in air temperature for the period of record at the ATM-CAMP AAM station (2009-2012 – see note regarding data gap in Section 2.5). Typically the air temperature was below zero between mid- October and mid-April. Ice formation in and on the creeks in the study watersheds roughly correspond with these dates, however full ice cover varies with location and generally lags behind several months. Figure 12 shows the 2011/2012 monitoring period with all available temperature data sources; variations in temperature readings are mainly related to the elevation differences of the stations.

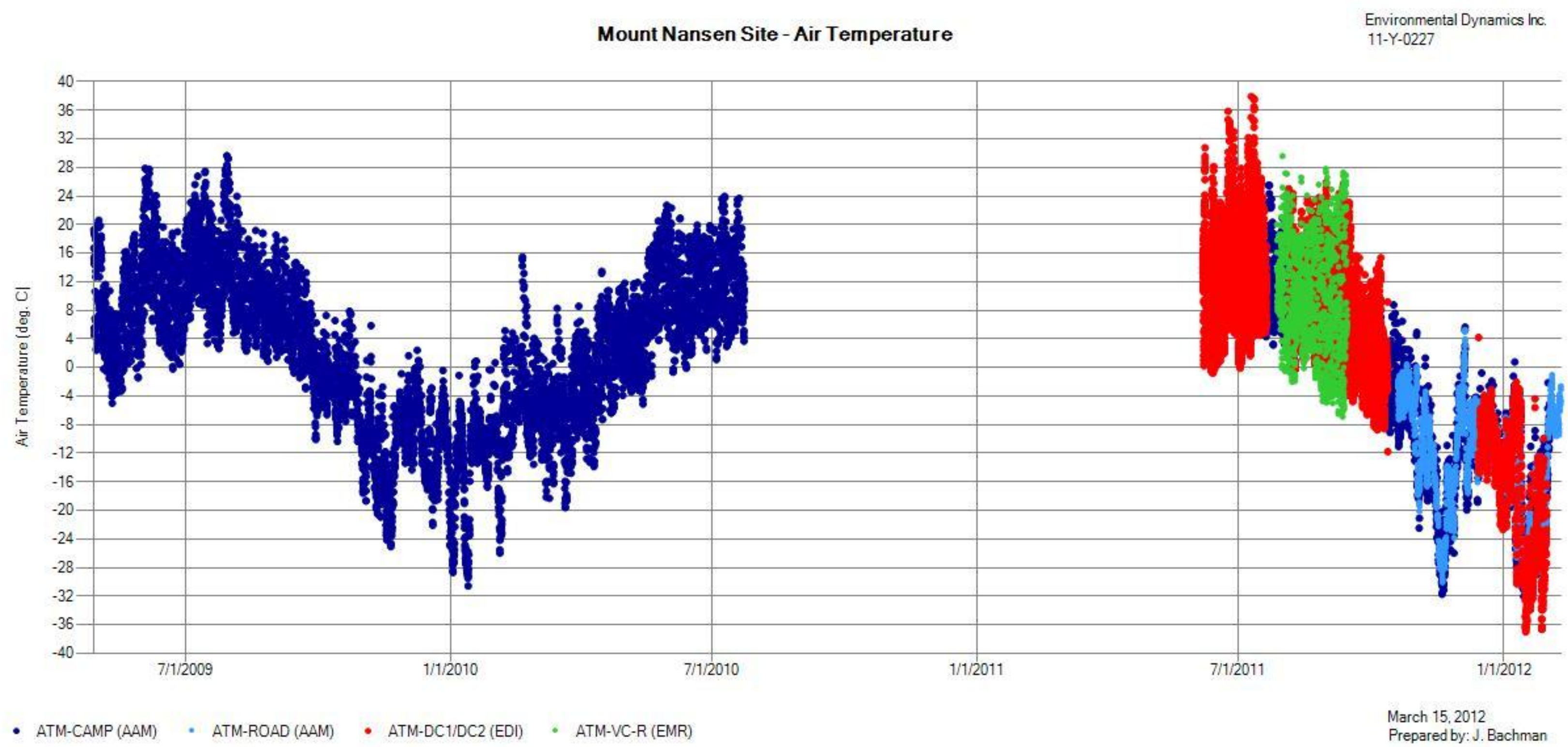

Figure 11. Mount Nansen Site – Air Temperature (2009-2012).

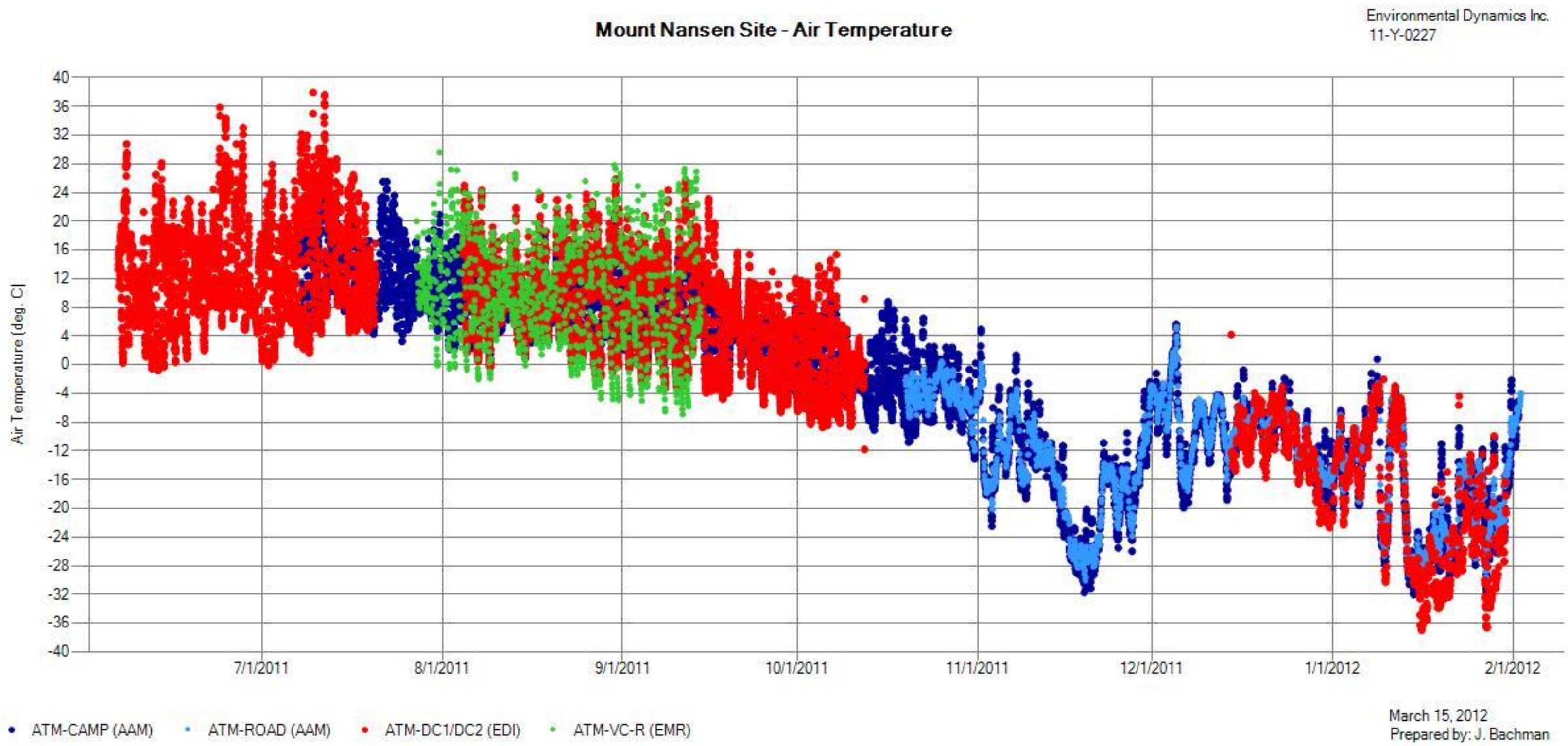

Figure 12. Mount Nansen Site – Air Temperature (2011-2012).

Hourly rainfall data for January 2010 through January 2012 is shown in Figure 13. The majority of rain storms occur in July and August; however, the maximum hourly intensity of rainfall that occurred in this period was 6.2 mm/hr on June 30, 2010. On average, the hourly rain events plotted in Figure 13 are less than 2.5 mm/hr however this value may increase or decrease once the longer historical site records are quality controlled. Rainfall data (July 27 to September 14, 2011) was obtained from EMR Client services to assist with filling the site rainfall summer data gap. Rainfall was measured at the EMR station near Victoria Creek at the Road. The maximum hourly rainfall intensity from this short record was 5.8 mm/hr on July 27, 2011.

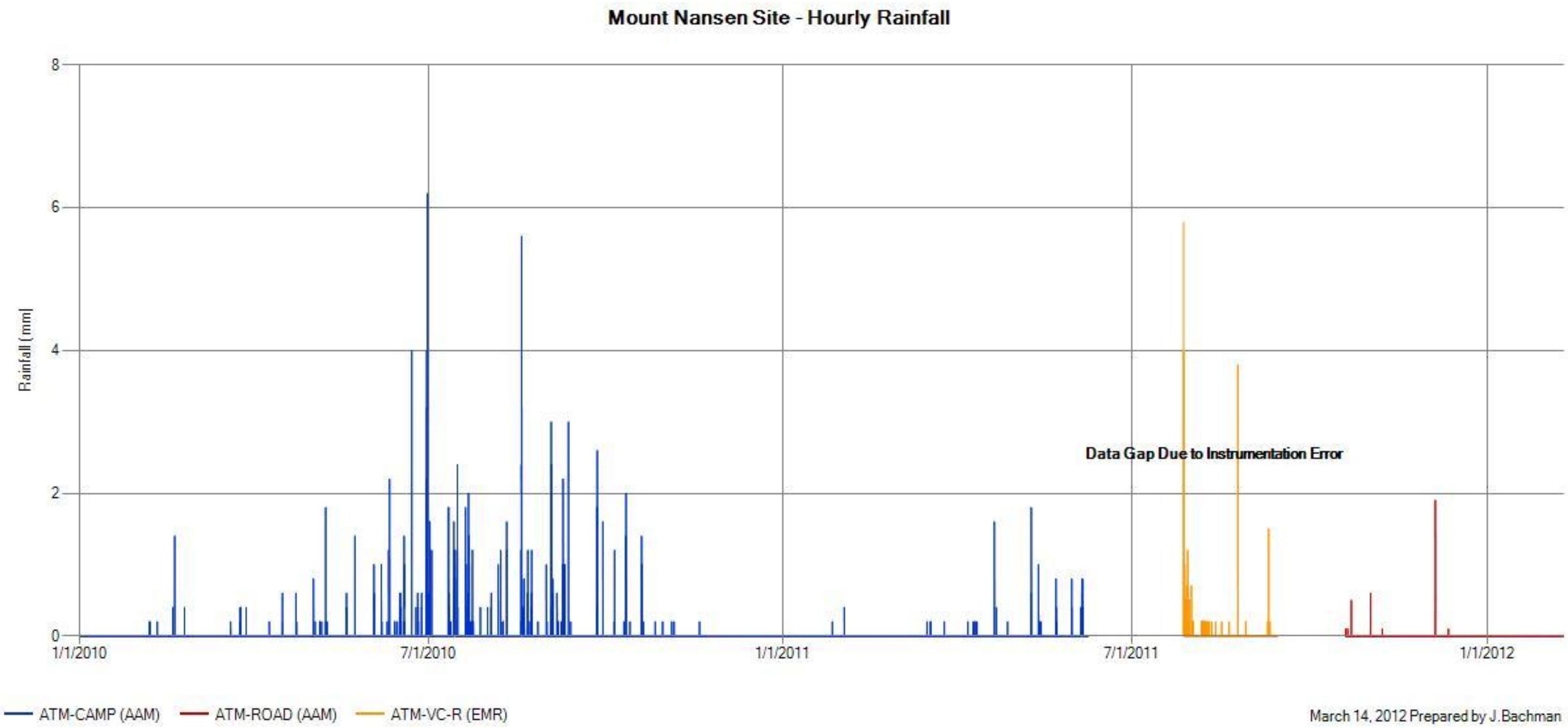

Figure 13. Mount Nansen Site – Rainfall (2010-2012).

Regional meteorologic data from Environment Canada and Yukon Government weather stations are sparse. The Carmacks station (Yukon Government) does not collect precipitation data, however it does record temperature and wind (direction and velocity).

Temperature data from the Mount Nansen ATM-CAMP AAM (el. 1241 masl) station was compared to corresponding temperature data from Carmacks (el. 540 masl) for the period February 2009- February 2012. Corresponding temperature time-series from the two stations were linearly regressed to obtain a model described by the equation $T_{ATM-CAMP}=-0.630206+0.715651*T_{CARMACKS}$. The model is based on overlapping datasets in both winter and summer seasons with a mean absolute error of 3.5 °C; however, it should be noted that the absolute error varies depending on temperature. For example, there is greater absolute error associated temperatures below 0°C (i.e. the Carmacks and Mount Nansen temperatures are less similar in winter).

An alternate method of comparing the Mount Nansen site meteorological data to the surrounding region using a tool called ClimateWNA available from the Department of Forestry at the University of British Columbia and endorsed by the Pacific Climate Impacts Consortium (PCIC 2012). ClimateWNA extracts and downscales PRISM monthly data for a reference period and calculations seasonal and annual climate variables based on latitude, longitude and elevation (PCIC 2012). Further details regarding the functions of ClimateWNA are found on the PCIC website (PCIC 2012) and methodologies and calculations are described in Wang et al. (2006).

Using the location and elevation of the Mount Nansen meteorologic station at the camp (ATM-CAMP AAM) and the Carmacks Yukon Government meteorologic station, climate data was obtained from ClimateWNA (Table 8). Temperature and precipitation measurements from Mount Nansen (2010-2012) are similar to the downscaled normal data presented in Table 8.

Table 8. **Calculated and derived annual and monthly climate variables obtained from Climate WNA (see PCIC 2012).**

Annual Variables

	Carmacks[1]	Mount Nansen Camp[2]
Mean Annual Temperature (° C)	6.6	-3.3
Mean Annual Precipitation (mm)	448	338
Mean Annual Summer Precipitation - May - Sept. (mm)	225	227
Precipitation as Snow (mm)	88	125

Monthly Variables

	Average Temperature (°C)		Maximum Temperature (°C)		Minimum Temperature (°C)		Precipitation (mm)	
Month #	Carmacks[1]	Mount Nansen Camp[2]	Carmacks[1]	Mount Nansen Camp[2]	Carmacks[1]	Mount Nansen Camp[2]	Carmacks[1]	Mount Nansen Camp[2]
1	-4.5	-19.1	-0.7	-13.7	-8.4	-24.5	38	15
2	-1.4	-15.6	2.9	-9.6	-5.8	-21.6	27	13
3	2.5	-10.6	7.5	-3.6	-2.5	-17.6	23	16
4	6.9	-2.8	12.8	3.6	1	-9.2	27	12
5	11.3	4.5	18	10.8	4.6	-1.8	42	25
6	14.6	9.7	21.5	16.2	7.8	3.3	52	52
7	17.4	11.8	24.8	17.9	10	5.8	52	62
8	17.2	9.7	24.6	15.7	9.9	3.8	41	57
9	12.3	4.6	18.9	9.8	5.7	-0.7	38	31
10	7.1	-3.3	12.7	1.3	1.5	-7.9	28	21
11	0.2	-12.6	3.9	-7.7	-3.5	-17.5	37	18
12	-4.2	-16.5	-0.7	-11.6	-7.6	-21.4	44	16

Notes:

[1] - Carmacks 65 6′5′′/ -136 17′27′′/ 540 masl ; Normal period 1971-2000

[2] - Mount Nansen Site (ATM-CAMP AAM) 62.048126° /137.146600°/ 1241 masl; Normal period 1971-2000

5 CONCLUSIONS AND RECOMMENDATIONS

The 2011/2012 hydrometric monitoring program was successful at capturing a large number of discharge measurements throughout the year in a dense hydrometric network for the study area size. Discharges were collected using a variety of hydrometric measurement methods and instrumentation including continuous water level loggers, the velocity area mid-section method, salt tracers, a v-notch weir, volumetric and float measurements. The methods were adapted for channel conditions during each visit at each discharge gauging location. The velocity area method was most useful on Victoria Creek and Back Creek; whereas volumetric, weir and salt tracers were found to the most effective means of measurement for all other stations due to smaller channel sizes. Winter discharge measurements provided estimates of streamflow recession to baseflow discharges for all stations that conveyed flow under the ice; however these measurements are considered less accurate than open water measurements. The site meteorologic station malfunctioned during the majority of the monitoring period and as a result updates to the regional climate relationships could not be completed. Instead regional and site climate estimates were obtained from a climate model for western North America based on site location, elevation and climate normals from the period 1971-2000.

5.1 RECOMMENDATIONS FOR 2012 MONITORING

The following is a list of recommendations for future hydrometric monitoring. These recommendations may vary in applicability depending on which remediation design is selected.

- Conduct a site reconnaissance with the water balance and water quality modelers from the Project Design Team. There are several site specific hydrologic considerations that may be important for the modeling team observe first-hand prior to modeling.
- Consider re-locating the 'Diversion Channel at the Bridge' hydrometric gauging station such that regular maintenance of the channel in the vicinity of the bridge has a minimal impact on the gauge.
- Consider re-locating 'Pony Creek Downstream of the Pit' (H-PC-DSP) or adding a hydrometric station downstream of the open pit adit so that any contributions to the creek from shallow groundwater may be captured. Discharge measurements can be correlated with pit lake levels and streamflow may be better correlated with the water quality site downstream of the adit. This may include a continuous data logger to capture seasonal hydrologic responses.
- Consider designing a weir or flume to measure discharge at 'Middle Dome Creek' (H-DC-M). This gauging station is unstable and difficult to gauge. A rated structure would provide channel stability for discharge measurement, however regular monitoring and/or maintenance for sedimentation may be required depending on the design. The station location may need to be shifted upstream or downstream.
- Consider moving the barometric logger from the weather station near the camp kitchen down to the new weather station.

- Conduct a survey of all hydrometric station locations and benchmarks and correlate to the Canadian Geodetic Vertical Datum (CGV28) or established Mount Nansen site datum.
- Conduct 2-4 concurrent discharge measurements at each gauging station where salt tracers and current meter are feasible to the measurement error estimates.

6 REFERENCES

6.1 LITERATURE CITED

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6.2 SPATIAL DATA

1:50,000 CanVec topographic data from Government of Canada, Natural Resources Canada, Earth Sciences Sector, Centre for Topographic Information. Geogratis website (http://geogratis.cgdi.gc.ca).

1:20,000 TRIM positional files from the Land and Resource Data Warehouse (http://lrdw.ca). Copyright belongs to Her Majesty the Queen in Right of the Province of British Columbia.

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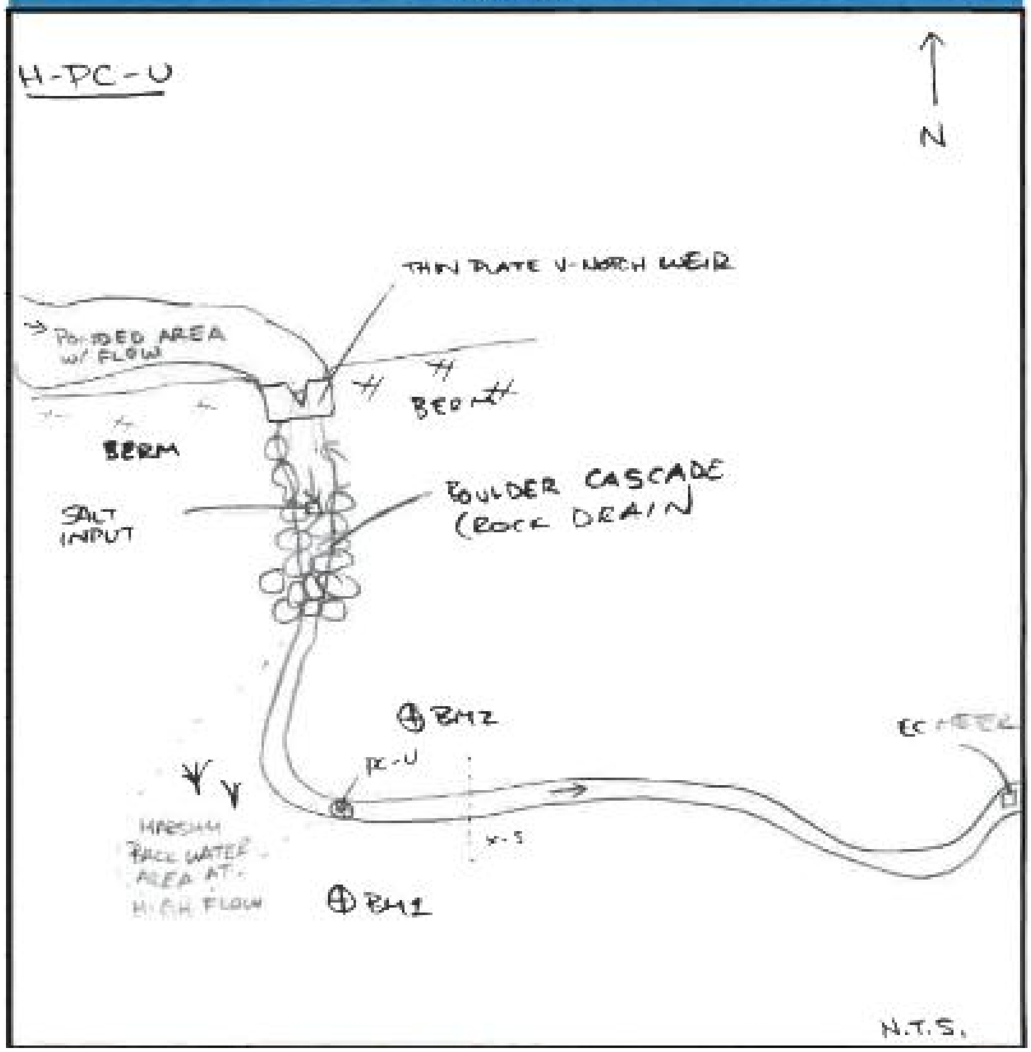
APPENDIX A HYDROMETRIC GAUGING STATIONS: SKETCHES & PHOTOS

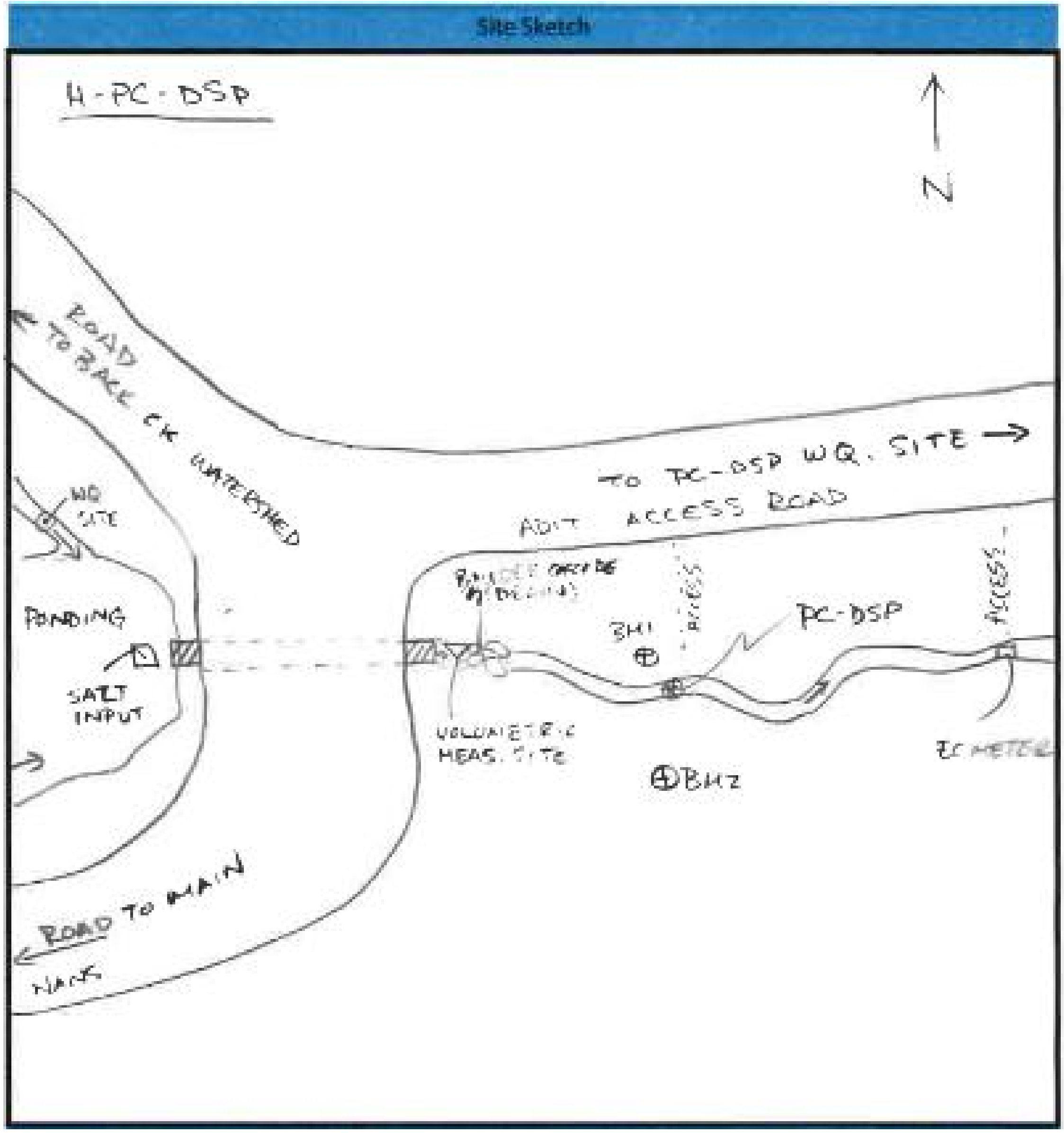
Site Sketch



A 1. – Upper Pony Creek site sketch.

Photo 1. Upper Pony Creek (H-PC-U) Weir – August 17, 2011.

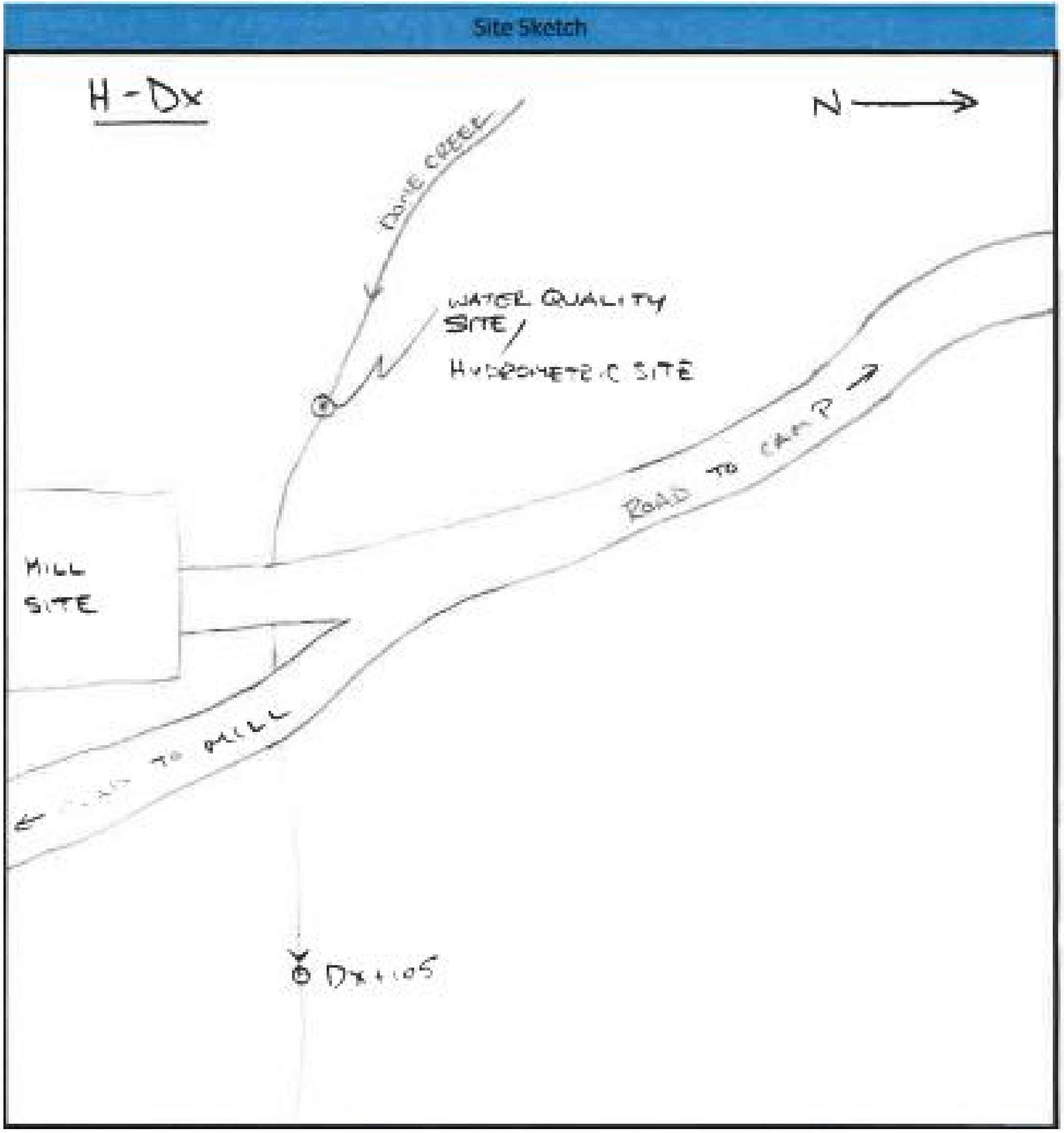
Photo 2. Upper Pony Creek (H-PC-US) Weir – Frozen to Substrate, February 1, 2012



A 2. Pony Creek Downstream of the Pit site sketch.

Photo 3. Pony Creek downstream of Pit (H-PC-DSP) - July 7, 2011.

Photo 4. Pony Creek downstream of Pit (H-PC-DSP) – Frozen to substrate at culvert – February 1, 2012.



A 3. Dome Creek DX site sketch.

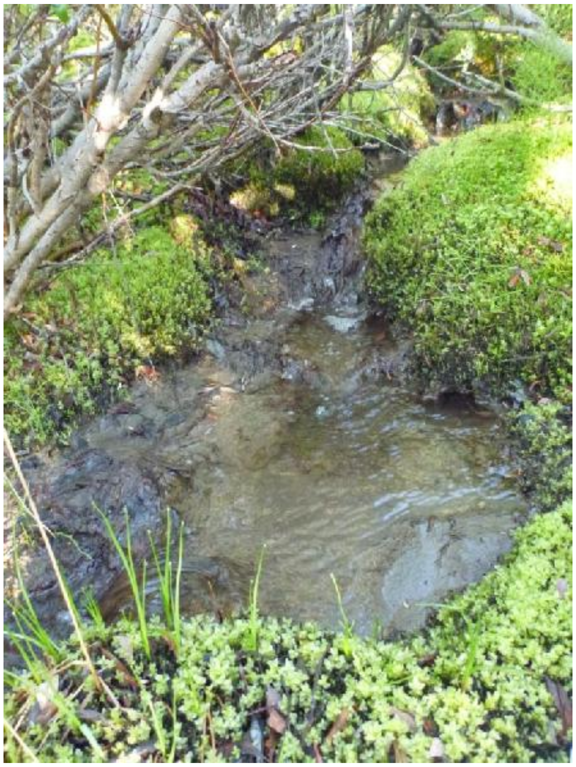
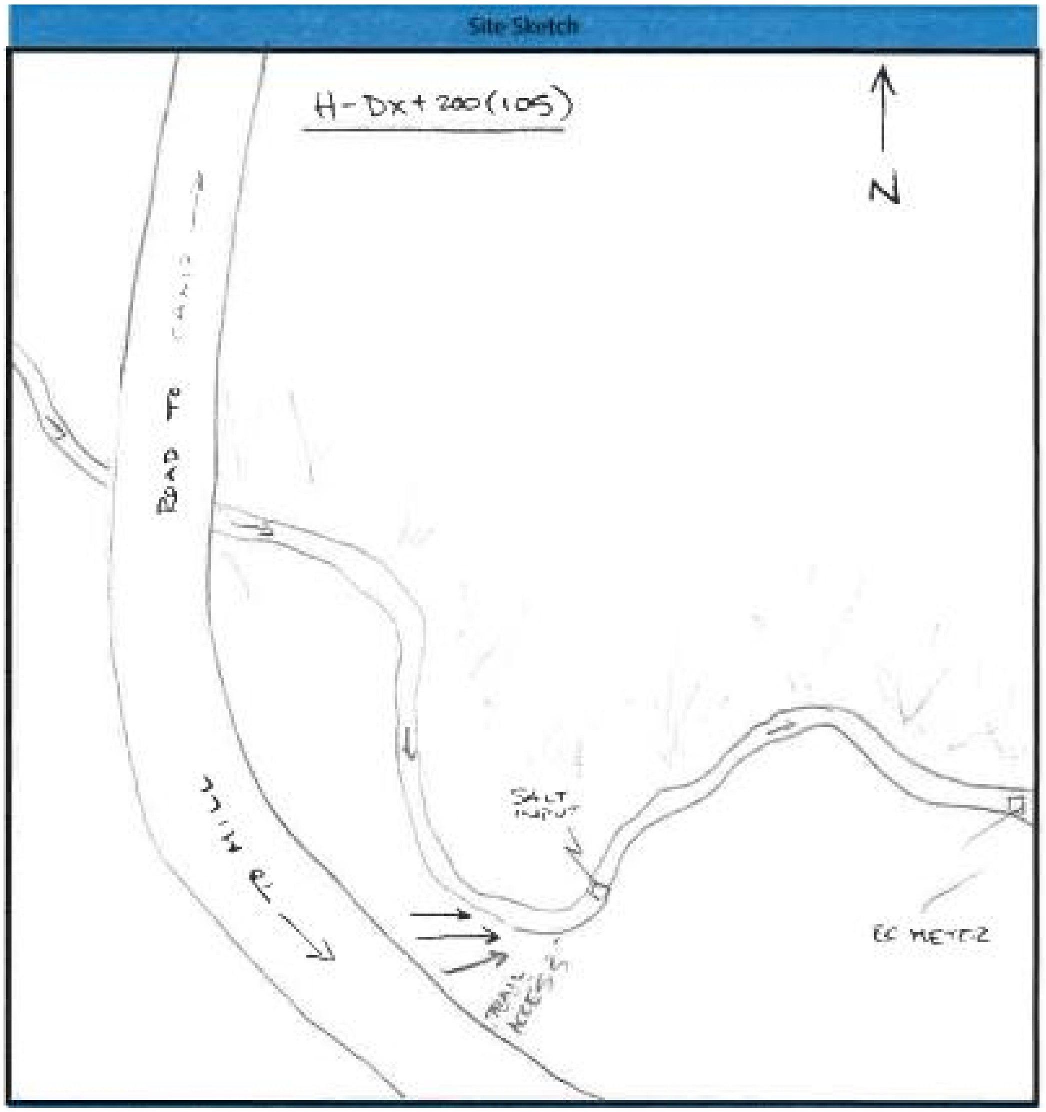


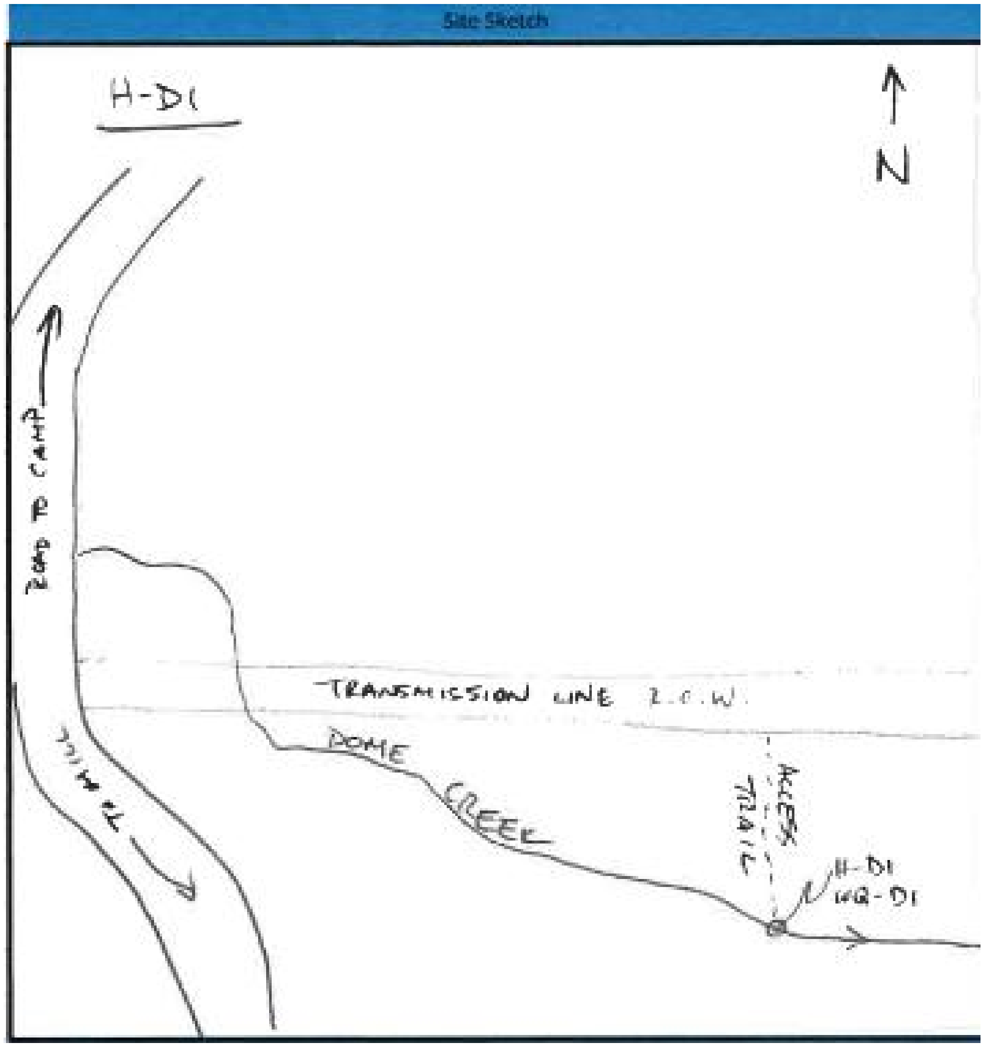
Photo 5. Dome Creek DX (H-DX) Site looking upstream – July 7, 2011.

Photo 6. Dome Creek DX Site (H-DX) – Frozen to substrate October 13, 2011.



A 4. Dome Creek DX+200 (105) site sketch.

Photo 7. Dome Creek DX+105 Site (H-DX+105) – Winter conditions January 31, 2012.



A 5. Dome Creek D1 site sketch.

Photo 8. Dome Creek D1 (H-D1) Site looking downstream – July 7, 2011.

Photo 9. Dome Creek D1 (H-D1) Site – Frozen to substrate March 5, 2012.

A 6. Upper Dome Creek 1 site sketch.

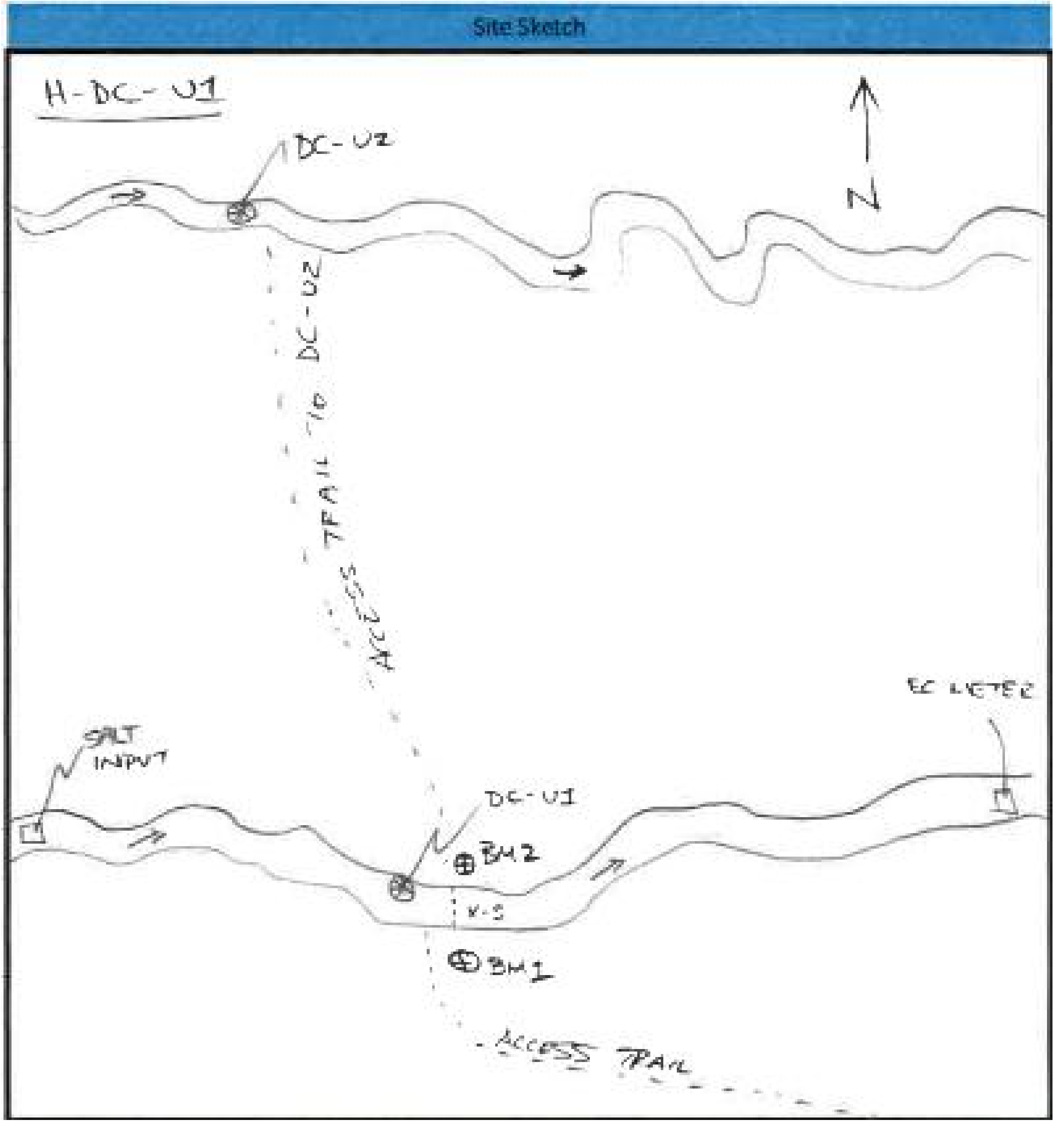


Photo 10. Upper Dome Creek 1 (H-DC-U1) looking upstream – August 31, 2011.

Photo 11. Upper Dome Creek 1 (H-DC-U1) – Frozen to substrate November 16, 2011.

A 7. Upper Dome Creek 2 site sketch.

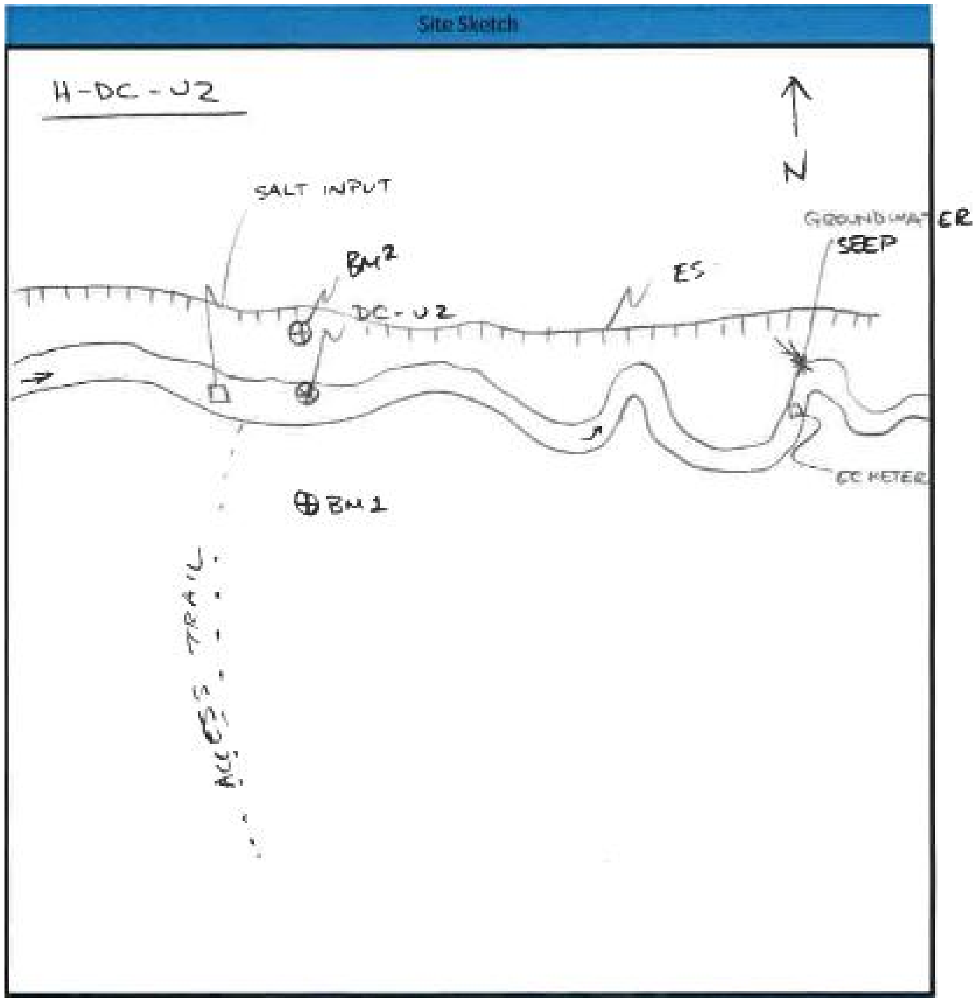


Photo 12. Upper Dome Creek 2 (H-DC-U2) looking downstream – July 6, 2011.

Photo 13. Upper Dome Creek 2 (H-DC-U2) overflow ice conditions – December 15, 2011.

A 8. Diversion channel at the bridge site sketch.

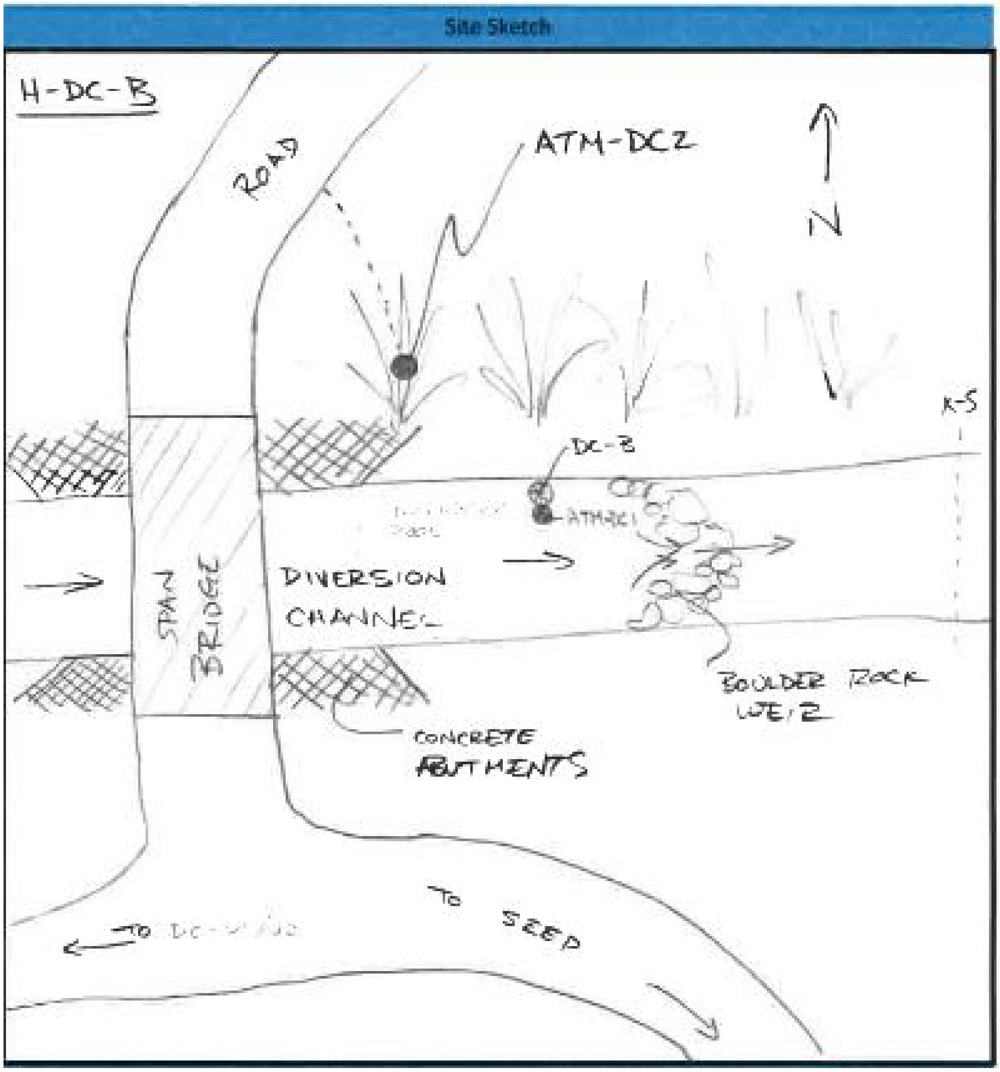


Photo 14. Diversion channel at bridge (H-DC-B) – July 6, 2011.

Photo 15. Diversion channel at Bridge (H-DC-B) – Overflow ice conditions on January 9, 2012.

A 9. Seep site sketch.

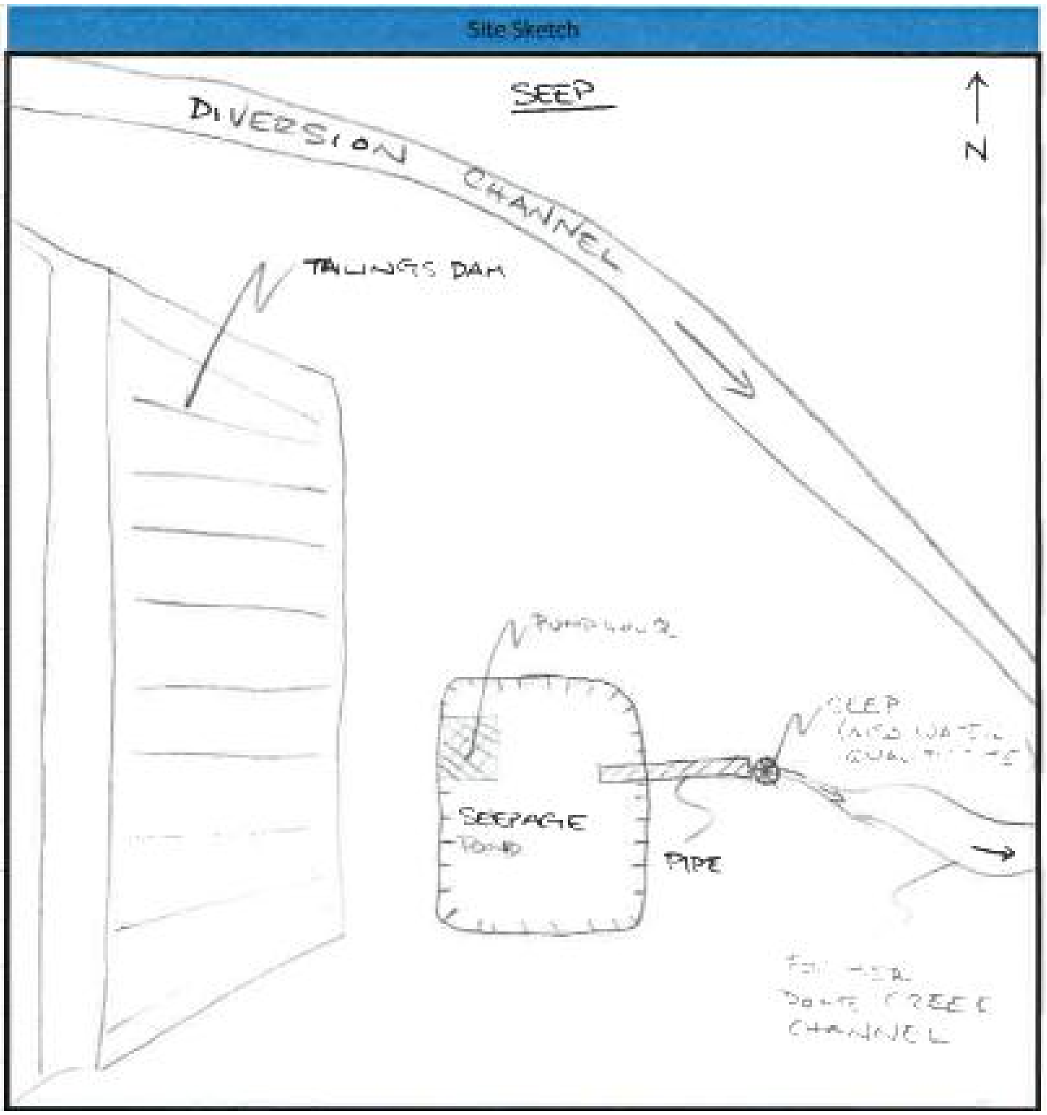


Photo 16. **Seepage Site (H-SEEP) - August 18, 2011.**

Photo 17. **Seepage Site (H-SEEP) – Winter conditions January 30, 2012.**

A 10. Middle Dome Creek site sketch.

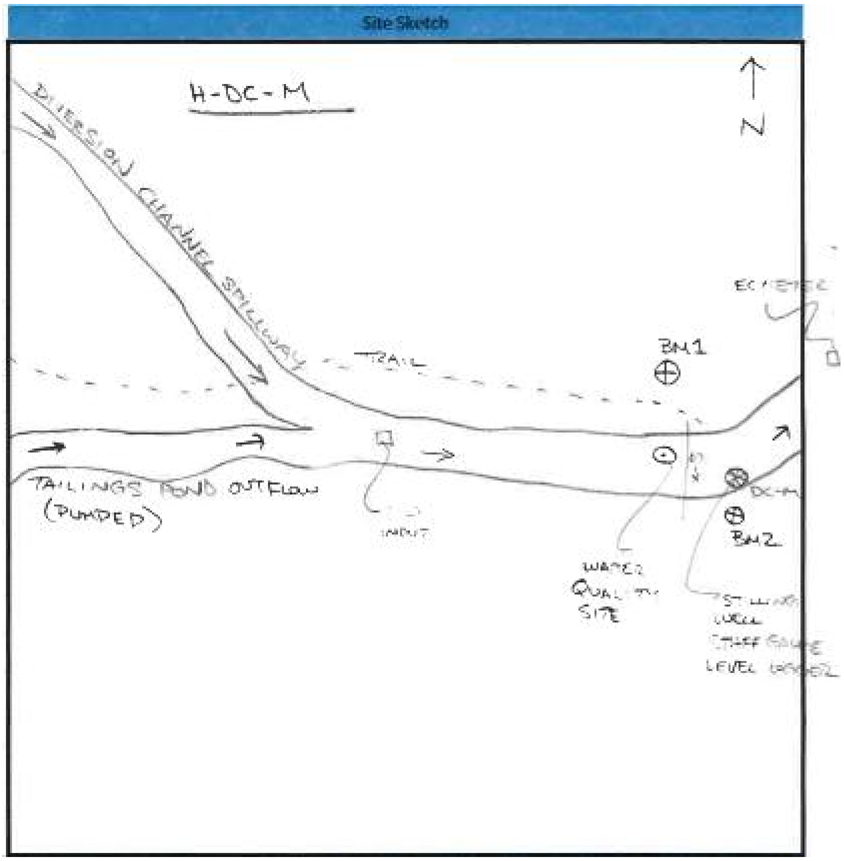


Photo 18. Middle Dome Creek (H-DC-M) looking downstream – June 23, 2011.

Photo 19. Middle Dome Creek (H-DC-M) looking upstream – January 30, 2012.

A 11. Dome Creek at the Road site sketch.

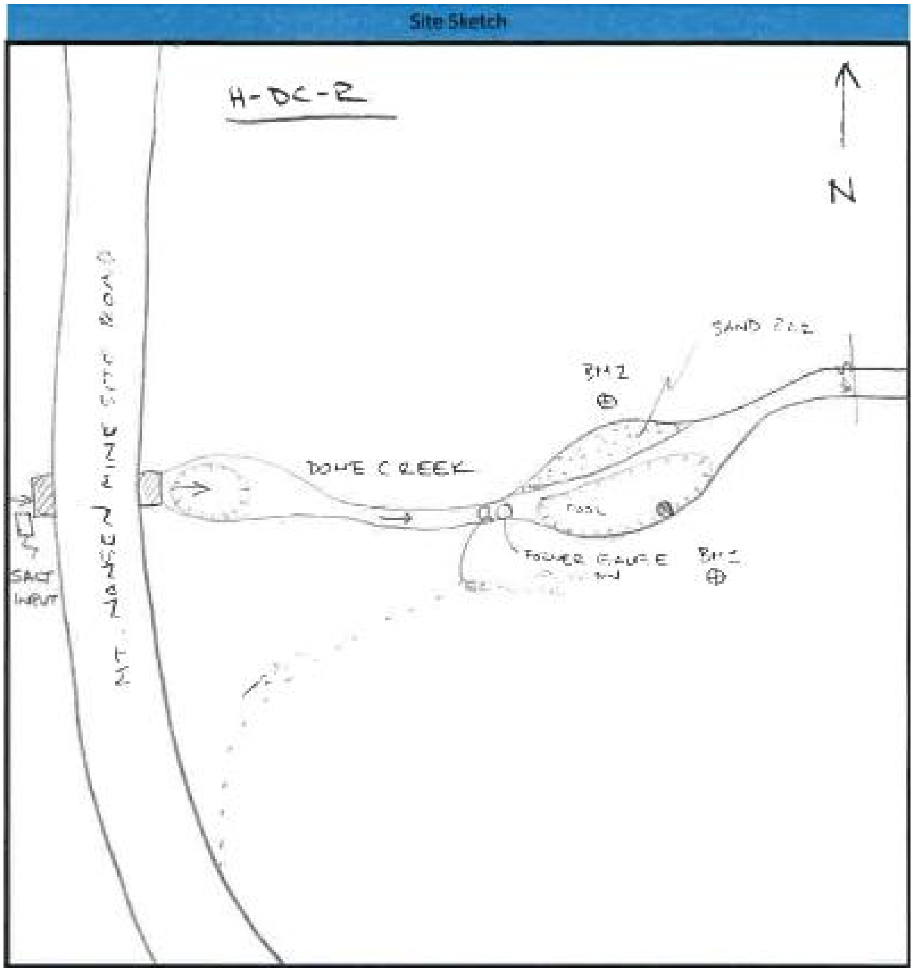


Photo 20. Dome Creek at Road (H-DC-R) looking upstream – July 6, 2011.

Photo 21. Dome Creek at Road (H-DC-R) – Overflow ice conditions March 7, 2012.

A 12. Back Creek site sketch.

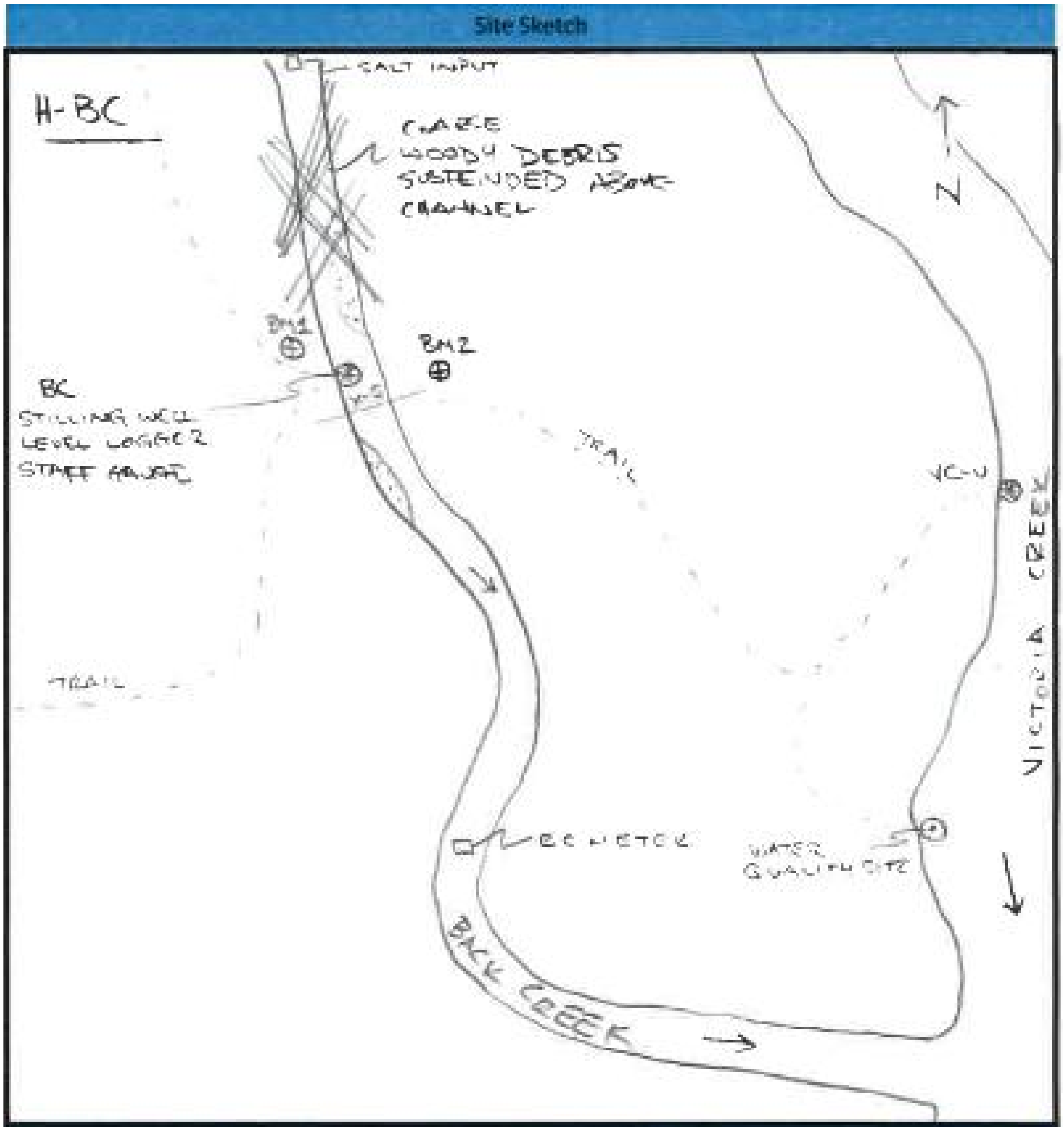


Photo 22. Back Creek Station (H-BC) - June 23, 2011

Photo 23. Back Creek (H-BC) frozen to substrate – November 16, 2011.

A 13. Minnesota Creek site sketch.

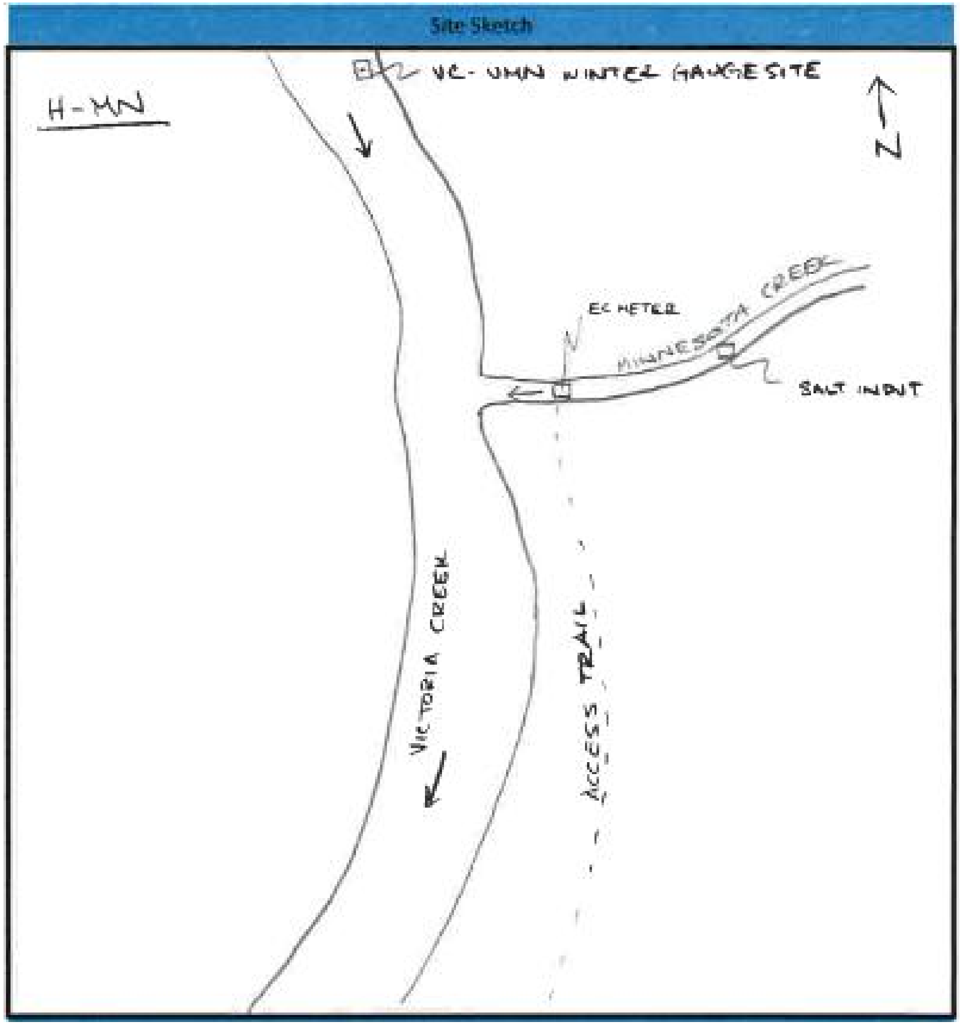


Photo 24. Minnesota Creek (H-MN) looking downstream – January 11, 2012.

Photo 25. Minnesota Creek (H-MN) – Frozen to substrate January 11, 2012.

A 14. Victoria Creek Reference site sketch.

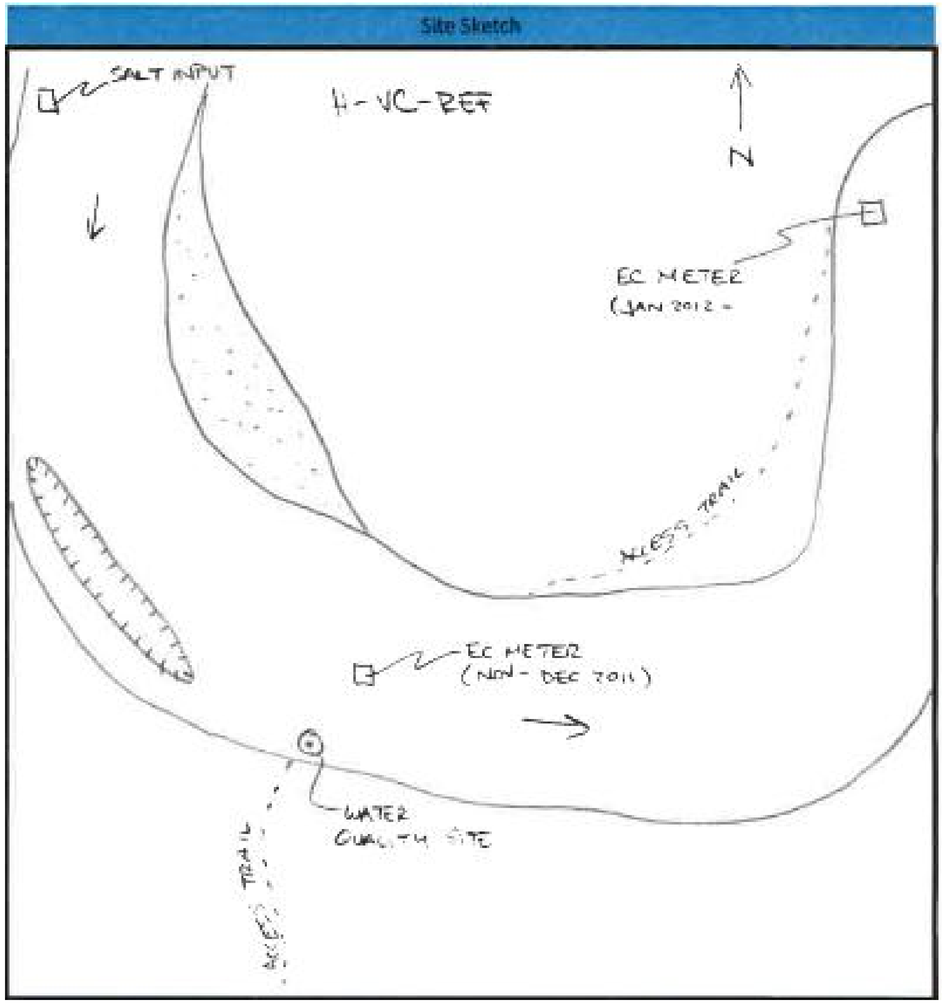


Photo 26. Victoria Reference (H-VC-REF) looking upstream – August 18, 2011.

Photo 27. Victoria Reference (H-VC-REF) looking upstream – January 31, 2012.

A 15. Upper Victoria Creek site sketch.

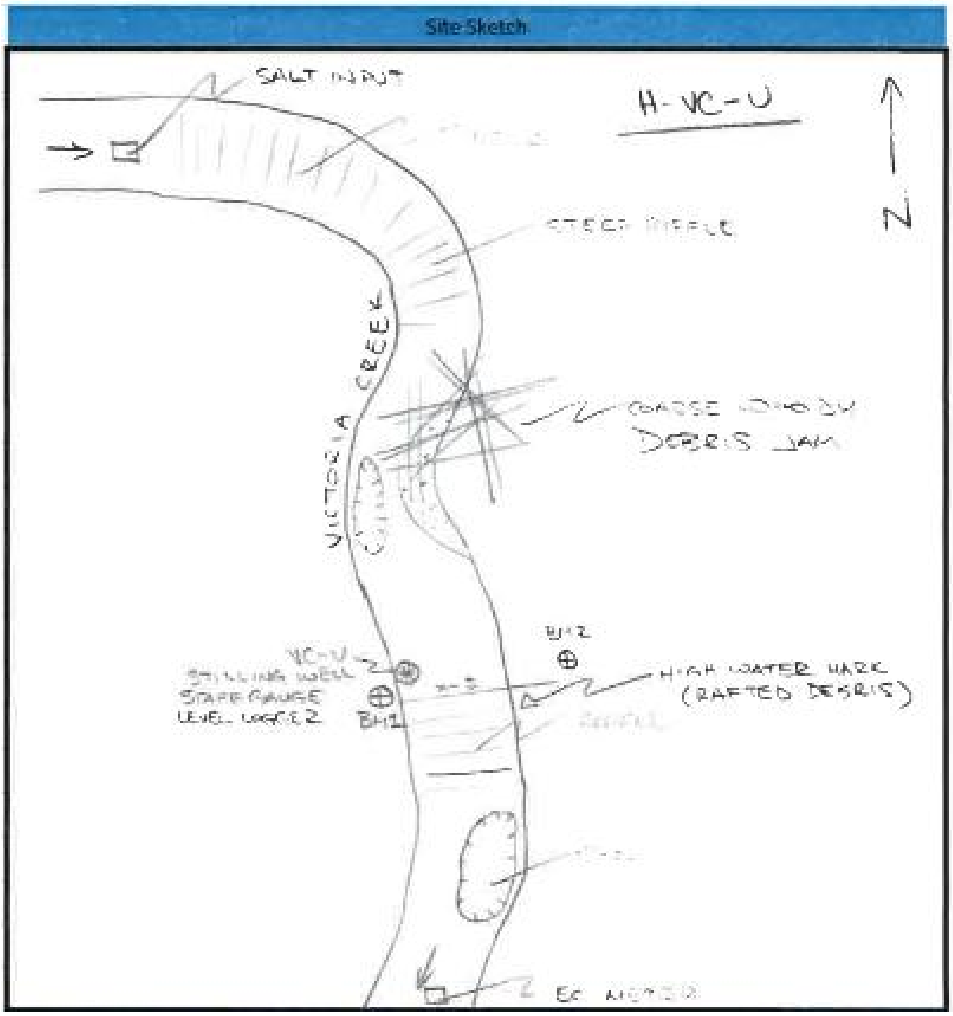


Photo 28. Upper Victoria Creek (H-VC-U) looking upstream – August 30, 2011.

Photo 29. Upper Victoria Creek (H-VC-U) looking downstream - January 31, 2012.

A 16. Victoria Creek downstream of Back Creek site sketch.

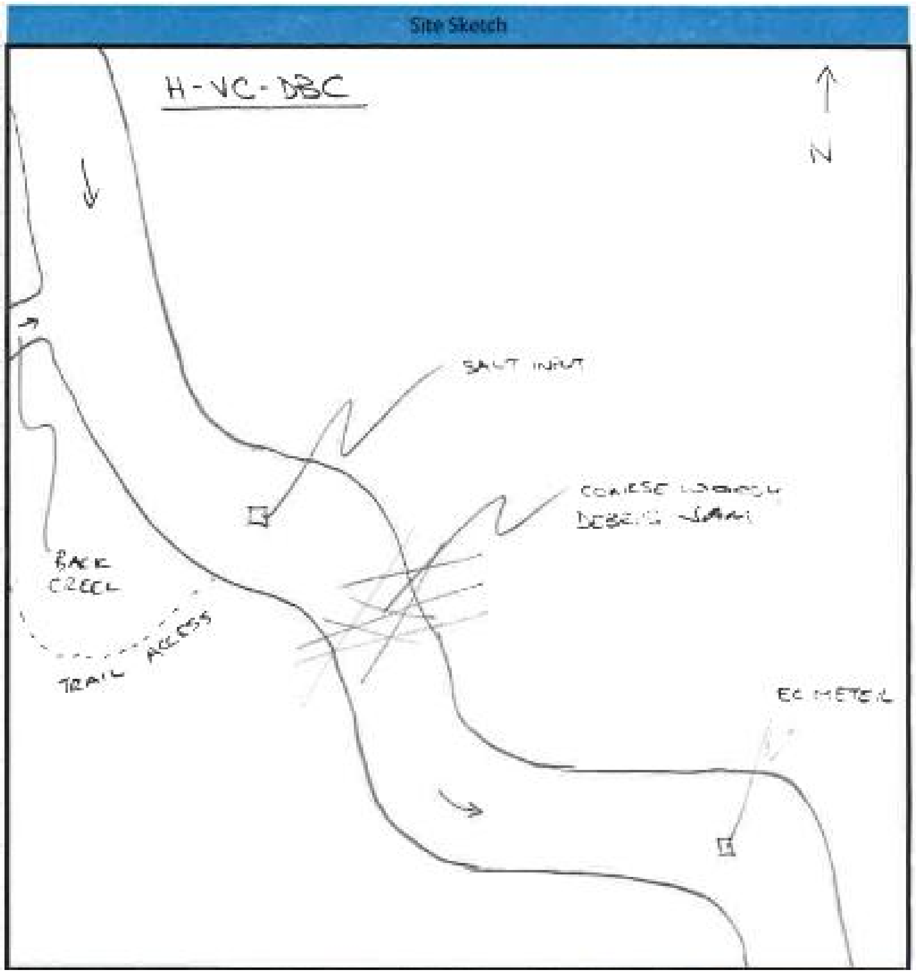


Photo 30. Victoria Creek downstream of Back Creek (H-VC-DBC) – February 1, 2012.

A 17. Victoria Creek upstream of Minnesota Creek site sketch.

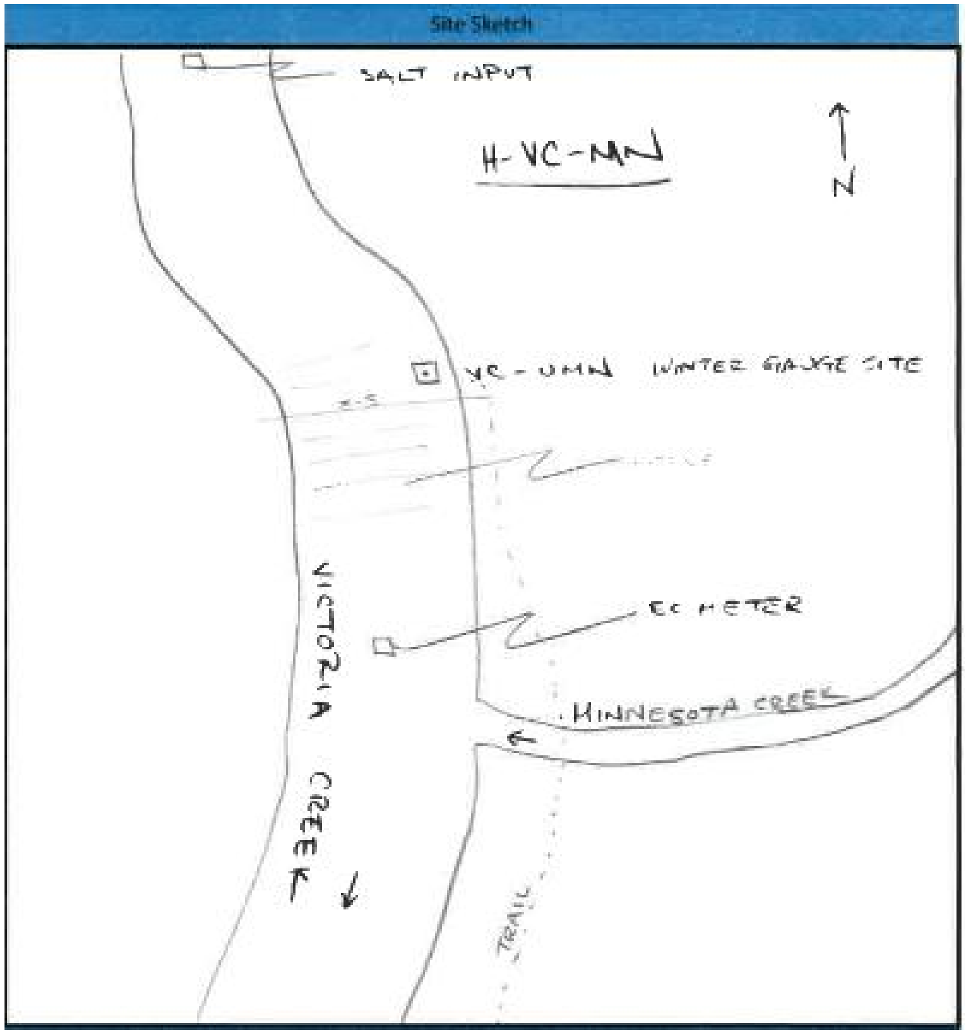


Photo 31. Victoria Creek upstream of Minnesota Creek (H-VC-UMN) – March 7, 2012.

A 18. Victoria Creek at the road site sketch (drawing labeled incorrectly).

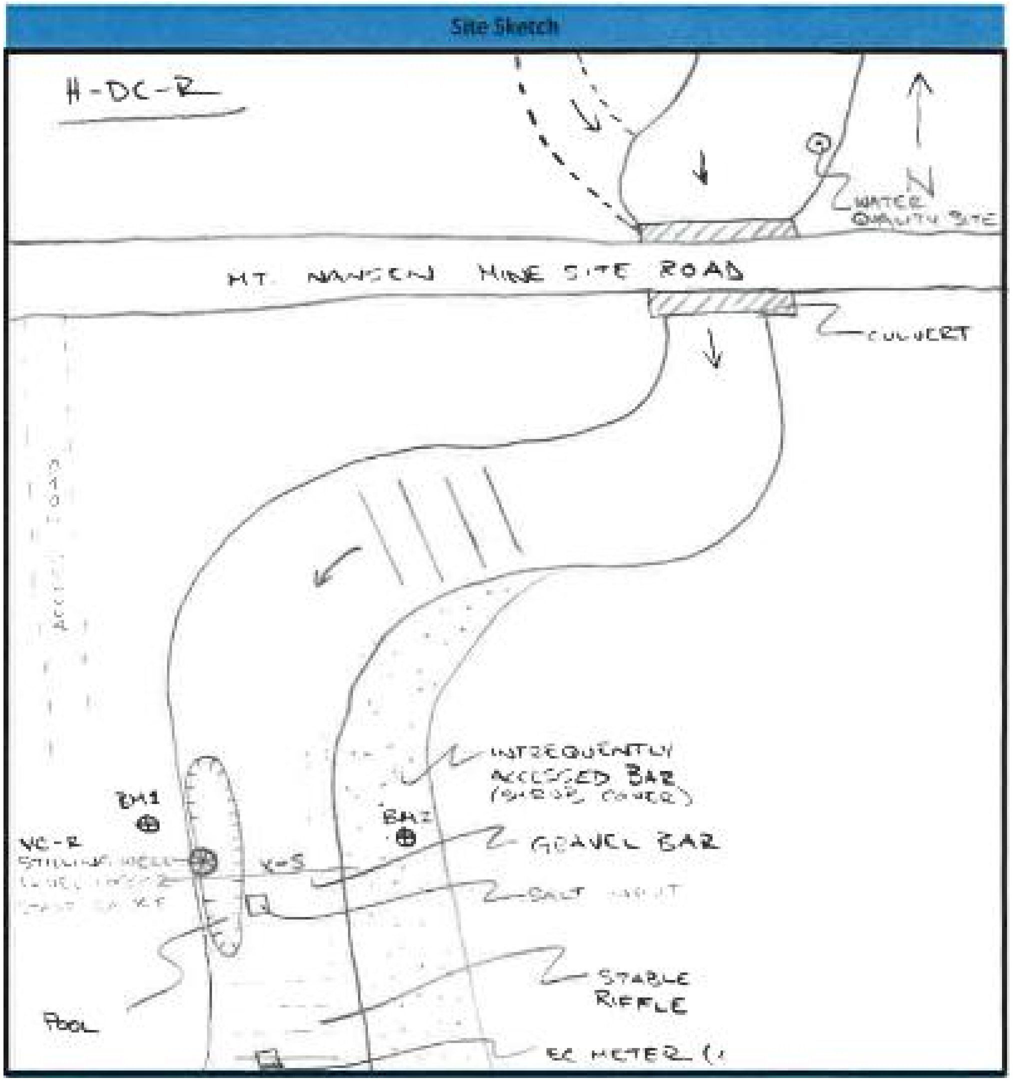


Photo 32. **Victoria Creek at Road (H-VC-R) looking downstream – July 6, 2011.**

Photo 33. **Victoria Creek at Road (H-VC-R) – Winter conditions March 6, 2012.**

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APPENDIX B HYDROMETRIC DATA TABLES & PLOTS

B 1. Summary of site visits and stage levels May 2011- March 2012 from Mount Nansen Hydrometric Database table tbl_rating_table_H_vsQ. MID = Measurement ID; HID = Hydrometric ID

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
1	H-BC	12-May-11	3:32 PM	Current Meter			0.13	
18	H-BC	25-May-11	4:30 PM	Current Meter			0.33	
32	H-BC	07-Jun-11	3:55 PM	Float	0.315	1.835	0.56	S
31	H-BC	07-Jun-11	3:55 PM	Salt Slug	0.315	1.835	0.05	
45	H-BC	23-Jun-11	2:30 PM	Current Meter	0.28	1.8	0.04	
49	H-BC	07-Jul-11	2:30 PM	Current Meter	0.31	1.83	0.06	
152	H-BC	21-Jul-11	1:11 PM	Velocity Head	0.384	1.904	0.20	S
153	H-BC	21-Jul-11	1:11 PM	Float	0.384	1.904	0.30	
58	H-BC	03-Aug-11	12:16 PM	Current Meter	0.369	1.889	0.34	
84	H-BC	18-Aug-11	4:55 PM	Current Meter	0.38	1.9	0.00	
87	H-BC	30-Aug-11	4:20 PM	Current Meter	0.345	1.865	0.10	
111	H-BC	14-Sep-11	12:18 PM	Current Meter	0.325	1.845	0.08	
124	H-BC	28-Sep-11	3:05 PM	Current Meter	0.329	1.849	0.05	
129	H-BC	12-Oct-11	10:02 AM	Salt Slug	0.295	1.815	0.02	
170	H-D1	15-Dec-11	9:40 AM	Float			0.02	
9	H-DC-B	12-May-11	12:00 PM	Salt Slug			0.05	
20	H-DC-B	25-May-11	12:00 PM	Current Meter			0.07	
21	H-DC-B	06-Jun-11	2:15 PM	Current Meter	0.25	1.93	0.03	
40	H-DC-B	22-Jun-11	4:45 PM	Current Meter	0.332	2.012	0.02	
41	H-DC-B	22-Jun-11	4:45 PM	Float	0.332	2.012	0.06	
53	H-DC-B	06-Jul-11	2:45 PM	Float	0.242	1.922		MD
52	H-DC-B	06-Jul-11	2:45 PM	Salt Slug	0.242	1.922	0.02	
60	H-DC-B	03-Aug-11	2:04 PM	Salt Slug	0.25	1.93	0.05	
61	H-DC-B	03-Aug-11	2:04 PM	Float	0.25	1.93	0.26	S

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
81	H-DC-B	17-Aug-11	1:18 PM	Current Meter	0.236	1.916	0.05	
99	H-DC-B	31-Aug-11	9:45 AM	Salt Slug	0.214	1.894	0.04	
98	H-DC-B	31-Aug-11	9:45 AM	Current Meter	0.214	1.894	0.03	
100	H-DC-B	31-Aug-11	9:45 AM	Float	0.214	1.894	0.05	
116	H-DC-B	28-Sep-11	12:31 PM	Salt Slug	0.249	1.929	0.03	
117	H-DC-B	28-Sep-11	12:31 PM	Float	0.249	1.929	0.13	S
136	H-DC-B	12-Oct-11	12:13 PM	Salt Slug	0.251	1.931	0.02	
44	H-DC-M	23-Jun-11	12:17 PM	Float	0.22	2.18	0.08	
43	H-DC-M	23-Jun-11	12:17 PM	Salt Slug	0.22	2.18	0.04	
51	H-DC-M	07-Jul-11	9:25 AM	Current Meter	0.211	2.171	0.02	
62	H-DC-M	03-Aug-11	3:00 PM	Current Meter	0.252	2.212	0.18	
82	H-DC-M	17-Aug-11	11:25 AM	Current Meter	0.264	2.224	0.04	
97	H-DC-M	31-Aug-11	8:30 AM	Current Meter	0.248	2.208	0.00	E/S
96	H-DC-M	31-Aug-11	8:30 AM	Float	0.248	2.208	0.09	
95	H-DC-M	31-Aug-11	8:30 AM	Salt Slug	0.248	2.208	0.04	
119	H-DC-M	28-Sep-11	11:24 PM	Current Meter	0.236	2.196	0.03	
137	H-DC-M	12-Oct-11	11:06 AM	Salt Slug	0.23	2.19	0.02	S
147	H-DC-M	16-Nov-11	2:20 PM	Salt Slug	0.199	2.159	0.00	
174	H-DC-M	09-Jan-12	1:20 PM	Salt Slug	0.19	2.15	0.02	
186	H-DC-M	30-Jan-12	2:30 PM	Salt Slug	0.197	2.157	0.00	
196	H-DC-M	05-Mar-12	3:38 PM	Salt Slug			0.01	F
8	H-DC-R	12-May-11	12:00 PM	Float			0.13	
13	H-DC-R	25-May-11	12:00 PM	Current Meter			0.12	
12	H-DC-R	25-May-11	12:00 PM	Salt Slug			0.09	
25	H-DC-R	07-Jun-11	4:45 PM	Salt Slug	0.371	2.331	0.07	
26	H-DC-R	07-Jun-11	4:45 PM	Float	0.371	2.331	0.03	

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
42	H-DC-R	22-Jun-11	6:00 PM	Current Meter	0.38	2.340	0.08	
48	H-DC-R	06-Jul-11	12:40 PM	Current Meter	0.369	2.329	0.03	
57	H-DC-R	03-Aug-11	10:26 AM	Float	0.45	2.410		MD
56	H-DC-R	03-Aug-11	10:26 AM	Salt Slug	0.45	2.410	0.08	S
71	H-DC-R	17-Aug-11	5:55 PM	Salt Slug	0.482	2.442	0.13	S
72	H-DC-R	17-Aug-11	5:55 PM	Float	0.482	2.442	0.23	
92	H-DC-R	31-Aug-11	2:15 PM	Salt Slug	0.406	2.366	0.04	
151	H-DC-R	31-Aug-11	2:15 PM	Float	0.406	2.366	0.09	
113	H-DC-R	14-Sep-11	10:04 AM	Float	0.402	2.362	0.07	
112	H-DC-R	14-Sep-11	10:04 AM	Salt Slug	0.402	2.362	0.03	
122	H-DC-R	28-Sep-11	2:10 PM	Float	0.419	2.379	0.09	
121	H-DC-R	28-Sep-11	2:10 PM	Salt Slug	0.419	2.379		F/S
138	H-DC-R	12-Oct-11	9:06 AM	Salt Slug	0.45	2.379	0.03	
145	H-DC-R	16-Nov-11	1:30 PM	Volumetric			0.00	B
7	H-DC-U1	12-May-11	12:00 PM	Volumetric			0.00	
11	H-DC-U1	25-May-11	10:30 AM	Current Meter			0.03	
10	H-DC-U1	25-May-11	10:30 AM	Salt Slug			0.04	
27	H-DC-U1	07-Jun-11	9:30 AM	Salt Slug	0.3	2.587	0.01	
38	H-DC-U1	23-Jun-11	3:40 PM	Salt Slug	0.31	2.597	0.03	
39	H-DC-U1	23-Jun-11	3:40 PM	Float	0.31	2.597	0.02	
63	H-DC-U1	03-Aug-11	4:26 PM	Salt Slug	0.32	2.607	0.02	
75	H-DC-U1	17-Aug-11	2:11 PM	Salt Slug	0.32	2.607	0.01	
76	H-DC-U1	17-Aug-11	2:11 PM	Float	0.32	2.607		MD/MW
89	H-DC-U1	31-Aug-11	11:04 AM	Float	0.296	2.583	0.02	
88	H-DC-U1	31-Aug-11	11:04 AM	Salt Slug	0.296	2.583	0.01	
105	H-DC-U1	14-Sep-11	4:45 PM	Float	0.295	2.582		MD/MW

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
104	H-DC-U1	14-Sep-11	4:45 PM	Salt Slug	0.295	2.582	0.01	
125	H-DC-U1	28-Sep-11	10:56 AM	Salt Slug	0.306	2.593	0.01	
126	H-DC-U1	28-Sep-11	10:56 AM	Float	0.306	2.593	0.02	S
130	H-DC-U1	12-Oct-11	1:41 PM	Salt Slug	0.31	2.597	0.01	
28	H-DC-U2	07-Jun-11	11:00 AM	Salt Slug			0.01	
36	H-DC-U2	22-Jun-11	3:15 PM	Salt Slug	0.244	2.224	0.02	
37	H-DC-U2	22-Jun-11	3:15 PM	Float	0.244	2.224	0.04	
54	H-DC-U2	06-Jul-11	4:53 PM	Salt Slug	0.214	2.194	0.02	
64	H-DC-U2	03-Aug-11	5:04 PM	Salt Slug	0.316	2.296	0.05	
65	H-DC-U2	03-Aug-11	5:04 PM	Float	0.316	2.296		MD
73	H-DC-U2	17-Aug-11	3:05 PM	Salt Slug	0.234	2.214	0.03	
74	H-DC-U2	17-Aug-11	3:05 PM	Float	0.234	2.214	0.19	S
90	H-DC-U2	31-Aug-11	11:52 AM	Salt Slug	0.221	2.201	0.02	
91	H-DC-U2	31-Aug-11	11:52 AM	Float	0.221	2.201	0.02	
103	H-DC-U2	14-Sep-11	5:24 PM	Salt Slug	0.216	2.196	0.02	
120	H-DC-U2	28-Sep-11	10:15 AM	Salt Slug	0.286	2.266	0.02	
140	H-DC-U2	12-Oct-11	2:21 PM	Salt Slug	0.352	2.332	0.03	
167	H-DC-U2	15-Dec-11	9:30 AM	Salt Slug			0.03	S
176	H-DX+105	10-Jan-12	3:45 AM	Float			0.01	
175	H-DX+105	10-Jan-12	3:45 AM	Salt Slug			0.01	S
193	H-DX+105	31-Jan-12	10:30 AM	Salt Slug			0.00	
199	H-DX+105	05-Mar-12	1:33 PM	Salt Slug			0.00	F
164	H-MN	14-Dec-11	2:25 PM	Salt Slug			0.02	S
3	H-PC-DSP	12-May-11	9:38 AM	Salt Slug			0.02	S
4	H-PC-DSP	12-May-11	9:38 AM	Volumetric			0.00	
17	H-PC-DSP	25-May-11	5:12 PM	Float			0.09	

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
16	H-PC-DSP	25-May-11	5:12 PM	Salt Slug			0.04	
23	H-PC-DSP	07-Jun-11	7:20 AM	Salt Slug	0.149	2.3495	0.01	
24	H-PC-DSP	07-Jun-11	7:20 AM	Volumetric	0.149	2.3495	0.01	
35	H-PC-DSP	22-Jun-11	1:40 AM	Volumetric	0.159	2.349	0.00	
203	H-PC-DSP	07-Jul-11	11:38 AM	Volumetric	0.181	2.371	0.01	
202	H-PC-DSP	07-Jul-11	11:38 AM	Salt Slug	0.181	2.371	0.00	
204	H-PC-DSP	21-Jul-11	11:18 AM	Volumetric	0.248	2.438	0.01	
205	H-PC-DSP	21-Jul-11	11:18 AM	Velocity Head	0.248	2.438		S
67	H-PC-DSP	03-Aug-11	6:30 PM	Volumetric	0.232	2.422	0.01	
66	H-PC-DSP	03-Aug-11	6:30 PM	Salt Slug	0.232	2.422	0.02	
78	H-PC-DSP	17-Aug-11	10:04 AM	Volumetric	0.242	2.432	0.01	
77	H-PC-DSP	17-Aug-11	10:04 AM	Salt Slug	0.242	2.432	0.02	
102	H-PC-DSP	31-Aug-11	1:23 PM	Volumetric	0.212	2.402	0.01	
101	H-PC-DSP	31-Aug-11	1:23 PM	Salt Slug	0.212	2.402	0.01	
107	H-PC-DSP	14-Sep-11	2:20 PM	Volumetric	0.184	2.374	0.00	
106	H-PC-DSP	14-Sep-11	2:20 PM	Salt Slug	0.184	2.374	0.01	
115	H-PC-DSP	28-Sep-11	4:50 PM	Volumetric	0.175	2.365	0.00	
114	H-PC-DSP	28-Sep-11	4:50 PM	Salt Slug	0.175	2.365	0.01	
133	H-PC-DSP	12-Oct-11	3:14 PM	Volumetric	0.15	2.34	0.00	
132	H-PC-DSP	12-Oct-11	3:14 PM	Salt Slug	0.15	2.34	0.00	
5	H-PC-U	12-May-11	10:58 AM	Salt Slug			0.01	S
6	H-PC-U	12-May-11	10:58 AM	Volumetric			0.00	S
15	H-PC-U	25-May-11	11:37 AM	Current Meter				F
14	H-PC-U	25-May-11	11:37 AM	Salt Slug			0.03	
22	H-PC-U	06-Jun-11	4:20 PM	Current Meter	0.18		0.01	S
34	H-PC-U	22-Jun-11	12:00 PM	Float	0.294	2.404	0.01	

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
33	H-PC-U	22-Jun-11	12:00 PM	Salt Slug	0.294	2.404	0.01	
155	H-PC-U	23-Jun-11	8:00 AM	Weir	0.294	2.404	0.00	
156	H-PC-U	07-Jul-11	12:43 PM	Weir	0.295	2.405	0.00	
184	H-PC-U	07-Jul-11	12:43 PM	Salt Slug	0.295	2.405	0.01	
157	H-PC-U	20-Jul-11	5:46 PM	Velocity Head	0.364	2.474		S
185	H-PC-U	20-Jul-11	5:46 PM	Weir	0.364	2.474	0.02	
68	H-PC-U	03-Aug-11	10:03 AM	Salt Slug	0.352	2.462	0.02	
69	H-PC-U	03-Aug-11	10:03 AM	Float	0.352	2.462	0.02	
158	H-PC-U	04-Aug-11	10:03 AM	Weir	0.352	2.462	0.01	
159	H-PC-U	17-Aug-11	8:00 AM	Weir	0.361	2.471	0.01	
79	H-PC-U	17-Aug-11	8:00 AM	Salt Slug	0.361	2.471	0.01	
80	H-PC-U	17-Aug-11	8:00 AM	Volumetric	0.361	2.471	0.01	
160	H-PC-U	31-Aug-11	3:30 PM	Weir	0.33	2.44	0.01	
94	H-PC-U	31-Aug-11	3:30 PM	Salt Slug	0.33	2.44	0.01	
93	H-PC-U	31-Aug-11	3:30 PM	Float	0.33	2.44	0.01	
161	H-PC-U	14-Sep-11	3:14 PM	Weir	0.308	2.418	0.00	
108	H-PC-U	14-Sep-11	3:15 PM	Salt Slug	0.308	2.418	0.00	
162	H-PC-U	28-Sep-11	5:48 PM	Weir	0.299	2.409	0.00	EO
128	H-PC-U	28-Sep-11	5:48 PM	Float	0.299	2.409	0.02	
127	H-PC-U	28-Sep-11	5:48 PM	Salt Slug	0.299	2.409	0.01	
135	H-PC-U	12-Oct-11	4:43 PM	Volumetric	0.298	2.408	0.00	SB
134	H-PC-U	12-Oct-11	4:43 PM	Salt Slug	0.298	2.408	0.00	SB
163	H-PC-U	13-Oct-11	9:00 AM	Weir	0.299	2.409	0.00	BE
171	H-SEEP	15-Dec-11	3:06 PM	Volumetric			0.00	
173	H-SEEP	09-Jan-12	1:36 PM	Volumetric			0.00	
187	H-SEEP	30-Jan-12	2:06 AM	Volumetric			0.00	

MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
197	H-SEEP	05-Mar-12	4:15 PM	Volumetric			0.00	
183	H-VC-DBC	11-Jan-12	9:20 AM	Current Meter			0.55	
182	H-VC-DBC	11-Jan-12	9:20 AM	Salt Slug			0.05	S
190	H-VC-DBC	01-Feb-12	2:30 PM	Salt Slug			0.00	
200	H-VC-DBC	06-Mar-12	5:12 PM	Salt Slug			0.06	
47	H-VC-R	06-Jul-11	10:30 AM	Current Meter	0.462	2.022	0.64	
169	H-VC-R	20-Jul-11	10:40 AM	Current Meter	0.633	2.193	1.71	S
55	H-VC-R	03-Aug-11	7:56 AM	Current Meter	0.51	2.07	3.67	
70	H-VC-R	17-Aug-11	4:25 PM	Current Meter	0.562	2.122	1.84	
85	H-VC-R	30-Aug-11	1:45 PM	Current Meter	0.486	2.046	0.96	
109	H-VC-R	14-Sep-11	8:40 AM	Current Meter	0.457	2.017	0.50	
118	H-VC-R	27-Sep-11	5:30 PM	Current Meter	0.442	2.002	0.47	
131	H-VC-R	11-Oct-11	2:54 PM	Current Meter	0.437	1.997	0.28	S
143	H-VC-R	16-Nov-11	9:15 AM	Current Meter	0.456	2.016	0.21	B
154	H-VC-R	16-Nov-11	9:15 AM	Salt Slug	0.456	2.016	0.08	
177	H-VC-R	11-Jan-12	4:20 PM	Salt Slug	0.419	1.979	0.06	B
178	H-VC-R	12-Jan-12	1:25 PM	Salt Slug	0.419	1.979	0.16	B
191	H-VC-R	01-Feb-12	9:15 AM	Salt Slug			0.06	BS
194	H-VC-R	06-Mar-12	2:45 PM	Salt Slug			0.04	B
2	H-VC-U	12-May-11	2:30 PM	Current Meter	0.395	2.235	0.78	
19	H-VC-U	25-May-11	3:30 PM	Current Meter	0.53	2.37	2.26	
30	H-VC-U	07-Jun-11	2:15 PM	Float	0.34	2.18	1.28	
29	H-VC-U	07-Jun-11	2:15 PM	Salt Slug	0.34	2.18	0.49	
46	H-VC-U	23-Jun-11	3:00 AM	Current Meter	0.34	2.18	0.53	
50	H-VC-U	07-Jul-11	3:06 PM	Current Meter	0.307	2.147	0.41	
208	H-VC-U	21-Jul-11	2:20 PM	Float	0.4	2.24	2.34	S

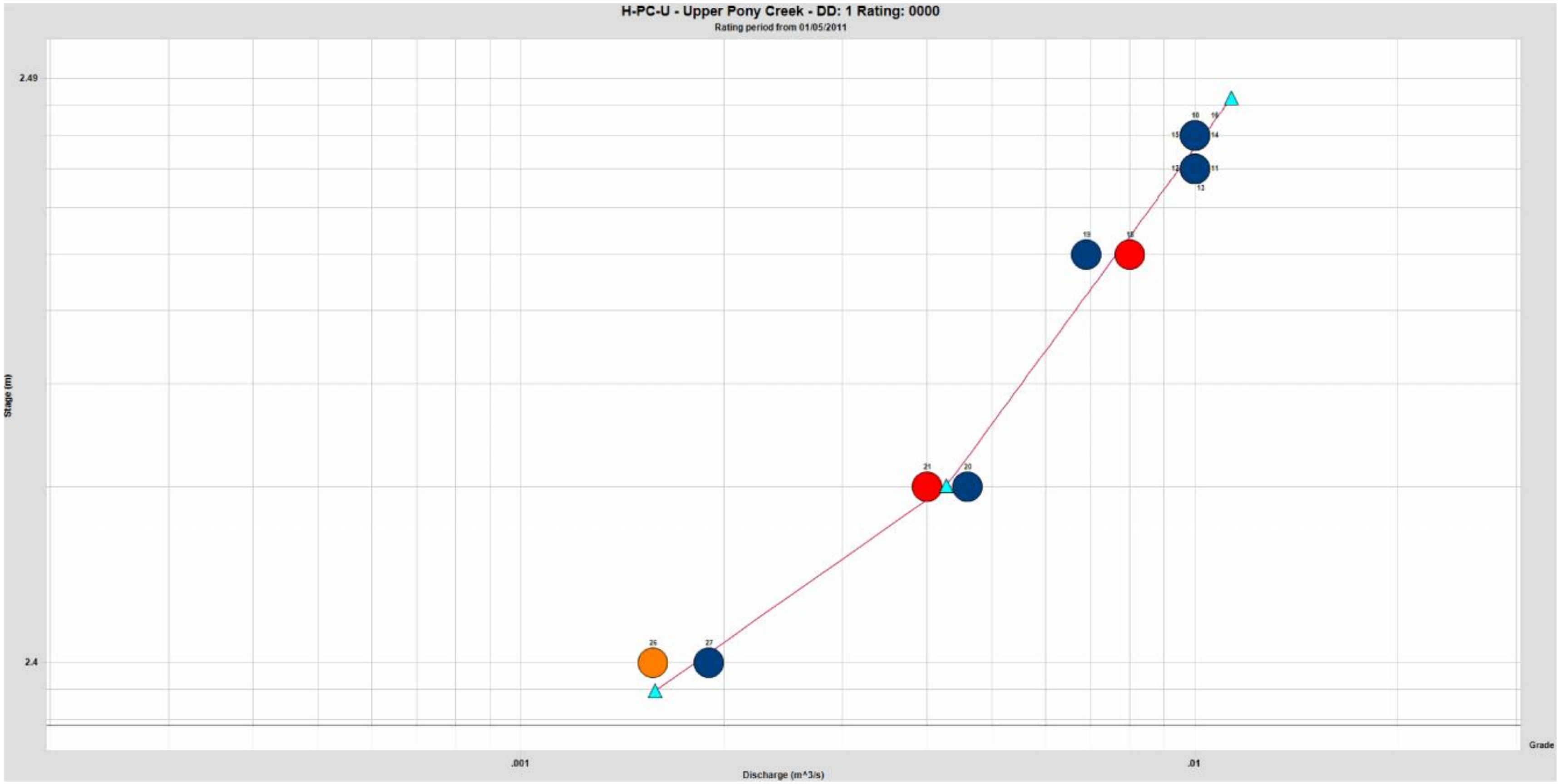
MID	HID	Measurement Date	Measurement Time	Measurement Method	Staff Gauge Reading (m)	Water Level above Assumed Datum (m)	Discharge (m^3/s)	Data Flag[2]
207	H-VC-U	21-Jul-11	2:20 PM	Velocity Head	0.4	2.24		S
59	H-VC-U	03-Aug-11	12:58 PM	Current Meter	0.382	2.222	2.62	
83	H-VC-U	18-Aug-11	3:15 PM	Current Meter	0.43	2.27	1.26	
86	H-VC-U	30-Aug-11	3:35 PM	Current Meter	0.35	2.19	0.65	
110	H-VC-U	14-Sep-11	11:15 AM	Current Meter	0.306	2.146	0.39	
123	H-VC-U	28-Sep-11	4:04 PM	Current Meter	0.289	2.129	0.31	
139	H-VC-U	11-Oct-11	4:07 PM	Current Meter	0.255	2.095	0.22	
142	H-VC-U	16-Nov-11	11:43 AM	Current Meter	0.239	2.079	0.32	
181	H-VC-U	11-Jan-12	10:26 AM	Salt Slug		2.059	0.01	S
189	H-VC-U	31-Jan-12	1:46 PM	Salt Slug			0.00	S
201	H-VC-U	06-Mar-12	5:30 PM	Current Meter			0.06	F
149	H-VC-UMN	17-Nov-11	1:20 PM	Salt Slug			0.01	S
166	H-VC-UMN	14-Dec-11	2:53 PM	Current Meter			0.26	EB
179	H-VC-UMN	11-Jan-12	3:10 PM	Salt Slug			0.04	B
192	H-VC-UMN	01-Feb-12	2:18 PM	Salt Slug			0.05	B
195	H-VC-UMN	06-Mar-12	11:00 AM	Salt Slug			0.05	B
206	VC-REF	14-Dec-11	5:00 PM	Salt Slug			0.02	
180	VC-REF	11-Jan-12	12:45 PM	Salt Slug			0.00	
188	VC-REF	31-Jan-12	4:30 AM	Salt Slug			0.04	

[1] - Applicable at sites with continuous data loggers only. Staff gauges were not (re-)installed until June 2011.

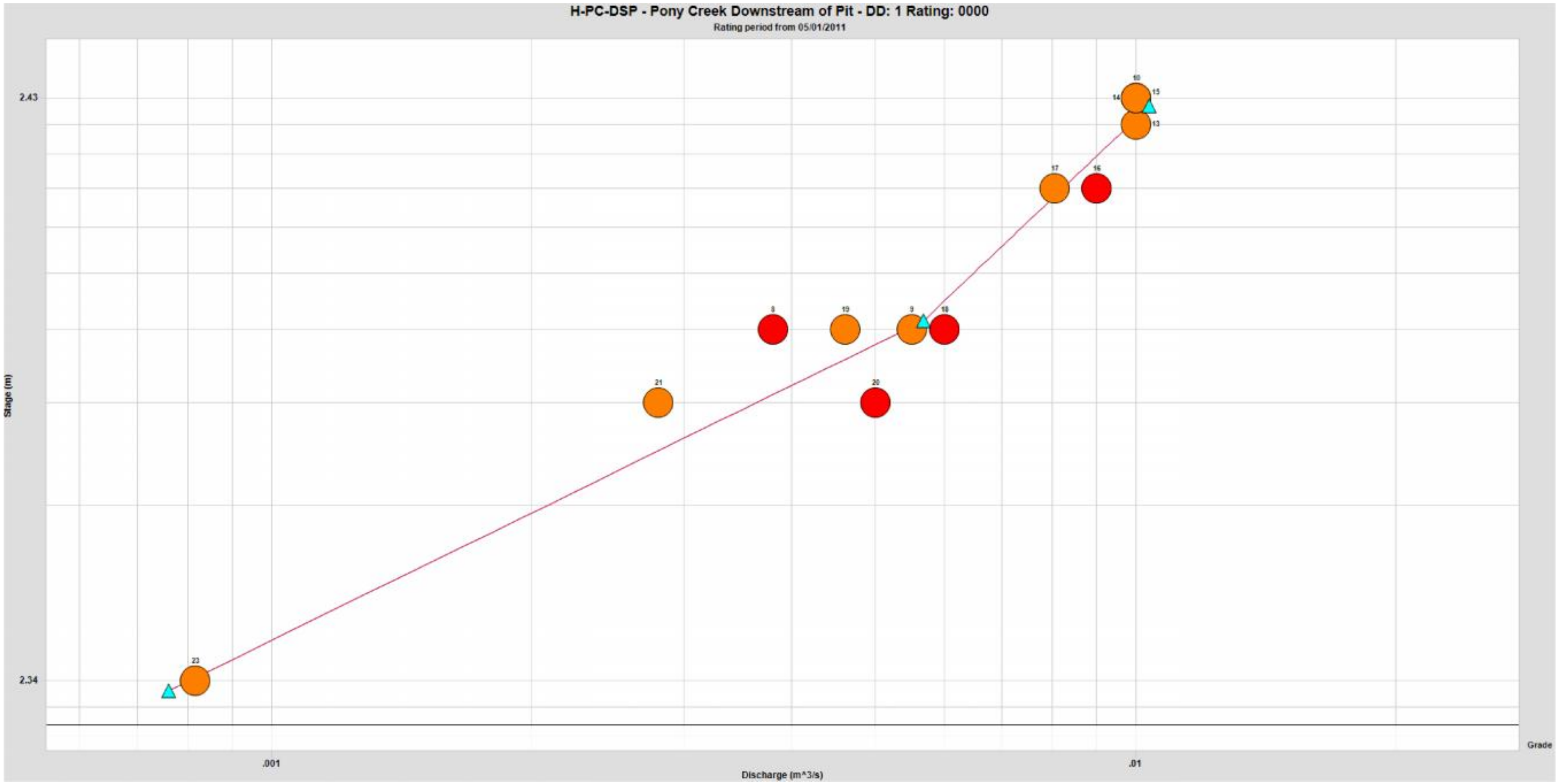
[2]- Data flags show in Table B2.

B 2. Hydrometric Data Flags

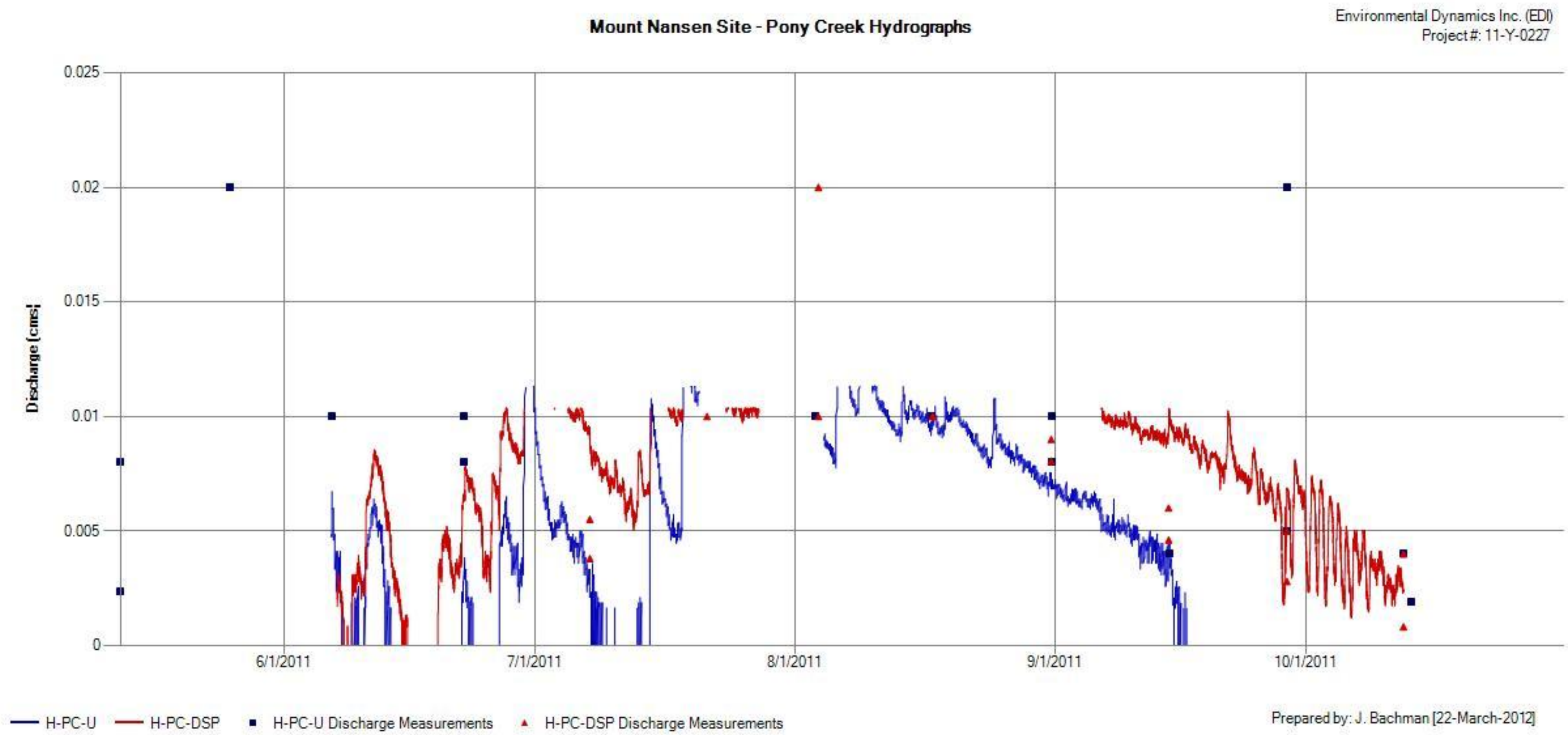
Flag	Flag Description
E	Estimated value; over bank discharge
B	Ice present
F	Instrument malfunction
M	Manual measurement
A	Automated measurement (logged)
ML	Missing length data
MD	Missing depth data
MW	Missing width data
O	Outside of instrument/structure operating accuracy range
S	Suspect data



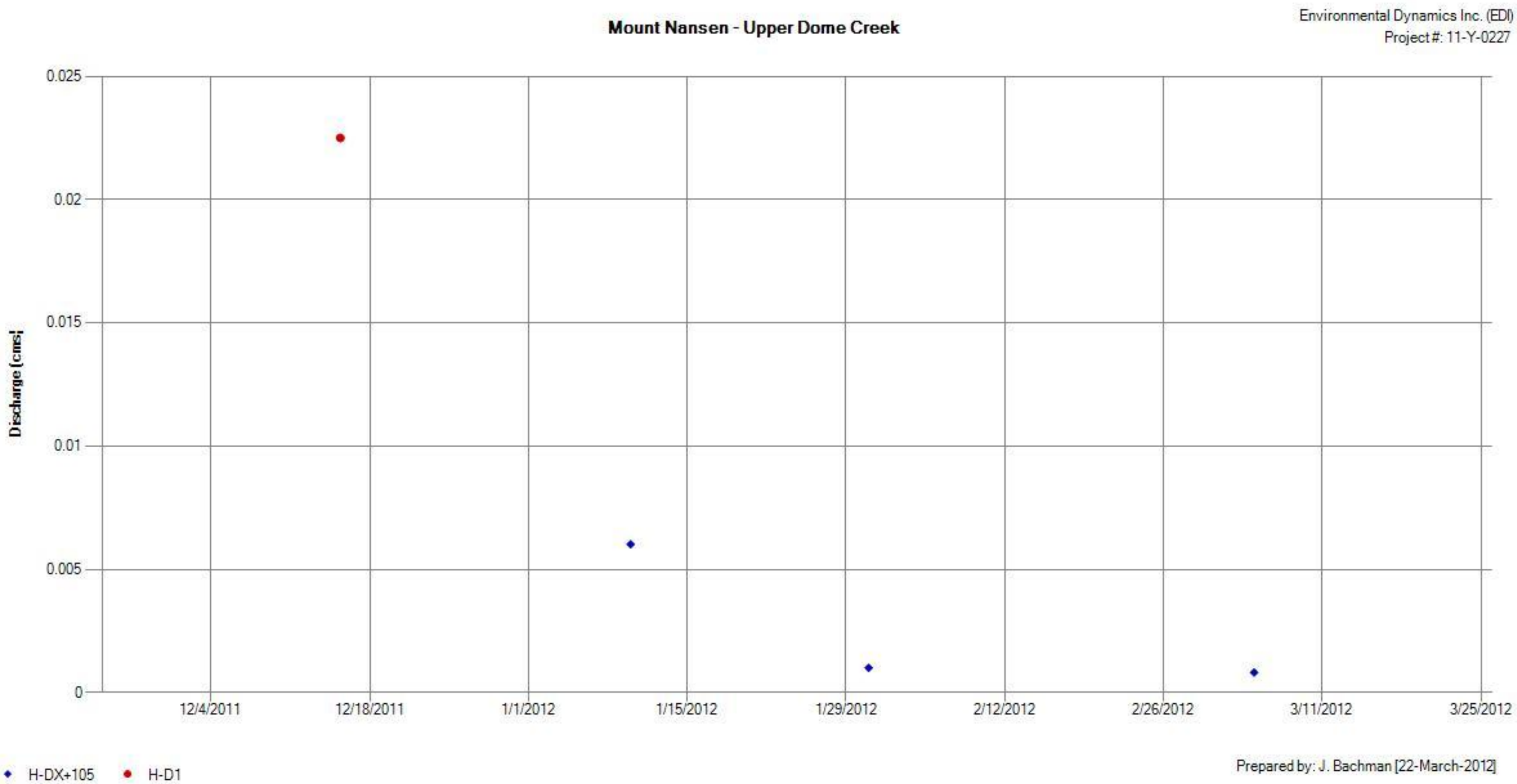
B 3 – Upper Pony Creek Rating Curve (H-PC-U)



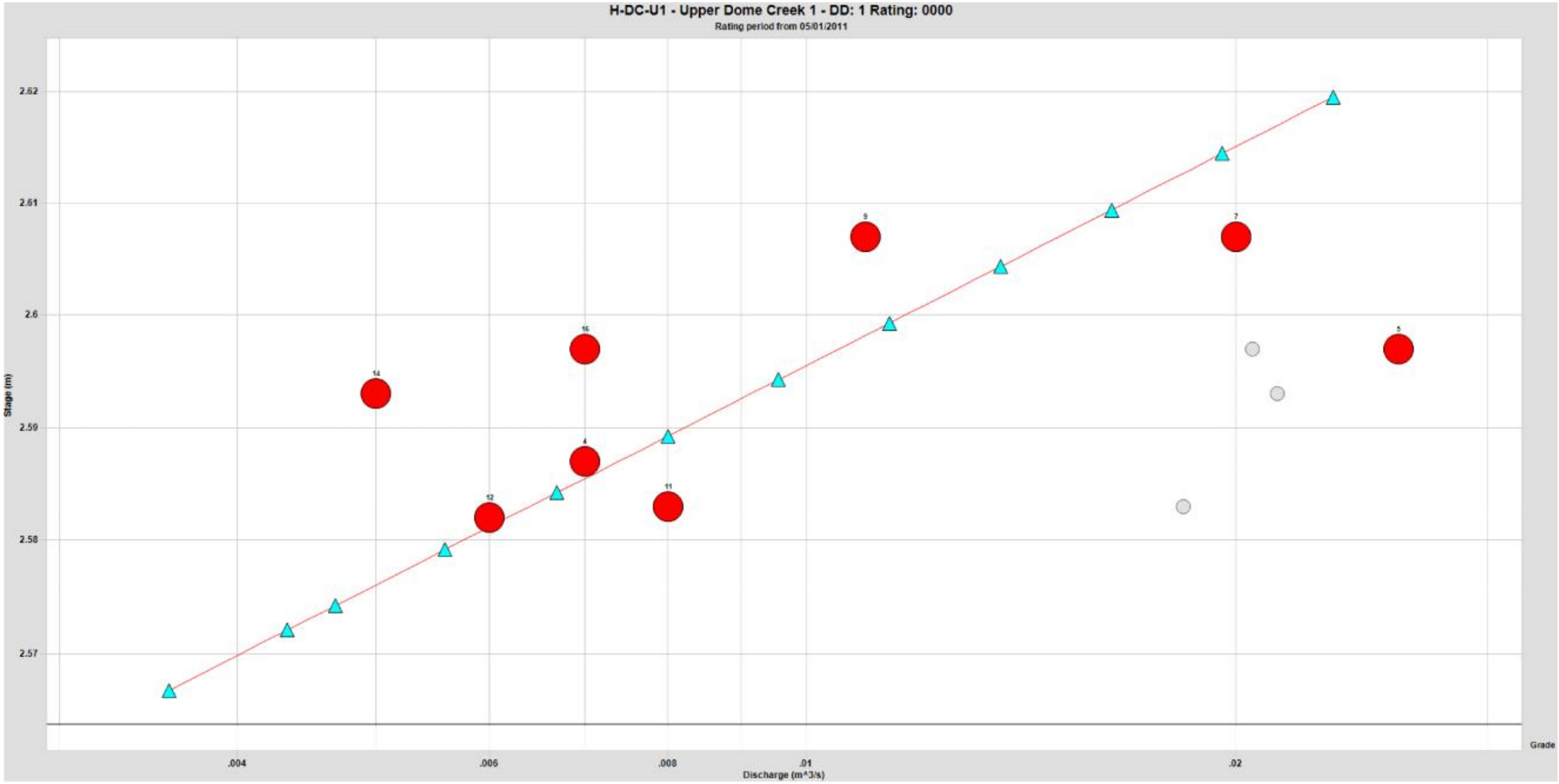
B 4 - Pony Creek Downstream of the Pit Rating Curve (H-PC-DSP)



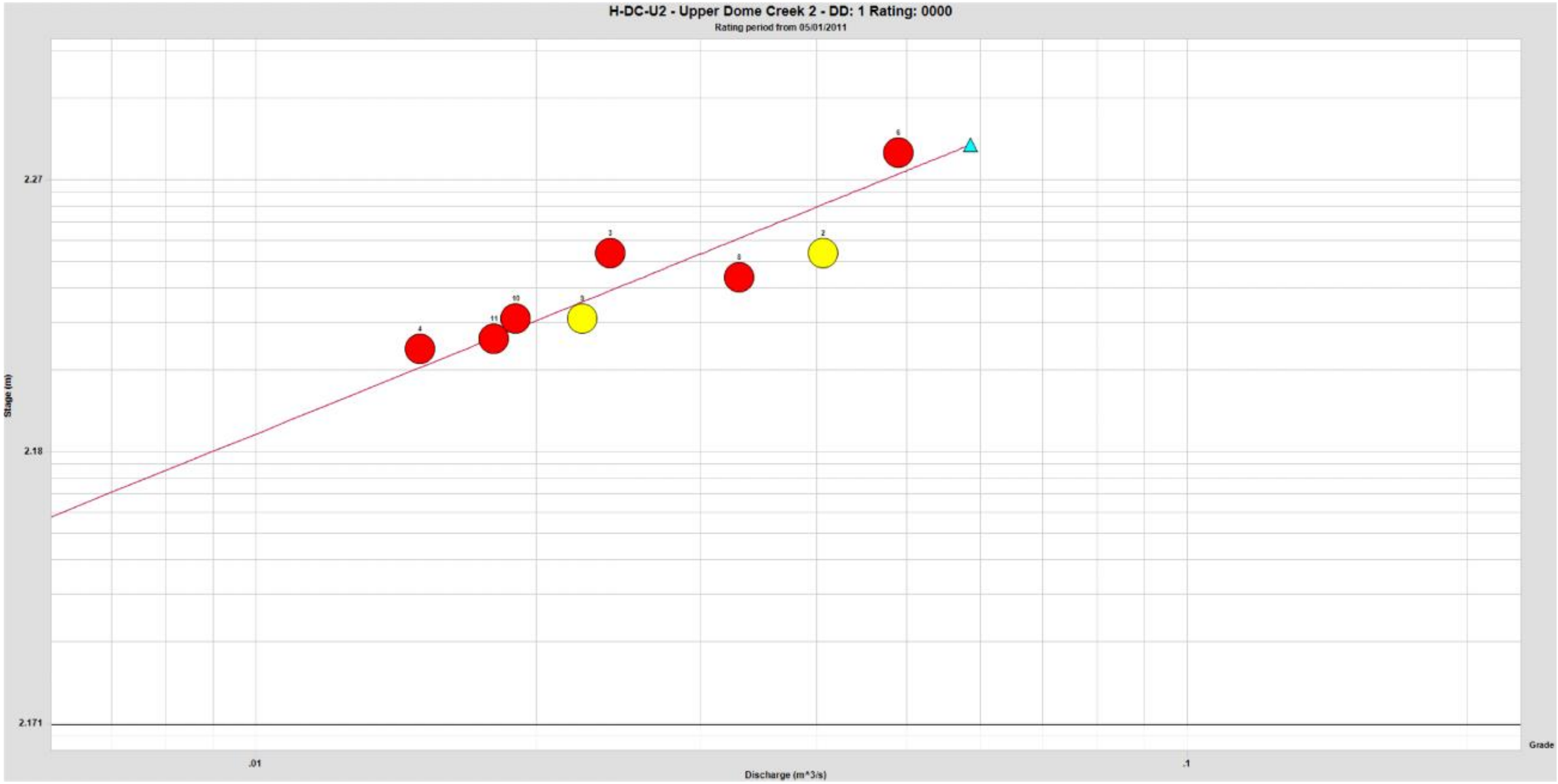
B 5 - Pony Creek Hydrographs (H-PC-U, H-PC-DSP)



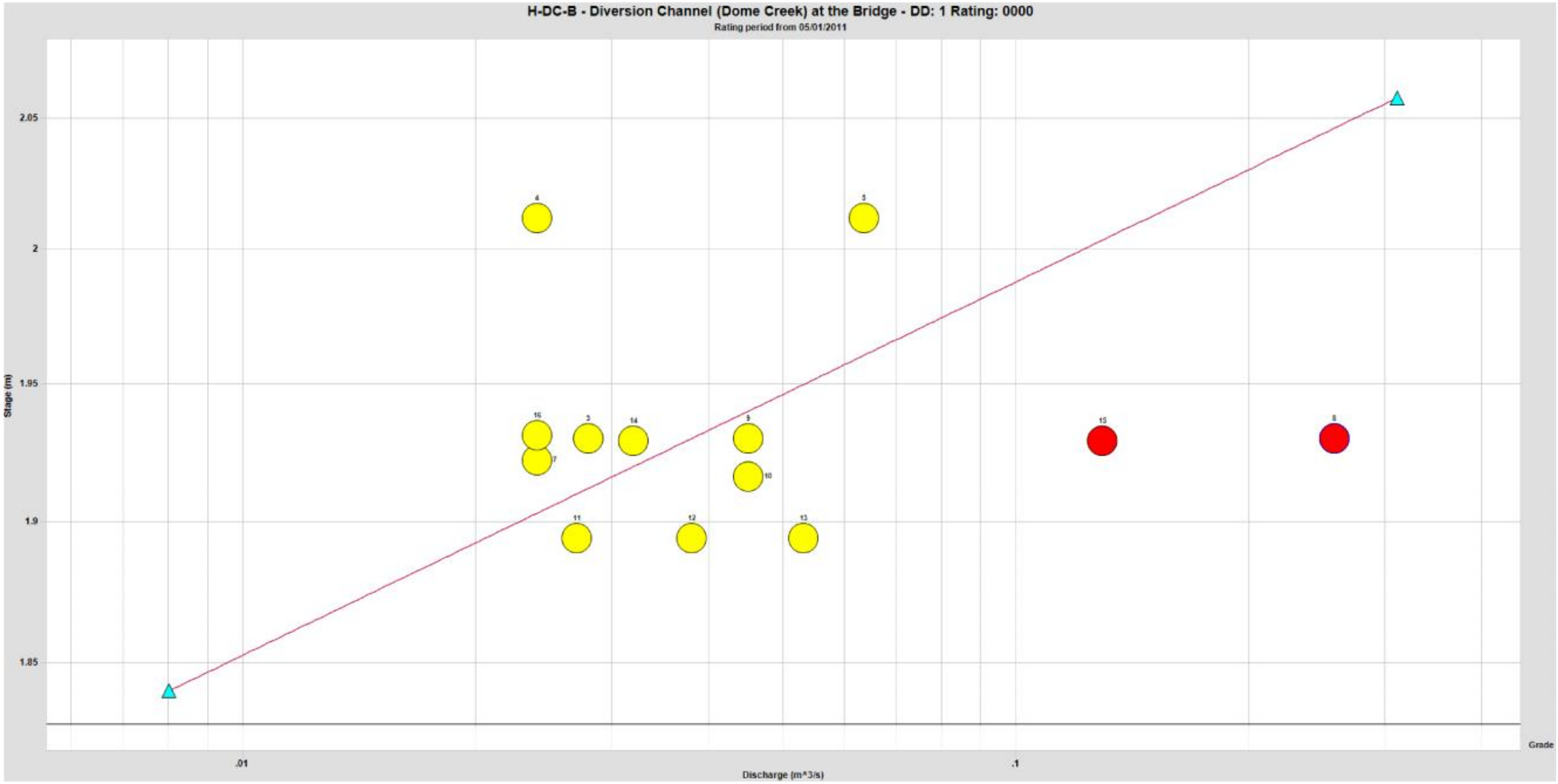
B 6 - Upper Dome Creek Hydrograph (H-DX+105, H-D1)



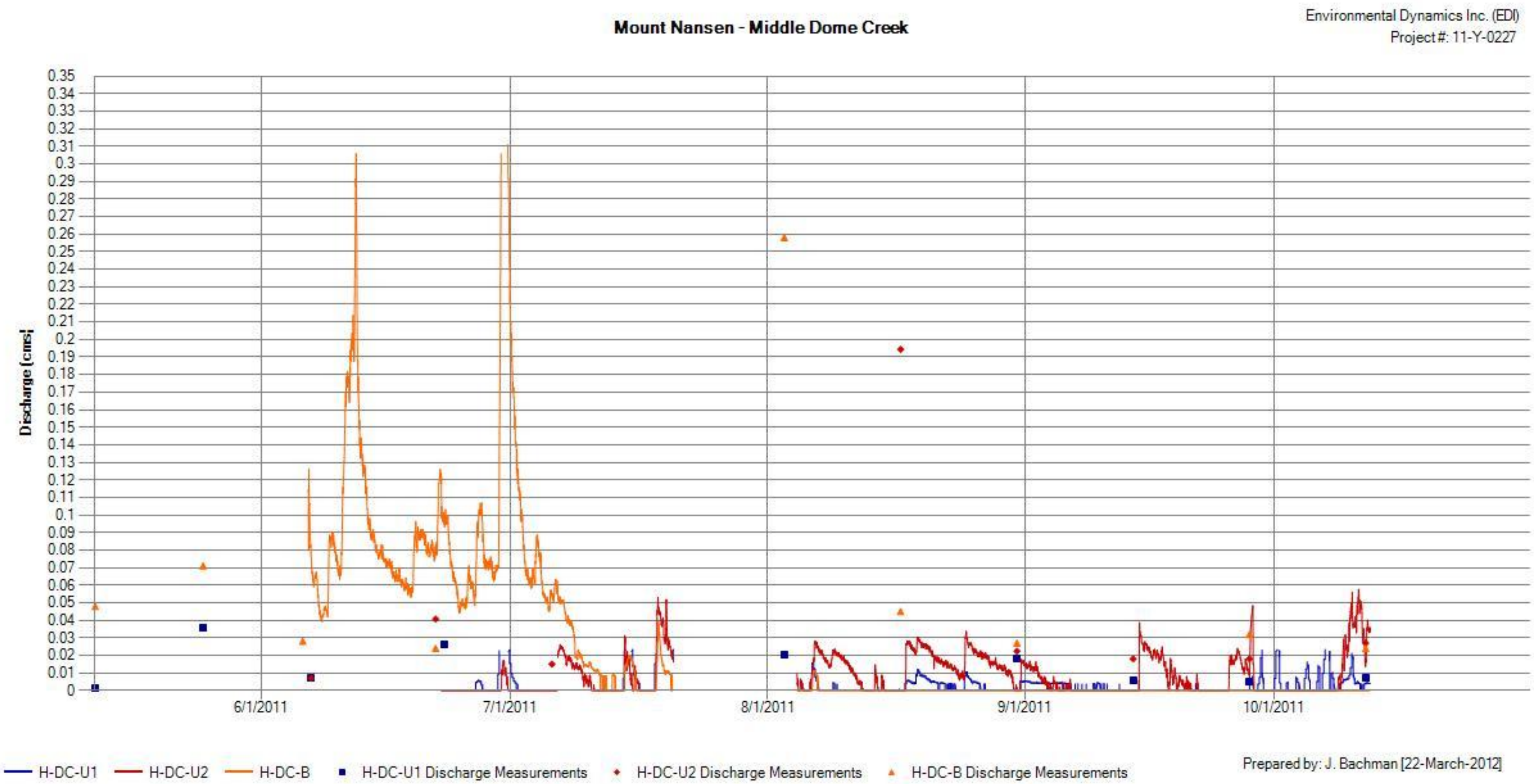
B 7 - Upper Dome Creek 1 Rating Curve (H-DC-U1)



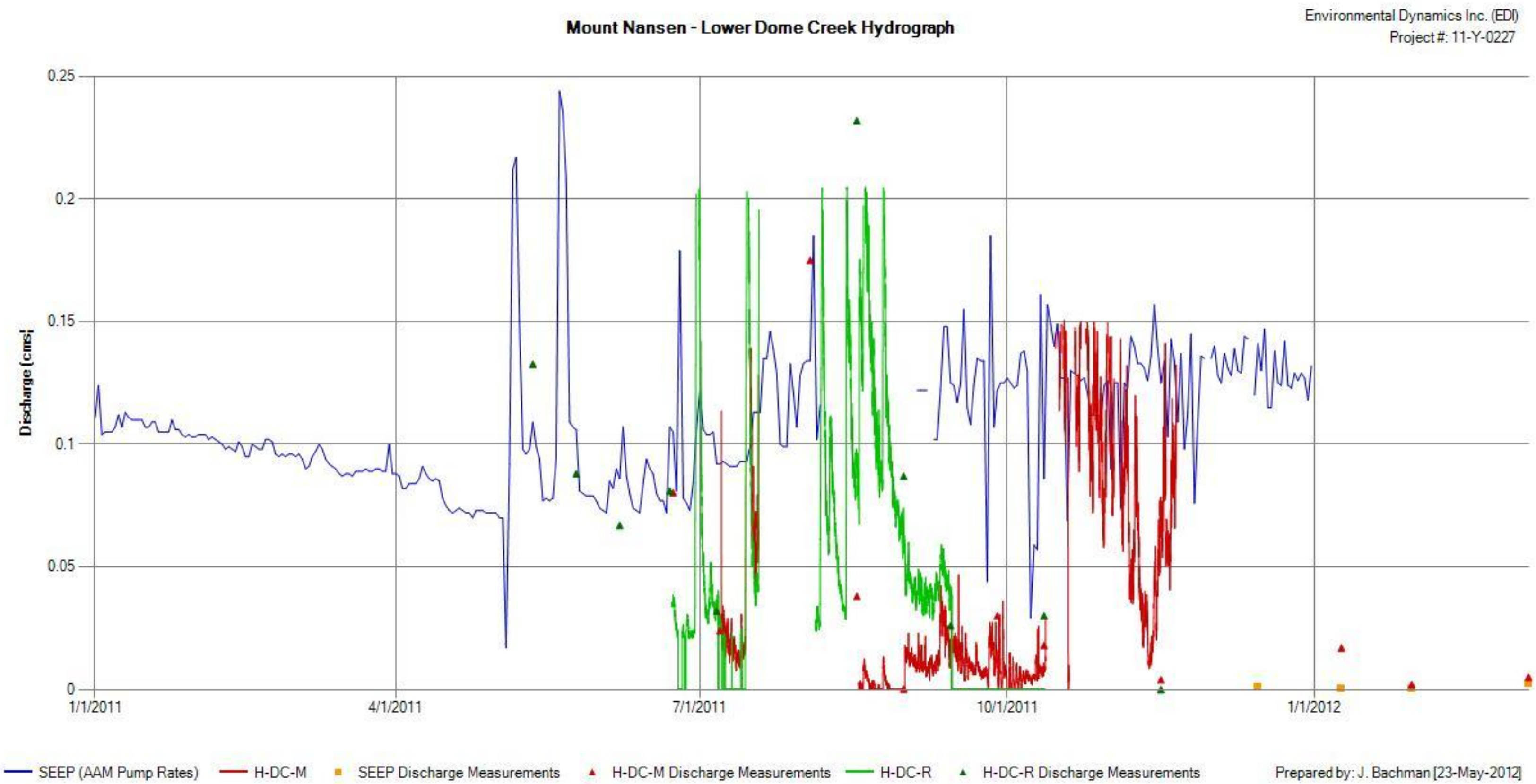
B 8 - Upper Dome Creek 2 Rating Curve (H-DC-U2)



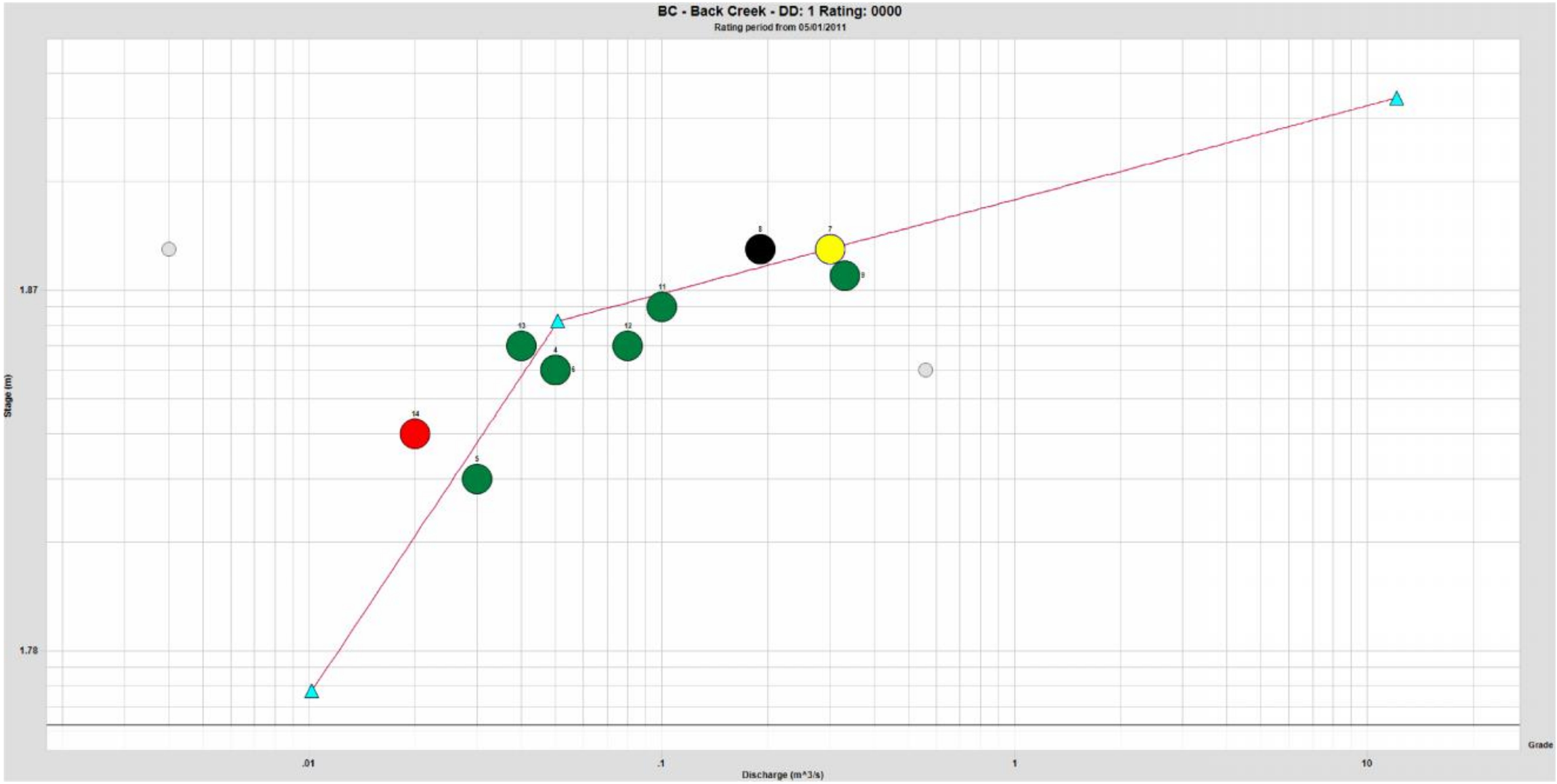
B 9 - Diversion Channel at the Bridge Rating Curve (H-DC-B)



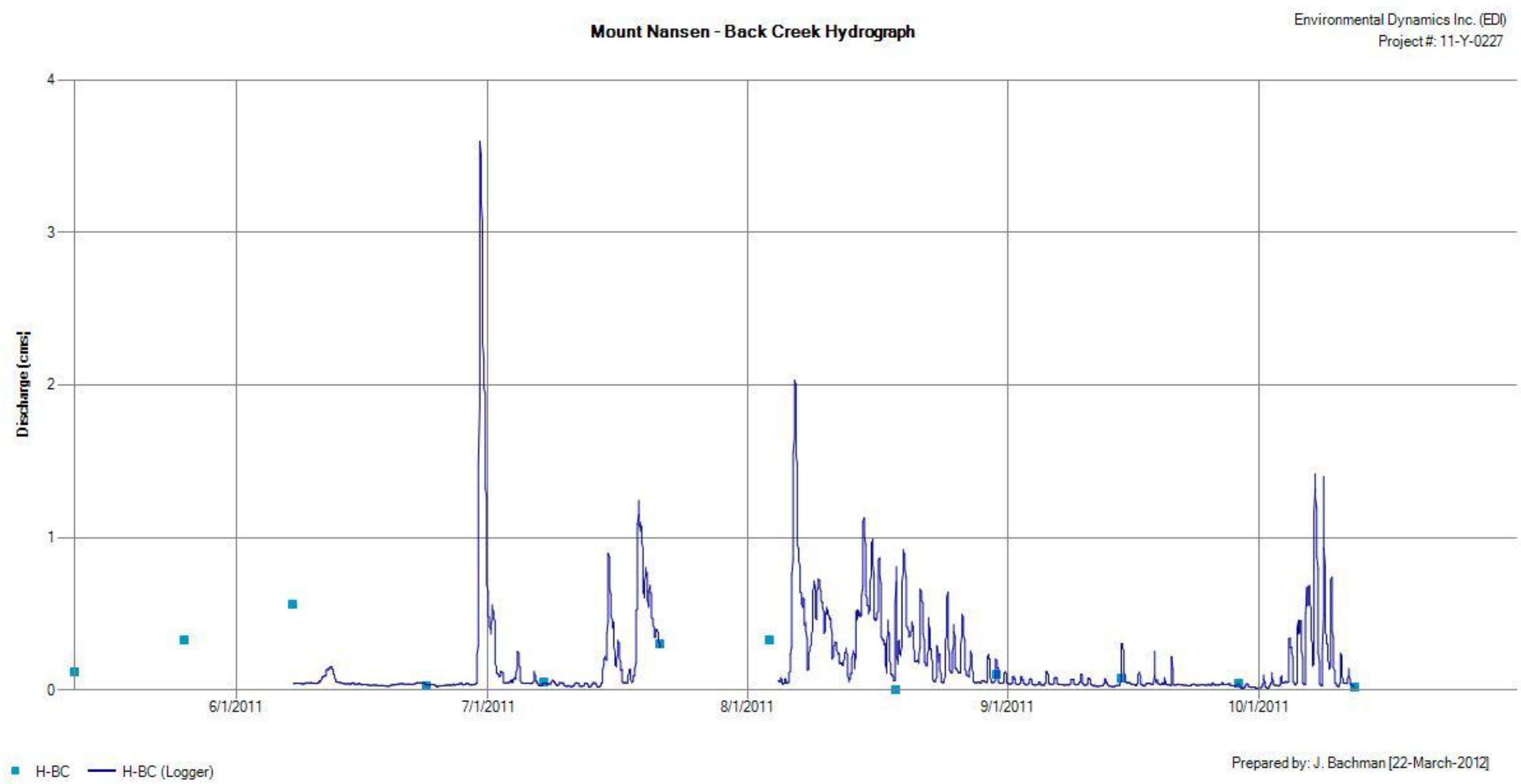
B 10 – Mid-Dome Creek Hydrographs (H-DC-U1, H-DC-U2, H-DC-B)



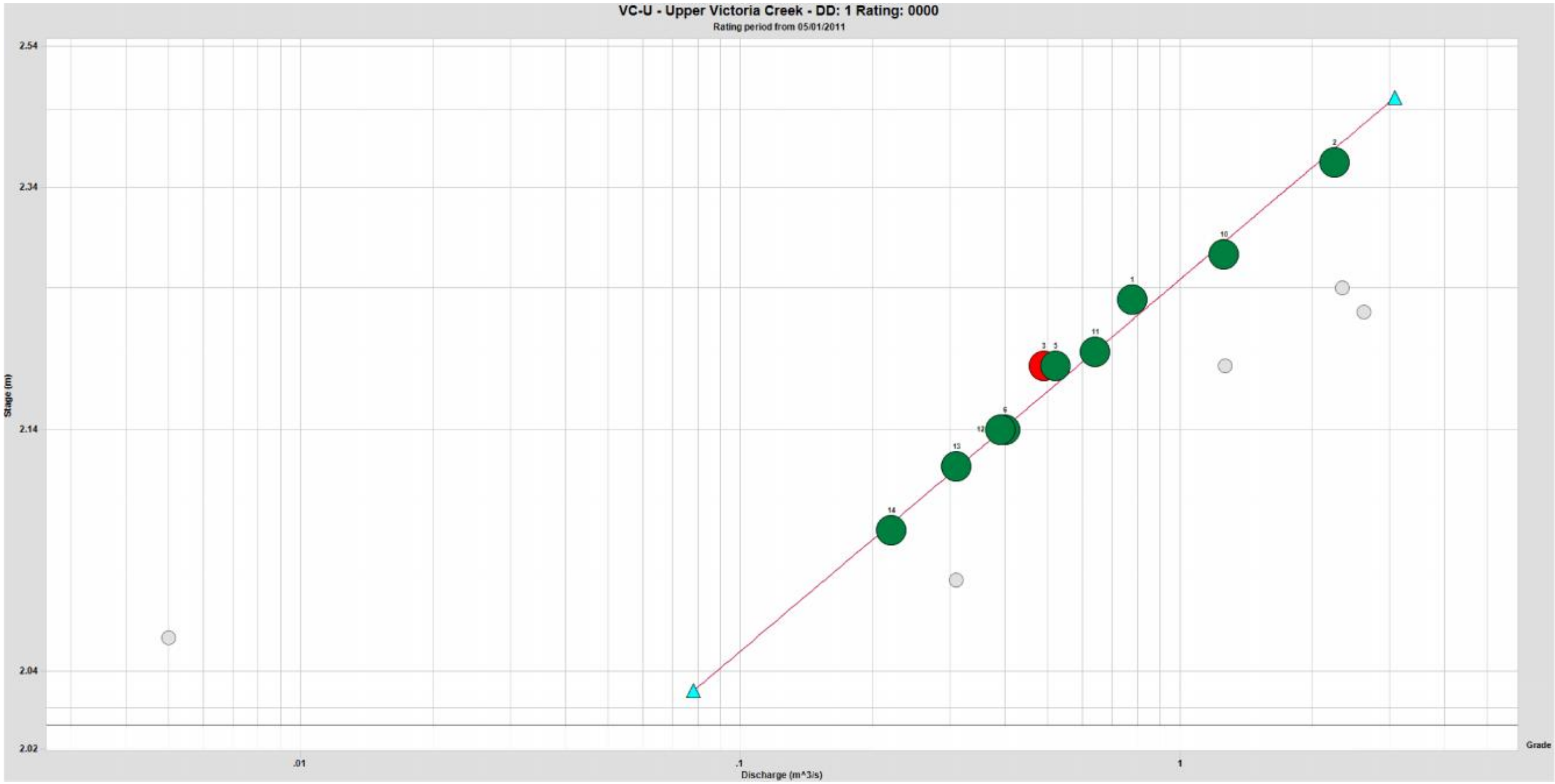
B 11 - Lower Dome Creek Hydrograph (H-SEEP, H-DC-M, H-DC-R).



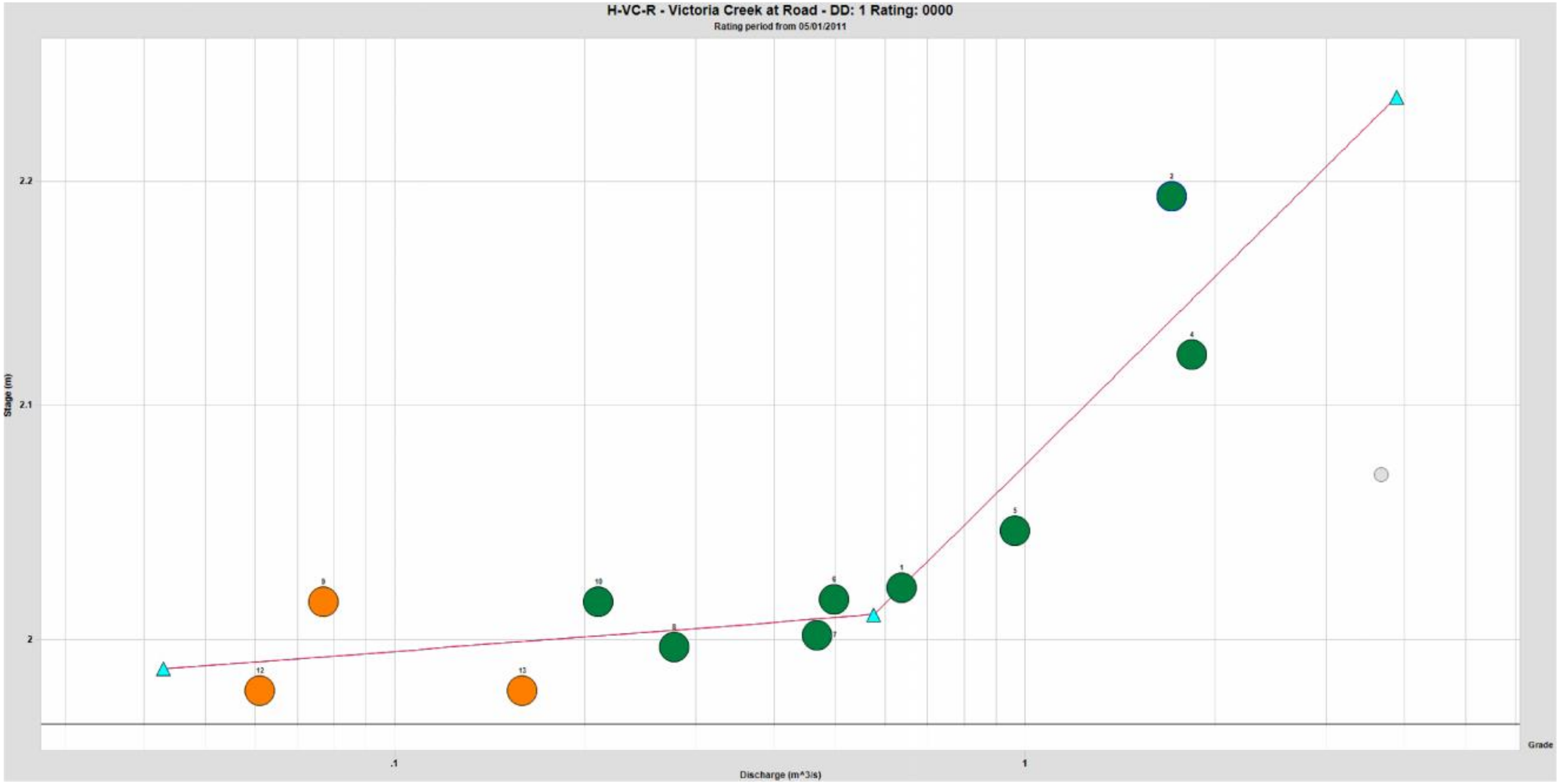
B 12. Back Creek Rating Curve



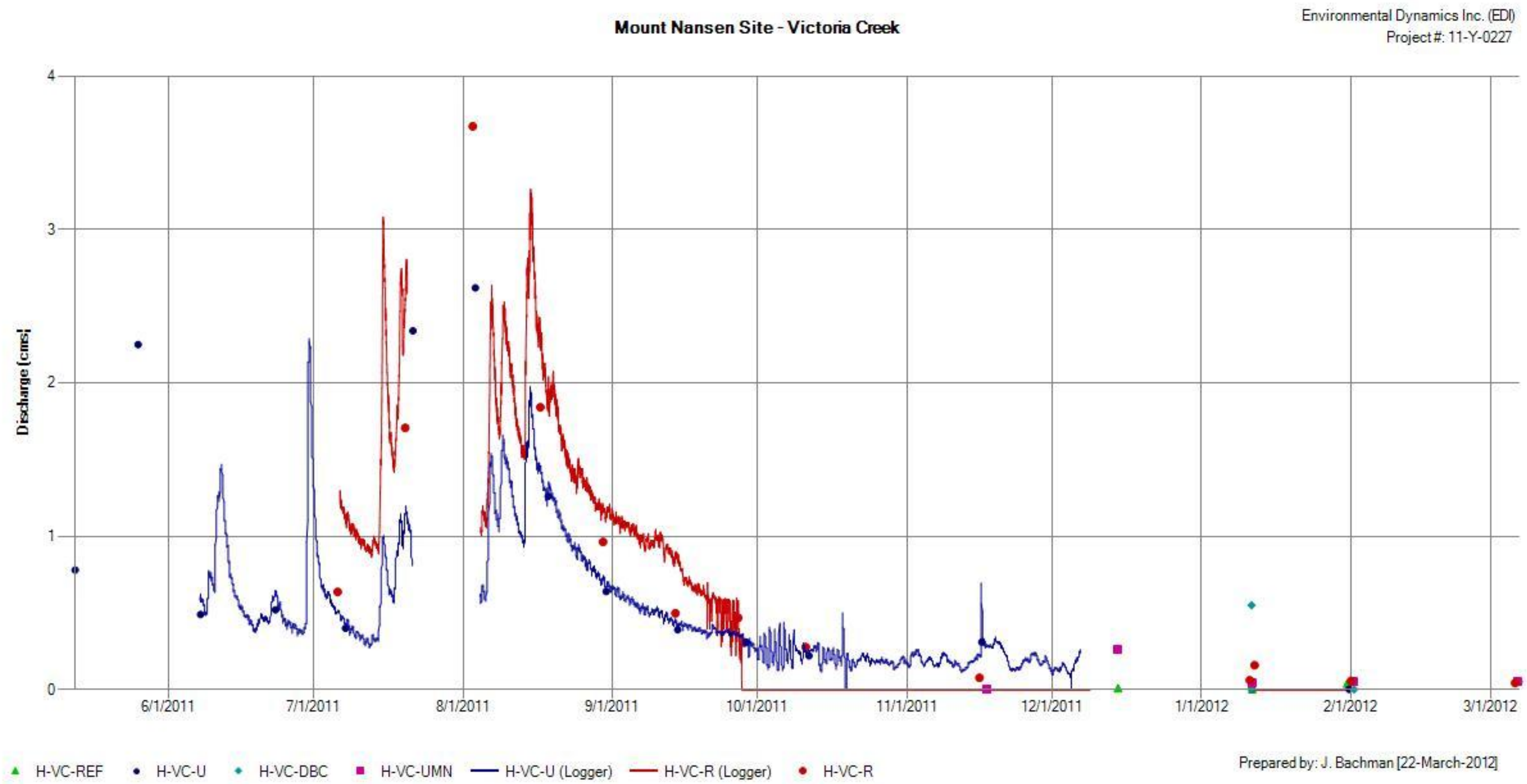
B 13 - Back Creek Hydrograph (H-BC)



B 14. Upper Victoria Creek Rating Curve (H-VC-U)



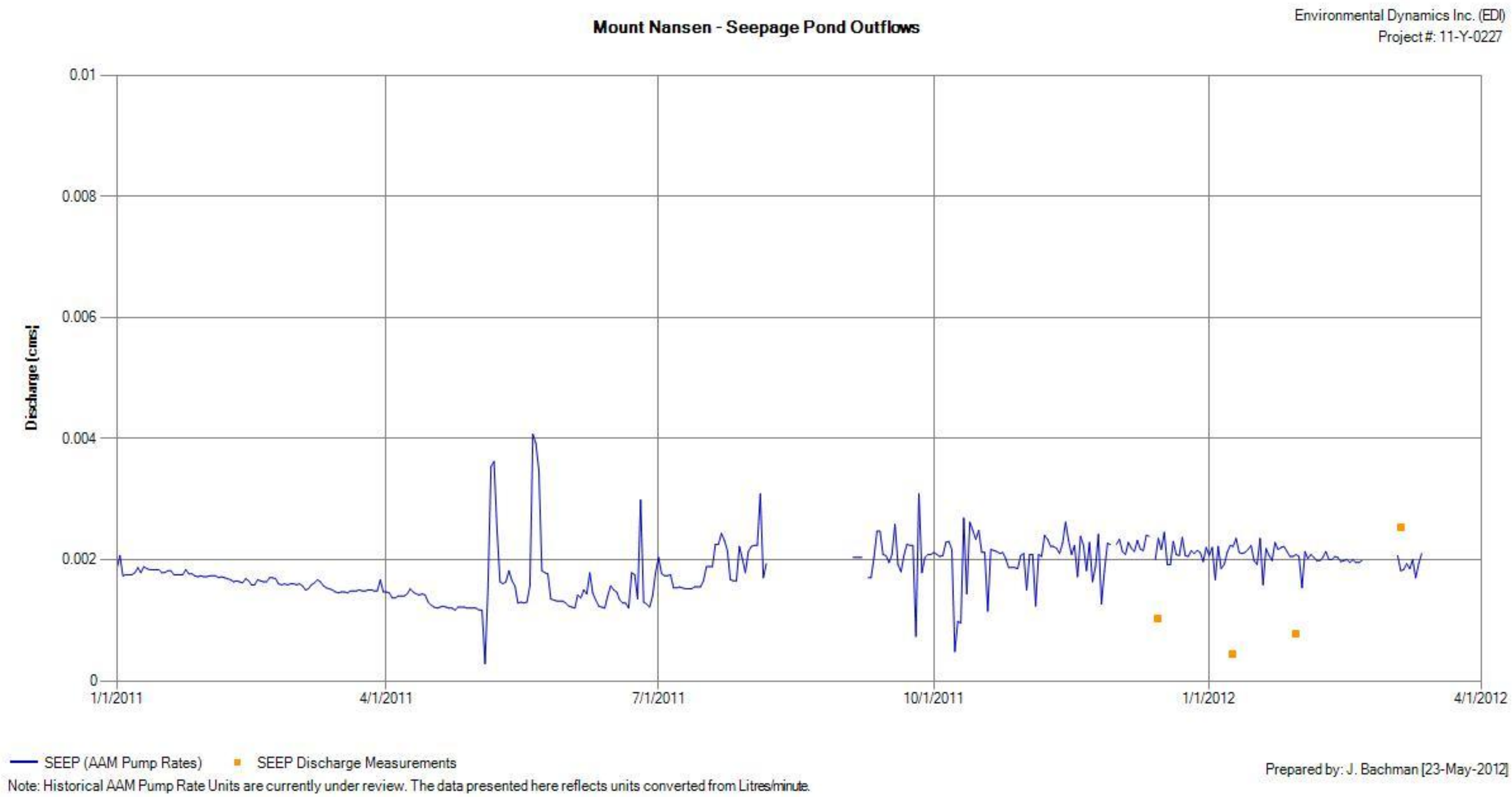
B 15. Victoria Creek at the Road Rating Curve (H-VC-R)



B 16 – Victoria Creek Hydrographs (H-VC-REF, H-VC-U, H-VC-DBC, H-VC-UMN, H-VC-R)

APPENDIX C 2011/2012 HYDROMETRIC MONITORING DATABASE (MS ACCESS)

APPENDIX D SEEPAGE POND DISCHARGE SUMMARY



D1. Seepage Pond Pump Rates and Outflow Pipe Discharge Measurement Plot

* Note: The units of the Seepage Pond Pump Rate are currently under review by AAM. Pump rates reported here have been converted from litres per minute (as per the historical records) and are considered preliminary until the units are validated.

D2. Seepage Pond Pump Rates and Outflow Pipe Discharge Measurement Table

Date	Pump Rate (old pump) (m^3/s)*	Volumetric Measurement (m^3/s)	Difference (Pump - Volumetric) (m^3/s)	% Difference from Volumetric
12/15/2011	0.0024	0.0010	0.0013	131%
1/9/2012	0.0022	0.0004	0.0018	412%
1/30/2012	0.0021	0.0008	0.0013	171%
3/5/2012	0.0018	0.0025	-0.0007	-28%

Date	Pump Rate (old pump) (l/s)*	Volumetric Measurement (l/s)	Difference (Pump - Volumetric) (l/s)	% Difference from Volumetric
12/15/2011	2.35	1.02	1.34	131%
1/9/2012	2.22	0.43	1.79	412%
1/30/2012	2.09	0.77	1.32	171%
3/5/2012	1.82	2.53	-0.71	-28%

* Note: The units of the Seepage Pond Pump Rate are currently under review by AAM. Pump rates reported here have been converted from litres per minute (as per the historical records) and are considered preliminary until the units are validated.