NPDES Field Studies Report – SD033

Prepared for
Cliffs Erie L.L.C. and
PolyMet Mining Inc

September 2011

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1.0 Introduction

1.1 Background

The northern portion of the former LTV Steel Mining Company (LTVSMC) Mining Area 5 discharges water to the Embarrass River watershed. The general site layout is shown on Figure 1-1. The discharge is administered under Minnesota Pollution Control Agency (MPCA) NPDES Permit MN0042536 (Permit). Discharge from the northern portion of Area 5 forms the headwaters of Spring Mine Creek, which flows north (via surface discharge station SD033) to the Embarrass River. The Permit is currently held by Cliffs Erie L.L.C. (CE). However, PolyMet Mining Inc. (PolyMet) is collaborating with CE on the reissuance of the Permit. A key aspect of the Permit renewal process will be the implementation of corrective actions defined in the April 6, 2010 Consent Decree between MPCA and CE. The work required under the Consent Decree is designed to address selected chemical parameters that have had elevated concentrations in the SD033 discharge. A one-year program of field study investigations (ending on June 16, 2011) was conducted at the site, following the scope of work described in the May 6, 2010 *NPDES Field Studies Plan – SD033* (approved by the MPCA on June 16, 2010). This Field Studies Report provides a summary of the results from the individual field studies that were conducted for SD033 under the Consent Decree.

In addition to this Field Studies Plan, the Consent Decree requires the preparation of a Short Term Mitigation Evaluation Plan for SD033. The objectives of the Short Term Mitigation Evaluation Plan are to investigate existing methods and technologies to partially or completely mitigate the elevated sulfate and parameters of concern. Emerging or unproven technologies for sulfate mitigation/treatment will also be studied. The Short Term Mitigation Evaluation Plan is intended to address and mitigate the existing elevated concentrations of sulfates and the parameters of concern in SD033 to the extent feasible and practical during the period that field studies are being conducted to determine an appropriate long-term mitigation strategy.

For the purposes of this document, ‘parameters of concern’ are total dissolved solids, bicarbonates, total hardness (Ca + Mg as $CaCO_3$) and specific conductivity in SD033.

1.2 Overall Objectives

The purpose of the Field Studies for Outfall SD033 was to develop an understanding of the potential sources and impacts of the elevated concentrations of sulfate and parameters of concern and to collect adequate data to support either the development of recommendations for long-term mitigation alternatives or the development of site specific standards. The Field Studies collected data to assess:

- Surface and groundwater flow patterns in the Area 5NE and 5NW Pits and adjacent stockpiles
- The likely source or sources of elevated sulfate in SD033
- The impact of the elevated sulfate in SD033 on receiving waters supporting the production of wild rice
- The impact of the elevated sulfate in SD033 on methylmercury concentrations in receiving waters
- The impact of elevated parameters of concern on the water quality and aquatic life (fish and macroinvertebrates) of receiving waters.

2.0 Historical Data Compilation

2.1 Objectives

The primary objective of the historical data compilation was to: identify, compile, and review readily-available information regarding the Area 5 site setting, water quality, hydrology, geology, and stockpile configuration. This activity was substantially completed in support of determining the detailed scope of the individual studies described in the *NPDES Field Studies Plan – SD033*. This review of available information allowed for a more complete understanding of the site prior to designing the field studies.

2.2 Scope / Sources of Information

The following general sources of information were compiled and reviewed with a focus on sulfate and parameters of concern. Specific sources of information reviewed for the individual studies were described in detail in the *NPDES Field Studies Plan – SD033*:

- Permit monitoring data (water quality – sulfate, parameters of concern, and flow)
- Other relevant data from field studies at Area 5 (pit water levels, seep reconnaissance, preliminary pit profiling)
- Data regarding the rock type in the pits and stockpiles at Area 5
- Data from completed and ongoing studies related to the environmental review for PolyMet's NorthMet Project
- Published reports and maps regarding local geology, hydrogeology, and water quality

3.0 Hydrologic Investigation

3.1 Background

A preliminary evaluation of the Area 5NE Pits and Area 5NW Pits hydrology was conducted by John Adams (Minnesota Department of Natural Resources (MDNR)), Mike Liljegren (MDNR) and Tina Pint (Barr Engineering) in November 2007. This evaluation was based on limited available data and field surveys. The evaluation was focused on identifying possible flow paths for water leaving the Area 5NW Pit, including: groundwater outflow through bedrock, groundwater outflow through surficial deposits, and outflow through stockpiles to SD033. Note that the main objective of this work was not to complete a water balance at SD033, but was instead intended to evaluate potential flow paths for water leaving the Area 5NW Pit.

Three out of the four recommendations for additional investigations suggested in the November 2007 evaluation were implemented, but a follow-up hydrologic assessment was not completed and confirmation of some key assumptions was still pending at the outset of this study. One such assumption that needed validation is whether the mean value of flows measured at SD033 indeed represents the average flow for the SD033 watershed; the corresponding mean value of 21 inches for annual runoff was used to imply that seepage from the Area 5NE Pit was primarily toward the Area 5NW Pit (see Figure 1).

For the hydrologic investigation described in this report, the conceptual representation of flow developed in the November 2007 evaluation was used as a starting point to build a more comprehensive understanding of surface and groundwater flow rates and directions (including seasonal and long-term variations) in the Area 5NE and Area 5NW Pits and surrounding stockpiles. This improved understanding of the site hydrology helps to determine the likely source or sources of elevated sulfate in SD033 (see Section 4.0) and to aid in the evaluation of impacts of the elevated sulfate and parameters of concern in SD033 on the water quality and aquatic life (fish and macroinvertebrates) of Spring Mine Creek (see Section 5.0).

3.2 Objectives

The primary objective of the Hydrologic Sampling Plan (contained in the May 6, 2010 *NPDES Field Studies Plan – SD033*, approved by the MPCA on June 16, 2010) was to define the sources, flow directions, and flow volumes of groundwater and surface water that is reaching SD033. The general approach to meeting this objective was to complete a water balance for the Area 5NE and 5NW Pits, including determination of percentage contribution of surface and ground water flows from different mine features to flows at SD033. The results from the implementation of the Hydrologic Sampling Plan are used in conjunction with the results from the Water Quality Sampling Plan (see Section 4.0) to define the sources and flow paths of the sulfate load measured at SD033. There is a considerable amount of overlap between the objectives and methods of the Hydrologic Sampling Plan and the Water Quality Sampling Plan, and the subsequent physical investigation work was integrated accordingly.

3.3 Scope and Methods

The general scope of the Hydrologic Sampling Plan consisted of three phases of work that have been completed in order to meet the objective outlined above. The first phase was a desktop study used to define the necessary scope of work for the second phase. The second phase was the field investigation. The third phase consisted of using the data collected during the first two phases to finalize the work started in the first phase.

3.3.1 Phase I

The initial phase of the Hydrologic Sampling Plan included a review of available data and previous studies relevant to the study area. Available data included permit monitoring records, pit water level records, previous seep and pit profile studies, available stockpile information, previous water balance studies, and published geologic, hydrologic and meteorological data.

The value of 21 inches for annual runoff that was used to represent average flow conditions at SD033 for the historical period of record (2001 – present) suggests that flow measurements may have been biased toward higher than average flow conditions. Typical watershed yield in the Embarrass and Partridge River watersheds is on the order of 10 inches of runoff per year. However, it was considered possible that the higher than expected runoff value could indicate that an area larger than the surface watershed is contributing flow to the pits and thus to SD033. The preliminary water balance, based on the historical flow record, indicated that this may be the case and that there could be a significant groundwater contribution to flow into the pits and SD033. This possibility is examined in the refined water balance described in Phase III.

3.3.1.1 Preliminary Water Balance

The preliminary water balance proposed for Phase I of this study was prepared prior to the initiation of field activities in April 2010. The available data used for the water balance included:

- Observed water levels in the Area 5NE and Area 5NW Pits from May 2003 through August 2008 (pit water level data for late 2008 and 2009 were not available at the time the preliminary water balance was prepared)

- Observed flow at SD033 from February 2005 through August 2008 (flow data from September 2008 through December 2009 were not included in the analysis due to the lack of corresponding pit water level data)
- Observed monthly precipitation at Embarrass
- Calculated open-water evaporation (Thornthwaite method, scaled to 21.1 inches per year), based on the mean monthly temperature at Embarrass
- Estimated elevation-volume and elevation-area curves for the Area 5NE and Area 5NW Pits, based on above-water 5-foot elevation contours
- Estimated surface watersheds for the Area 5NE and Area 5NW Pits, as well as for Spring Mine Lake, based on watersheds delineated by MDNR and 5-foot elevation contours
- Land cover data, including information on the extents of existing mine features from MDNR (2008), the National Wetlands Inventory, and the National Land Cover Dataset (2001)

Because it was unclear from the site topography whether Spring Mine Lake contributes surface flow to the Area 5NW Pit (and consequently to SD033), the Spring Mine Lake watershed was included in the preliminary water balance. However, this water balance showed that the possible contribution from Spring Mine Lake is less than 8% of the total outflow at SD033. The preliminary water balance showed that the large majority of the flow at SD033 appears to originate in the Area 5NE Pit (31% of the total) or the Area 5NW Pit (48% of the total).

The preliminary water balance indicated that there remained significant uncertainty with regards to the magnitude of groundwater contributions to the Area 5NE and Area 5NW Pits. A total constant (i.e., not dependent on precipitation) groundwater contribution of 500 gallons per minute (gpm) was estimated from this analysis (approximately 67 acre-ft/month); this accounted for 45% of the total flow at SD033 during the modeled period. This value is larger than would be expected based on the surface watershed of the pits and their position close to the regional bedrock high point, and may indicate that the historic flow record at SD033 is biased high. The preliminary water balance also was not constructed with the goal of determining whether this constant groundwater contribution is from surficial or bedrock groundwater.

3.3.1.2 Site Reconnaissance

In addition to the preliminary water balance discussed above, a site reconnaissance visit was performed on April 6, 2010, prior to the initiation of field data-gathering activities. This site visit indicated that it is unlikely that there is significant surface flow from Spring Mine Lake and its watershed to the Area 5NW Pit. Flowing water was observed leaving the Spring Mine Lake area and entering the LTVSMC Tailings Basin and standing water (no flow) was observed between Spring Mine Lake and the Area 5NW Pit. No obvious channel or route for surface flow was evident from Spring Mine Lake to the abandoned Spring Mine Creek. Additional site visits during the study period also did not show any evidence of surface flow to the Area 5NW Pit.

The site reconnaissance visit also indicated that it is unlikely that there is significant shallow groundwater outflow from the Area 5NE Pit to the south. Very little seepage from the exposed bedrock on the north face of the Area 5SW Pit was observed during the site visit. Additional monitoring at seepage site MS-010 during the study period also did not show significant seepage into the Area 5SW Pit except during a storm event.

These findings of the preliminary water balance and the site reconnaissance visit are reflected in the assumptions of the final water balance, discussed below.

3.3.2 Phase II

The second phase of the Hydrologic Sampling Plan included the collection of field data during the study period of July 2010 to June 2010, as proposed in the Field Studies Plan. This section presents the methods used for collection and analysis of hydrologic data for the Hydrologic Investigation. Also documented are deviations from the work plan set out in the Field Studies Plan.

3.3.2.1 Bathymetric Data Compilation

Pit cross-section data is available in CE's files, and the Field Studies Plan proposed to use this data to develop the bathymetry of the Area 5NE and Area 5NW Pits. However, the available data from CE was found to be incomplete and to not include all of the existing in-pit stockpiles, especially in Pit 5NE. For the purposes of the refined water balance the elevation-volume and elevation-area relationships are only needed with respect to the changes in total pit storage due to changing water levels. Because the water level fluctuations during the study period were minor, no additional bathymetric data were needed for the water balance beyond the above-water contours used for the preliminary water balance.

3.3.2.2 Pit Monitoring Chains

Monitoring chains were installed to measure continuous variations in temperature and specific conductivity in the deepest part of each pit. See Section 4.3.2 for discussion of the monitoring chain installation and data.

3.3.2.3 Seepage Flow Surveys

Estimates of seepage quantity were performed during site water quality sampling. See Section 4.3.1 for the methods and locations for stockpile seepage monitoring.

3.3.2.4 Tracer Studies

The optional tracer studies or installation of additional shallow wells discussed in the Field Studies Plan were not implemented during the study period. The refined water balance indicates that there is not a large unknown quantity of groundwater seepage entering the pits and seepage from the stockpiles has been observed and characterized.

3.3.2.5 Water Level Monitoring

Pit water levels were recorded by CE personnel monthly or biweekly at staff gauges installed in the Area 5NE and Area 5NW Pits from June-December 2010 and from May-July 2011. Water levels in a pool just downstream of SD033 were measured with a continuous sensor from August 2010 through the completion of this study in June 2011. Additional water level monitoring around Area 5 suggested in the Field Studies Plan was not performed, because the results of the field reconnaissance did not identify significant additional sources of water to the pits.

3.3.2.6 Flow Measurements for Rating Curve Development

Physical flow measurements were performed by Barr and/or Northeast Technical Services (NTS) personnel just downstream of SD033 following protocol developed by the United States Geological Survey (USGS). Measurements were performed at the same location on each visit, and care was taken to avoid altering the flow patterns by removal or introduction of obstacles to flow. Flow measurements were performed biweekly during August to October of 2010 and monthly from February 2011 through the completion of this study, with additional measurements at the time of snowmelt in April 2011.

3.3.3 Phase III

The results of the Hydrologic Sampling Plan field studies, in conjunction with the results from the Water Quality Sampling Plan field studies (see Section 4.0), have been used to produce the following work products that are incorporated into the overall field studies summary report:

- A characterization of flow patterns in the vicinity of the Area 5NE and Area 5NW Pits, aiming to help quantify sulfate loads from surface stockpiles, partially-submerged in-pit stockpiles, and pit wall rock to water quality of both mine pits; and

- A refined water balance for the Area 5NE and Area 5NW Pits and the Spring Mine Creek discharge at SD033. The water balance is combined with a mass balance (as described in Section 4.4) to evaluate the relative contribution of mass load in the pits and at SD033 from various sources. The refined water balance is presented in the form of relative (percentage) surface and groundwater flow contribution from different mine features, and it is accompanied by a qualitative discussion of potential seasonal and long term variations.

3.4 Results and Discussion

3.4.1 Measured Flow at SD033

The flow of Spring Mine Creek at SD033, unlike many other streams in the area, has a strong component of "baseflow" or constant, year-round flow. This characteristic is due to the fact that the majority of the SD033 watershed does not contribute water directly to the stream at SD033 but rather flows to the Area 5NE and Area 5NW Pits. Outflow from the Area 5NW Pit follows the relic Spring Mine Creek channel under waste rock stockpiles and surfaces just upstream from SD033. This subsurface flow is relatively constant and does not stop in the winter, allowing the channel just downstream of SD033 to remain ice-free year round.

A continuous water level sensor was placed just downstream of SD033 on August 5, 2010 and remained in operation throughout the study period, including the entire winter period (when other sensors and staff gauges used for the stream investigations needed to be removed). During this period, the measured water level varied by no more than 0.5 feet and did not peak sharply in response to storm events. The measured water levels are shown in Figure 3-1, along with dates on which physical flow measurements were performed.

The physical flow measurements, combined with the sensor-recorded water level, were used to develop two rating curves for flow as a function of water level (see Figure 3-2). The flow measurements taken after the snowmelt high-flow event of April 2011 indicated that the rating curve changed during the high-flow event; the rating curve developed from available data at that time no longer provided a good fit to subsequently-collected data. In order to account for this difference, the physical flow measurements were separated and used to develop two distinct rating curves: the first to apply from August 2010 to March 2011 and the second to apply from April 2011 to the end of the study period. One data point from February 2011 was not used in the development of the rating curves; flows on this date were estimated rather than physically measured due to weather constraints.

The resulting continuous flow record for SD033 is shown in Figure 3-3. Measured flows ranged from a winter low of approximately 0.3 cubic feet per second (cfs) to a high of approximately 6 cfs during April snowmelt. This flow range is consistent with the observed record from 2003 to 2009 in terms of instantaneous flows (see Figure 3-4), but the average monthly flows observed during this study period were lower than the instantaneous flows collected previously (which had been assumed to represent monthly conditions). The average flow during the study period was 0.87 cfs or approximately 8.7 inches of watershed yield per year.

The computed average watershed yield of 8.7 inches per year is more similar to the expected range for the Embarrass River watershed (discussed in Section 3.3.1) than the previously-estimated value of 21 inches per year, which was developed from the instantaneous data collected from 2003 to 2009. It is likely that the relatively few measurements collected during the winter low-flow months during the 2003 to 2009 period caused the previously-estimated average flow to be skewed high. It is also possible that the measurement methods used prior to this study resulted in over-estimation of flows for individual measurement events, especially those with relatively higher flows. Previous velocity measurements were taken inside of the culvert at SD033 and the flow of water leaving the embankment around the culvert was estimated visually; the measurements for the current study were taken at a point slightly downstream where the combined culvert and seepage flows could be precisely measured. This method avoids the potential inaccuracies of visual flow estimation, which could account for the possible high bias of the previous data.

3.4.2 Pit Water Levels and Precipitation

Water levels in the Area 5NW Pit were nearly constant during the study period, varying by only 0.2 feet during the entire year. This is consistent with previous data that shows a variation of no more than 0.4 feet from 2001 to 2011, excluding one data point that appears to be in error (see Figure 3-5). Because the Area 5NW Pit overflows directly to the relic Spring Mine Creek channel year-round (providing the observed baseflow at SD033), the pit water level is not expected to vary significantly except during major flood or drought events (not observed during the period of record). Any extra storm runoff or other inflow simply leaves the pit via SD033.

The Area 5NE Pit typically experiences wider variation in water levels in response to precipitation events than does the 5NW pit, with historic variation of more than six feet. This trend was repeated during the study period, with 5NE water levels varying by 1.4 feet (see Figure 3-5). The outflow from Area 5NE Pit to Area 5NW Pit appears to be via bedrock (rather than a buried channel) and therefore the flow rate from Area 5NE Pit may be more constrained by the lower permeability bedrock. This results in the Area 5NE Pit water levels being more "flashy" than the Area 5NW Pit, with more significant water level increases in the Area 5NE Pit following precipitation and runoff events.

Total precipitation at Embarrass for June 2010 through May 2011 was 27.7 inches. The average annual precipitation for 2001 to 2010 at this site is 27.0 inches, similar to the study period precipitation.

3.4.3 SD033 Water Balance

Based on the observed outflow and pit level data discussed above, the preliminary water balance developed in Phase I of this study has been updated for the entire study period. This section presents the results of the water balance study with respect to the estimated relative contribution of each water source to the flow leaving the system at SD033.

As discussed in Section 3.3.1.2, the initial site reconnaissance did not indicate that significant flow from Spring Mine Lake or nearby areas enters the Area 5NW Pit or flows to SD033. Additional site visits in support of the Water Quality Sampling Plan confirmed this observation, and the continuous flow data (see Section 3.4.1) indicated that there is not a significant additional source of watershed yield beyond that anticipated from the direct watershed to SD033. For the refined water balance, therefore, only the surface watersheds of the Area 5NE and Area 5NW Pits and the areas contributing downstream of the Area 5NW Pit to SD033 were included. The contributing surface watersheds are shown in Figure 3-6.

The water balance was further refined by separating the sources of groundwater to the flooded mine pits. *Shallow groundwater* represents the flow through the unconsolidated surficial material, stockpiles and haul roads into the pits. The watersheds contributing shallow groundwater are different from the surface watersheds because of the differences in surficial topography (impacted by mining activities such as stockpiles) and the bedrock topography (largely unimpacted except by mine pits). The contributing shallow groundwater watersheds are shown in Figure 3-6.

Shallow groundwater is modeled as a constant fraction of the average annual precipitation (i.e., same for the entire water balance), ranging from 5% for the undisturbed vegetated areas to 35% for the rock stockpiles outside of the pits. See Figure 3-7 and Table 3-1 for the land use/land cover of the Area 5 pits and surrounding areas. *Deep groundwater* represents flow through the bedrock into the pits, and is assumed to not vary seasonally.

The water balance was calibrated to the observed outflow at SD033 by adjusting the values assumed for the shallow groundwater and runoff fractions from each land use type and the assumed quantity of deep groundwater. The calibrated fractions for each land use type are shown in Table 3-1. The calibrated value for deep groundwater is a constant 35 gpm into each pit, determined by calibrating to the observed winter baseflow of approximately 0.4 cfs (185 gpm), assumed to represent the sum of shallow and deep groundwater only (no surface runoff).

The resulting water balance for the outflow at SD033 from August 2010 through June 2011 is shown in Figure 3-8 and Table 3-2 in terms of monthly outflows. The observed and modeled outflow for 2005 through 2010 are also shown in Figure 3-8, but were not considered in the calibration due to the apparent high bias of the data discussed in Section 3.4.1. For the entire study period, the total modeled outflow is within 1% of the observed outflow; for each month the modeled outflow is within ± 50% of the observed outflow.

The relative contribution to flow at SD033 from each water source is shown in Figure 3-9 and Table 3-3. Direct contributions to SD033 that do not pass through the Area 5 pits represent 22% of the total flow, with the remainder split between the watersheds of Area 5NE Pit (45%) and Area 5NW Pit (33%). The largest source of water (by land-use type) is shallow groundwater from the stockpiles and haul roads (32% of the total flow at SD033), which has the potential to contribute loading of sulfate and parameters of concern to the discharge. Approximately 25% of the total flow at SD033 originates from direct precipitation on the pits or runoff and shallow groundwater from undisturbed areas, which are expected to be minor sources of loading.

4.0 Water Quality Sampling and Hydrogeochemical Characterization

4.1 Introduction

This section describes the water quality sampling program implemented as part of the Field Studies Plan for addressing the discharge at SD033. The discharge at SD033 and the associated pit lakes that supply water to this discharge are characterized by elevated concentrations of sulfate, total dissolved solids, bicarbonate, total hardness (Ca + Mg as $CaCO_3$) and specific conductivity. These elevated concentrations are a result of dissolution of reactive minerals associated with the mined Biwabik Iron Formation (BIF) contained in stockpiles and exposed mine pit walls. The sulfate and parameters of concern at SD033 are likely derived from one or more of the following potential source areas: 1) mine rock stockpiled in the Area 5NE and Area 5NW Pits (now partially submerged), 2) mine rock stockpiled at the surface in the areas surrounding the Area 5NE and Area 5NW Pits or adjacent to Spring Mine Creek upstream of SD033, and 3) pit wall rock.

A water quality sampling program was initiated to assess the source(s) of the elevated concentrations and to guide recommendations for either site specific standards or long-term source mitigation. The following sections present the objectives, sampling events and methods, results, interpretation, and conclusions for the water quality sampling program. Section 4.4 presents a discussion of the incorporation of the data collected during the water quality sampling program into a refined sulfate mass balance and a hydrogeochemical conceptual model of the site. Lastly, a discussion of sulfate loading from various sources at the site is presented.

4.1.1 Objectives and Scope of Water Quality Sampling Plan

The objectives of the Water Quality Sampling Plan were all related to the overlying objective of quantifying the source(s) and relative contribution of the sulfate loading at SD033. The objectives included:

- Defining the major sources (i.e., sources that make up at least 80% of the total loading), and the current relative contribution of the sulfate load from each of these sources to the load at SD033;
- Determining the quantity of available source material(s)
- Evaluating whether there is a seasonal distribution to the loading that is important to understanding system behavior; and
- Estimating the time period over which the sulfate sources may become depleted.

The detailed scope of the Water Quality Sampling Plan was based on the results from a review of available information and preliminary water and sulfate mass balances. The following work tasks were conducted as part of the Water Quality Sampling field study:

- Water sampling was conducted to fill gaps in the previously-existing data. Based on the data gaps that were identified, the following sampling activities took place:
  - Samples were collected from mine pits, seeps, and streams that flow into SD033;
  - Samples were collected along depth profiles in the Area 5NE and Area 5NW Pits;
  - Water quality information was collected from around the edges of the pits in an effort to ascertain whether there is significant flow into the pits from isolated zones; and
  - Field rinse testing of several samples of exposed wall rock was conducted to assess potential sulfate loading from runoff to the pits.

4.1.2 Geology and Physical Setting

Mining and Geology

The BIF is subdivided into four main members: Upper Slaty, Upper Cherty, Lower Slaty, and Lower Cherty (Figure 4-1). The Area 5N pits were mined by Erie Mining Company and LTVSMC from 1976 to 1988. During this period, Lower Cherty ore was removed for processing, and stripping took place in the unconsolidated overburden (mostly till) and the Lower Slaty. These materials were placed in stockpiles adjacent to and within the pit limits (Figure 4-2). Published company production records document a total of 36 million tons of crude taconite ore were mined from these pits. Figure 4-3 depicts the stockpile ages for stockpiles associated with the Area 5N pits.

The Area 5S pits were mined from 1987 to 1995. The ore zone in these pits is mainly located in the Upper Cherty member, with stripping of the unconsolidated overburden and the Upper Slaty iron formation. A total of 25 million tons of crude taconite ore were mined from these pits.

The generalized stratigraphic column for the Aurora area developed by LTVSMC specifically indicates the presence of finely disseminated pyrite and pyrite in fracture fillings in the Lower Slaty member (Figure 4-4). In addition, mineralogical analysis of recently logged drill cores from the LTVSMC property indicated the presence of up to 5 wt.% pyrite disseminated and in veins (Barr, 2010) in the Lower Slaty "Q" submember. Pyrite was less abundant in the Lower Cherty and Upper Cherty than in the Lower Slaty or underlying Virginia Formation, and, where present, was disseminated. Siderite (generalized as $FeCO_3$) was the primary carbonate identified in the mineralogical analysis (Barr, 2010). The regional siderite composition given by French (1968) indicates cation substitution into the siderite structure, and is approximated as $Ca_{0.05}Mg_{0.23}Fe_{0.72}CO_3$. Similarly, the regional ankerite composition is also a mixed cation composition carbonate.

Distribution of Sulfide in Stockpiles

Pyrite occurring predominantly in the Lower Slaty rock is likely widespread across the site stockpiles (Figure 4-2). The history of stockpiling at the site is such that rock was loaded from different mining areas and placed in different stockpiles between 1976 and 1988 (Figure 4-3). Stockpile 5021 was used for the longest period of time (until 1988), while neighboring stockpile 5020 was used only from 1976-1978. Most of the other stockpiles were used for a relatively short period of time between 1977-1981. There is no indication that sulfide-bearing materials were segregated and managed separately during stripping.

The occurrence of sulfide minerals in stockpiles at a different portion of the former LTVSMC property was extensively investigated from 2008-2010 (Barr, 2010). The study took place in Area 6, a mining area located to the south and west of Area 5, but in an area with similar bedrock geology (mined out Lower Cherty, with Lower Slaty stockpiles surrounding and within the pit). The Area 6 study included drilling through and collecting samples from several stockpiles. Rock samples were analyzed for total sulfur, sulfide, sulfate, and carbonate content. The mineralogy and petrology of the rock samples was also characterized, and pore water samples were collected for chemical analysis from within the stockpiles. The results of the study indicated that the stockpiles contained an average of approximately 0.24 wt.% sulfide, mostly as pyrite. The sulfide minerals occurred in disseminated form and in veinlets, and were found throughout the stockpiles. In addition, the study used historical mining records and pit lake chemistry to derive a field-based sulfide oxidation rate for the rock on site, which corresponded well with sulfide oxidation rates based on humidity cell experiments. Although Area 6 is not a perfect hydrologic analogue for Area 5 (e.g. one pit lake versus several, groundwater discharge rather than surface water), the observations from the study are used in building a conceptual model for Area 5, and are further used to corroborate the findings from the SD033 field study.

Hydrology and Water Quality

Figure 4-5 shows the site layout. Surface water at the site flows from Area 5NE Pit to Area 5NW Pit via surface seeps or shallow groundwater. From the Area 5NW Pit, water discharges north toward the trace of former Spring Mine Creek located north of the pit. This discharge flows through the base of several stockpiles, which were placed on top of the Spring Mine Creek channel, and daylights just upstream of the SD033 discharge point. Spring Mine Creek also receives water from surrounding hillsides, some of which have stockpiles on them. Based on the relative permeabilities between the stockpile materials and the underlying till and bedrock, it is believed that infiltration into stockpiles migrates toward the pits as surface flow or near-surface groundwater at the contact with underlying till or bedrock. Bedrock may transmit a small amount of infiltrated water, but due to the low hydraulic conductivity of the underlying bedrock and because flowpaths are very short at the site, most water that infiltrates the stockpiles likely reports to nearby pits within a relatively short period of time (see Section 3 for discussion of infiltration, runoff, and shallow groundwater).

Water chemistry data from SD033 indicate that the discharge is generally dominated by sulfate (often in excess of 1,000 mg/L), along with calcium and magnesium, which contribute to the total alkalinity of the water. By contrast the SD030 discharge flowing out of Area 5SW Pit generally has an order of magnitude less dissolved sulfate (approximately 100 mg/L) and significantly less alkalinity. The Area 5N and Area 5S pits are also separated by a watershed divide (Figure 3-6).

4.2 Methods

This section presents the methods used for collection and analysis of water quality samples and field shake flask leach tests. Any field deviations from the work plan set out in the *NPDES Field Studies Plan – SD033* are also documented.

4.2.1 Water Quality Sampling

Water quality sampling was conducted at a series of monitoring stations that were established during the initial sampling event and revisited during subsequent sampling events. Sampling events were conducted during August, 2010, October, 2010 (this event corresponded with a rainfall event), April-May, 2011 (this series of events took place during the spring thaw event), and June, 2011. Table 4-1 summarizes field observations during these events, and indicates which monitoring stations were sampled and for which parameters during each event. Appendix 4-A contains photos of the sampling sites during each event.

Water quality sampling was conducted according to the surface and groundwater monitoring locations, parameters, and frequencies proposed in the *NPDES Field Studies Plan – SD033*. The majority of the sample collection and analysis was conducted by NTS.

Surface and groundwater sampling was performed following methods designed to minimize the potential for sample contamination. Surface water samples collected for dissolved cations were collected in unpreserved containers and were filtered and preserved (within 48 hours) upon receipt at the laboratory. Groundwater samples to be analyzed for dissolved cations were filtered in the field using an in-line 0.45 um disposable filter. Each sample container was labeled with a unique sampling identification number, placed in a cooler with ice, and submitted to the laboratory for analysis. At each surface water sampling site, sample bottles were filled using a clean sample bottle (transfer container). For stream sites, all water samples were collected facing upstream. Field duplicate samples were collected once per sampling event. Field duplicate samples were submitted to the laboratory as blind or mask samples, providing information for the evaluation of precision for the entire measurement system, including sample acquisition, homogeneity, handling, storage, preparation, and analysis.

Site surface and groundwater samples were collected from monitoring locations shown on Figure 4-5. Samples were sent under chain-of-custody to NTS for chemical analyses for general parameters and cations by standard U.S. Environmental Protection Agency (EPA) methods. The results of the water chemical analyses for surface waters and groundwaters from the vicinity of the site are presented and discussed in Section 4.3.

Pit lake water quality measurements were made throughout the water column in the deepest parts of the Area 5NW and Area 5NE Pits. Field water quality measurements for temperature, dissolved oxygen, pH, and conductivity were collected at 1-meter intervals during two different events (August, 2010 and May, 2011). Additionally, continuous monitoring devices collected temperature and conductivity data in the pits (Appendix 4-1). Finally, pH, conductivity, dissolved oxygen, and temperature were measured at regular increments around the perimeters of the Area 5NW and Area 5NE Pits and the pond south of SD033.

4.2.2 Field Shake Flask Leach Tests

Field leach tests were conducted on site rock samples according to the procedures described in USGS Techniques and Methods 5-D3, *U.S. Geological Survey Field Leach Test for Assessing Water Reactivity and Leaching Potential of Mine Wastes, Solids and Other Geologic and Environmental Materials* (Hageman, 2007). The extraction uses 50 g of rock material in 1 L of deionized water.

The temperature, pH, oxidation-reduction potential, specific conductivity, and dissolved oxygen of the decanted leachate were measured using an YSI 556 Multiprobe System handheld multiparameter field instrument. The field rinse tests followed the USGS procedures and samples were submitted to NTS for analysis using standard EPA methods. The results of these analyses are discussed in Section 4.3.

4.2.3 Deviations from Field Studies Plan

The following list summarizes deviations from the Field Studies Plan:

- Proposed monitoring station MS026 was not visited during any sampling event, after it was discovered to be in the same pit lake basin as MS025. Monitoring stations MS006, MS008, and MS022 were not visited after the August 2010 sampling event. No water (or any low area where water would have accumulated) was found at MS006 and MS008; MS022 was located off of the CE/PolyMet property.

- Monitoring stations MS013-B, MS010-B, MS010-C, and "Seep" were added to the monitoring program after continuous or intermittent flow was discovered at these locations.

- Lab pH was added to the parameter list

- Field alkalinity measurements were not collected after the first two sampling events, except at two locations (MS005 and MS007) where there was discrepancy between the field and lab measure values.

- Trolling data were not collected from the middle basin at the Area 5NE Pit during the May-April sampling event. Due to safety restrictions, trolling data were collected at least 50 feet from the highwall along the southeast shoreline of the pits.

4.3 Results and Discussion

This section presents and discusses the water quality sampling results, including those from surface water sample collection, field shake flask leach tests, and pit lake water quality data collection.

4.3.1 Monitoring Station Water Quality

Monitoring stations were established at surface water locations at the site that may contribute water to the pits or SD033 (Figure 4-5). In addition, several stockpile seeps that flow away from the pits or SD033 were included in the monitoring program, because measurement of water quality at these seeps aids in characterizing the overall water quality of stockpile seepage. Table 4-1 contains a brief description of each of the monitoring stations.

Surface Water and Seeps

Table 4-2 contains the water quality data from the surface water and seep monitoring locations (not including pit lake data, which is discussed below). Sulfate and specific conductivity data for the monitoring locations are shown on Figure 4-6. The major element chemistry and total dissolved solids (TDS) are also shown graphically on Figure 4-7. Generally, actively flowing seeps have the highest TDS and sulfate concentrations. Rainwater runoff sampled at Area 5SW and surface water associated with Spring Mine Lake have the lowest concentrations of TDS and sulfate. Most waters at the site are magnesium-sulfate waters, although the water ponded at the toe of stockpiles 5004 and 5029 has significant sodium and bicarbonate as major ions. Generally, the water chemistry at SD033 remains the same year-around, although the sample collected in April, 2011 had a significant decrease in total dissolved solids (from almost 2,000 mg/L to about 1,000 mgL), probably reflecting freshening during spring snowmelt / runoff.

The data collected over the one year study period indicate conflicting information regarding seasonality. Several seeps and surface water sampling locations freshened during the spring runoff event (generally late April-early May). For example, the lowest sulfate concentrations and specific conductivity measurements observed at MS019 (a seep issuing from stockpile 5020), and MS023 (a seep discharging along the edge of the highwall on the east end of Area 5NE Pit) corresponded to the April sampling event. However, at other seeps (MS014 and MS013), the lowest sulfate concentrations and conductivity measurements corresponded to the October sampling event (although this event also corresponded to a moderate rain event). In general, sulfate concentrations at each individual monitoring station did not fluctuate widely (Table 4-2).

Groundwater

Table 4-2 contains the water quality data from samples collected at Groundwater Wells A and B. Wells A and B are screened as water table wells in surficial unconsolidated materials. Groundwater at Well A has an average sulfate concentration of 447 mg/L, while groundwater from Well B has an average sulfate concentration of 1,008 mg/L. While not located directly underneath waste rock stockpiles, these wells are likely influenced by seepage into the groundwater system from adjacent stockpile 5031, and provide a reference to indicate what shallow groundwater concentrations might potentially be at locations downgradient from the toes of stockpiles. However, concentrations of sulfate in seepage directly from the toes of stockpiles suggests that groundwater directly under stockpile may have significantly higher concentrations of sulfate.

4.3.2 Pit Lake Water Quality

Monitoring stations were established at locations near the shoreline of the Area 5NW pit and the sub-basins of Area 5NE Pit. Pit lake water quality data were also collected at depth from the deepest parts of the Area 5NW and Area 5NE Pits. In addition, field measurements were collected by trolling around the edges of the pits and the pond above SD033. Table 4-3 contains the water quality data from samples collected at the surface and with depth from the Area 5NW and Area 5NE Pits.

Profile Data

Figures 4-8 and 4-9 depict the field parameter data and the analytical sulfate data for the pits. Water samples were collected at depth intervals corresponding to the surface and bottom of the water column, as well as the middle of any stratified zones observed from analysis of the 1-meter interval field data.

Monitoring chains that collect continuous temperature and conductivity data were also installed in the deepest parts of the pits. The 1-meter interval field profile data were used to corroborate the data collected via the monitoring chains. These data are presented and summarized in Appendix 4-B.

In general, the monitoring chain data and the 1-meter field data indicate that the Area 5NE Pit mixes to at least 14 meters, and may mix completely, although the small footprint and the surrounding topography may prevent full mixing during fall and spring turnover. The Area 5NW Pit tends to mix in the upper 13 meters, but remains stratified below a stable chemocline year-around. For reference, the Area 5NE Pit is approximately 28 meters deep at the deepest point, and the Area 5NW Pit is approximately 49 meters deep at the deepest point.

Sulfate concentrations are higher at the bottom of both pits, although the range of sulfate concentrations at Area 5NW Pit (from 970 mg/L to 1,590 mg/L) is greater than the range at Area 5NE Pit (from 1,000 mg/L to 1,410 mg/L).

Near-Shore Water Quality Survey Data

Figures 4-10 and 4-11 show the routes and results of the field parameter measurements collected by trolling around the edges of the pits and the pond above SD033. The surveys were completed in August, 2010 and April, 2011 (with the exception of the pond survey in 2010, which was completed in October). The pH was 8.5 at Area 5NE and Area 5NW Pits during the April 2011 trolling event, and did not fluctuate significantly along the trolling route. During the August, 2010 event, an excursion in temperature, conductivity, and pH was measured in the northeast corner of the Area 5NW Pit. This corresponds to the area where water from the Area 5NE Pit enters the Area 5NW Pit. The remaining data were generally steady along the shoreline of the pit. Excursions along the pit wall in the Area 5NE Pit included one area in the “C” subbasin where water collects in a shallow pool before emptying into the pit, resulting in slightly decreased conductivity and warmer, more oxygenated water, and a similar setting in the “B” subbasin. An excursion in conductivity, DO, and pH were noted at point 9 in the pond south of SD033 during the October, 2010 event, which corresponded to an area where a visible seep discharges into the pond (MS014). However, with the exception of those noted, no other high-magnitude excursions in conductivity, pH, or temperature were apparent that may have indicated delivery into the pits of large amounts of either water having high conductivity/TDS or fresh groundwater.

4.3.3 Waste Rock Runoff Water Quality

Table 4-4 contains the water quality data from leachate samples derived from conducting field leach tests on rock materials collected from along the northern pit wall of Area 5NE Pit (Figure 4-12). Sulfate concentrations in the leachate ranged from 1.1 mg/L to 45.6 mg/L, with an average of 20.9 mg/L. pH values in the leachate ranged from 4.4 to 9.5.

4.4 Sulfate Mass Balance and Site Conceptual Model

The results of the Water Quality Sampling Plan field studies, in conjunction with the results from the Hydrologic Sampling Plan field studies (see Section 3), were used to construct the sulfate mass balance and the site conceptual model, and to capture seasonal changes in the mass balance as necessary.

4.4.1 Refined Sulfate Mass Balance

The purpose of the sulfate mass balance is to provide estimates of the sulfate load reporting from various sources at Area 5 to the total load at SD033, in order to identify and rank potential sources of sulfate loading to SD033. The sulfate mass balance is based on the water balance (discussed in Section 3), by assigning sulfate concentrations to each of the terms included in the water balance. As opposed to the water balance, which is based on a monthly time step (resulting in a transient water balance), the sulfate mass balance is constructed by assigning sulfate concentrations to flow terms that were averaged over the study period. This results in a steady-state sulfate mass balance. The sulfate concentration data at individual seeps support this methodology, as no strong seasonal variation was evident in the data.

The sulfate concentrations assigned to each term in the mass balance are based on sulfate values reported in literature or measured at the site. The following sections describe the input and output terms for the mass balance, and the sensitivity and uncertainty inherent in those terms. Table 4-5 presents all of the sulfate values that were assigned, and justification for their use in the mass balance.

Balance Terms – Pit Wall Runoff

Several submembers of the Biwabik iron formation, including the pyritiferous Q submember, are exposed along the southern and eastern highwalls at Area 5NE Pit. Because the Q submember is exposed just above the water surface in the pit, most of the runoff which falls on the pit walls likely interacts with submember Q before reporting to the pit lake. Along the shallowly sloping northern pit wall, submember Q is not exposed; however, runoff here interacts with blasted rock and tailings, because many of the haul roads in this area are bermed or constructed with these mine materials. Sulfate concentrations from water running off pit walls have not been measured directly at Area 5NE Pit, because runoff does not tend to channelize or pool for significant periods of time during rainfall events. However, the results of the field leach tests conducted on various surficial mine materials at Area 5NE (including stockpiled rock and haul road materials, including mine tailing) are used as a proxy to estimate the concentration of sulfate in pit wall runoff.

Balance Terms – Runoff, Shallow Groundwater, and Groundwater

The runoff component is split into two components, “runoff”, and “shallow groundwater”. Conceptually (and mathematically in the mass balance), the “runoff” component is considered precipitation that does not infiltrate, but reports immediately along the surface flowpath to the adjacent pit lake. The runoff term is generated according to the surface watershed boundaries. The “shallow groundwater” component of runoff is assumed to infiltrate immediately, and to interact with the shallow substrate before reporting along short groundwater flow paths to the adjacent pit lake. The shallow groundwater term is generated according to the bedrock watershed boundaries. See Section 3 for further discussion of the definition of these terms in the water balance.

Because the runoff term is conceptualized (compared to the shallow groundwater term), the runoff component has far less time to interact with stockpiled rock, and thus picks up less load. For the mass balance, the results of the field leach tests conducted on various surficial mine materials at Area 5NE are used to constrain this sulfate term (Table 4-5).

The sulfate concentration of shallow groundwater reporting to the Area 5NE and Area 5NW Pits from areas overlain by stockpiles/haul roads was taken as the average sulfate concentration from MS019, MS020, MS021, and MS023; while the average shallow groundwater sulfate concentration reporting to SD033 is calculated as the average of MS013B and MS014. The statistical description of the sulfate data measured at these seeps is presented in Table 4-6. The division of the seep samples into two groups, yielding two separate average sulfate concentrations for shallow groundwater, is supported by the results of an independent samples t-test (assuming unequal variances) on the two sets of seep data which indicates that the mean sulfate concentration for shallow groundwater reporting to the Area 5NE and Area 5NW Pits (M=2969 mg/L, SD=1457 mg/L) is significantly different that the mean sulfate concentration of the shallow groundwater reporting to SD033 (M=1793 mg/L, SD=1164 mg/L); $t(12)=1.89, p=0.04$.

The uncertainty in the sulfate balance is expected to be dominated by uncertainty in the shallow groundwater sulfate concentration term because: 1) the shallow groundwater represents a major contribution to the total flow into Area 5NW Pit, Area 5NE Pit, and SD033 (as discussed in Section 3); and, 2) the sulfate concentration of the shallow groundwater is relatively poorly constrained. In order to reflect the uncertainty associated with the sulfate balance, the shallow groundwater sulfate concentration is presented as a mean sulfate concentration along with the 95% confidence intervals. This portrays the sampling error associated with sampling the seeps; additional error may be introduced by the assumption that the sulfate concentration of the seepage is identical to that of shallow groundwater. The sulfate balance is bracketed by calculating it three ways: using the mean shallow groundwater sulfate concentration and also using both the plus and minus 95% confidence level concentrations. This results in a mass balance with three scenarios: one in which the "low" shallow groundwater sulfate values are used, one with the mean sulfate values, and one with the "high" sulfate values.

The sulfate concentrations for deep groundwater and for groundwater from undisturbed areas in the mass balance are based on literature values. Cotter et al., 1965 compiled chemical analyses for untreated groundwater in municipal supplies across the Mesabi and Vermillion Iron Range. Based on 24 analyses from wells in the glacial drift aquifer, the average sulfate concentration was 34 mg/L (range 3.8-88 mg/L). The average sulfate concentration in 15 wells in the Biwabik Iron Formation was 23 mg/L (range 2.0-88 mg/L). These concentrations are used in the mass balance as estimates of sulfate in deep groundwater entering the pit lakes, and as the "shallow groundwater" component of the runoff term from undisturbed areas. It is assumed that the "runoff" component from the undisturbed areas does not contribute sulfate (i.e. concentration is set to 0 mg/L), and that the "shallow groundwater" component from the undisturbed areas has sulfate in amounts comparable with average groundwater concentrations in the local drift aquifer (i.e. 34 mg/L).

Mass Balance for Spring Mine Lake

Water flowing from Spring Mine Lake has, in the past, reported to the former Spring Mine Creek channel near stockpile 5031 (Figure 4-2; Table 4-1). If this were to occur, the discharge would eventually contribute to the water balance at SD033. However, observations made during the 2010 field studies program indicated that surface water flowing out from Spring Mine Lake actually flows to the west toward the former LTVSMC tailings basin, and not east toward the former Spring Mine

Creek channel. Therefore, the contribution from Spring Mine Lake is not considered in the sulfate mass balance for SD033.

Mass Balance for Area 5NE

Water flows from Area 5NE Pit into the Area 5NW Pit before reporting to SD033. The water balance for Area 5NE consists of deep groundwater inflow (deep groundwater makes up a relatively small part of the water balance - see Section 3 for a discussion of the estimated deep groundwater to the Area 5NE and Area 5NW Pits), runoff and shallow groundwater from undisturbed areas, runoff and shallow groundwater from stockpiles and haul roads, and runoff from pit walls. These terms are shown as a function of total inflow in Figure 3-9. The water balance terms and associated sulfate concentrations for Area 5NE are presented in Table 4-5. The sulfate loads from the various terms in the balance are shown on Figure 4-13.

The sulfate concentration used for the shallow groundwater component from stockpiles and haul roads was estimated by averaging the sulfate concentrations measured from seeps issuing from stockpiles at Area 5NE. The mass balance for Area 5NE is sensitive to this average concentration, and assigning a higher or lower concentration, such as the 95% confidence interval (as shown on Figure 4-13) affects the modeled sulfate load moving from the Area 5NE Pit to the Area 5NW Pit. The "missing load" for Area 5NE is calculated as the difference between the observed load leaving the pit (which is the product of the measured sulfate concentration and the modeled flow from the water balance) and the modeled load leaving the pit. Hence, this "missing load" term is also sensitive to changes made to the concentration of sulfate in the shallow groundwater from stockpiles and haul roads.

Mass Balance for Area 5NW

The water balance for the Area 5NW Pit consists of inflow from the Area 5NE Pit, deep groundwater inflow, runoff and shallow groundwater from undisturbed areas, runoff and shallow groundwater from stockpiles and haul roads, and runoff from pit walls. These terms are shown as a function of total inflow in Figure 3-9. The water balance terms and associated sulfate concentrations for Area 5NW are presented in Table 4-5. The sulfate loads from the various terms in the balance are shown on Figure 4-13.

No actively flowing seeps were observed reporting to the Area 5NW Pit. Therefore, the sulfate concentration used in the mass balance for the shallow groundwater component from stockpiles and haul roads at Area 5NW was assigned the same average sulfate concentrations measured from seeps issuing from stockpiles at Area 5NE. Inflow from Area 5NE Pit dominates the sulfate load reporting to the Area 5NW Pit (Figure 4-13).

Mass Balance for SD033

The water balance for SD033 consists of inflow from Area 5NW Pit, runoff and shallow groundwater from undisturbed areas, and runoff and shallow groundwater from stockpiles and haul roads. These terms are shown as a function of total inflow in Figure 3-9. The water balance terms and associated sulfate concentrations for SD033 are presented in Table 4-5. The sulfate loads from the various terms in the balance are shown on Figure 4-13.

The sulfate load reporting from the Area 5NW Pit (determined from the Area 5NW Pit water balance) makes up the majority of the load that reports to SD033, making most of the other components of the mass balance relatively insensitive to the sulfate load at SD-033.

Several flowing seeps were observed reporting to the pond south of SD033 (located at the toe of the combined 5001-4003-5025-5024 stockpile). However, these seeps were flowing very slowly, and often did not have enough water to collect analytical samples. Similar to the balances for Areas 5NE and 5NW, the sulfate concentration for the shallow groundwater component from stockpiles and haul roads at SD033 was determined by averaging the sulfate concentrations measured from the seeps discharging to the pond above SD033, and the mean plus the 95% confidence interval is used to construct the mass balance.

4.4.2 Conceptual Model

A conceptual model illustrating flows, sulfate concentrations, and mean sulfate loads reporting to SD033 is presented on Figure 4-14. This model was used in conjunction with estimates of stockpile volumes (based on stockpile geometry and pre-mining elevation contours) to estimate loads from individual stockpiles. For example, the total load reporting to the Area 5NE Pit from stockpiles and haul roads (301 mt/yr) was proportionally distributed among all the stockpiles within the watershed area, based on the volumes of the stockpiles. Proportionally assigning loads in this manner assumes that all stockpile sources have been identified, that all stockpiles generate sulfate load at the same rate, and that loading from haul roads is negligible, compared to loading from stockpiles.

Relative Load Sources

The portions of stockpiles falling within each surface and groundwatershed (by surface area), their volumes within each watershed, and the sulfate load assigned to each of the stockpiles are presented in Table 4-7. In addition, Table 4-8 presents the load allocations as a percent of the total load at

SD033 (total load from SD033 in 2010-2011 was approximately 816 mt/yr). Table 4-9 presents the most significant load sources to SD033, based on the three-tiered mass balance. They are:

- Using the low sulfate values for shallow groundwater from stockpiles and haul roads, the most significant load sources, in order by percentage of the total sulfate load at SD033 are the in-pit "missing" load at Area 5NE (22%), the in-pit "missing" load at Area 5NW (13%), a "missing" load at SD033 (16%), stockpile 5021 (15%), stockpile 5027 (8%), and the combined stockpile 5001-4003-5025-5024 (6%). Together, these sources would make up an estimated 80% of the load at SD033.

- Using the mean sulfate values for the mass balance, the most significant sources are stockpile 5021 (21% of total load), stockpile 5027 (14%), stockpile 5026 (13%), the combined stockpile 5001-4003-5025-5024 (13%), the in-pit sulfate source at Area 5NE (11%), and stockpile 5031 (8%). Together, these sources make up an estimated 80% of the total sulfate load at SD033. The locations of these significant sources (for the mean sulfate value scenario) are shown on Figure 4-15.

- Using the high sulfate values for the mass balance, the most significant sources are stockpile 5021 (27%), stockpile 5026 (21%), stockpile 5027 (20%), and the combined stockpile 5001-4003-5025-5024 (20%). Together, these sources make up an estimated 88% of the total sulfate load at SD033.

The stockpile volumes were used in the same manner to estimate the sulfate load that bypasses SD033 and potentially reports to Spring Mine Creek downstream of SD033. The portions of stockpiles that are located outside of the SD033 watershed were assigned sulfate load, proportionally to the load that was assigned to the portion of the stockpile within the watershed (Table 4-7). The sum of those loads is depicted on the conceptual model (Figure 4-14). Approximately 149 mt/yr (85 mt/ yr for the "low" scenario and 212 mt/yr for the "high" scenario) of sulfate is estimated to report to the north, bypassing SD033. The fate of this sulfate load that flows to the north (e.g., whether it undergoes sulfate reduction in the groundwater system prior to reaching Spring Mine Creek) is unknown.

The in-pit "missing" sulfate load at Area 5NE is significant to the overall load leaving SD033, making up approximately 11% of the total load from SD033, using the mean balance (Table 4-8). This in-pit load is not assigned to a flow term from the water balance, and is the difference between the modeled load leaving Area 5NE (sum of mass balance inputs) and the measured load leaving

Area 5NE (product of the measured concentration leaving the pit and the modeled flow leaving the pit). It is thought to be the result of one or more of the following three sources:

- Underestimation of the sulfate concentration of runoff and shallow groundwater associated with stockpiles and haul roads. The value used in the balance is 2,969 mg/L, based on the average concentrations of stockpile toe seeps observed at Area 5NE; however, concentrations as high as 4,560 mg/L have been measured at one seep. The "missing" load from the Area 5NE Pit disappears when using the 95% confidence interval value of 3,849 mg/L for this term.

- Fluctuation of the water table through in-pit stockpiles 5022 and 5030. Where in-pit stockpiles were investigated at Area 6 (Barr, 2010), field leach testing and solubility calculations indicated the presence of readily soluble sulfate salts (such as jarosite) over an approximately 20-foot interval within the capillary fringe zone within the in-pit stockpiles. The accumulation of these readily soluble salts and the subsequent flushing of the salts due to fluctuating water levels in the pit could provide a mechanism for an in-pit source of sulfate that would not be accounted for in the Area 5NE water balance. Additional support for this mechanism is the measured water level fluctuation that occurs in the Area 5NE Pit (the water level has fluctuated 1.4' in the last year, and 6.3' in the last 5 years, versus 0.2' and 0.4' for Area 5NW Pit, respectively; Figure 3-5).

- Remnant sulfate still remaining in the pit from initial flushing of the stockpiles. This load would have been generated by the initial oxidation of sulfide in the rock during stockpile placement and while the pit was dewatered. When the pit filled with water, the accumulated sulfate would have gone into solution, and stayed in the pit until the pit began overflowing. If load from this mechanism remains in the pit and is being slowly attenuated over time, this load would not be accounted for in the steady state mass balance presented here.

Sulfide Oxidation and Sulfate Depletion

The total volume of Lower Slaty waste rock removed from the Area 5NW and Area 5NE Pits is approximately 1.38 x 10^7 cubic yards, based on the operational cross sections for the pits. This translates to an estimated mass of Lower Slaty waste rock in the Area 5 stockpiles of 2.8 x 10^{10} kg (using a bulk density of 1.84 long tons/cubic yard; J. Tieberg, personal communication, Aug. 12, 2011). If the sulfide content in the Area 5N stockpiles is similar to that in the Area 6 stockpiles (0.24 wt.% sulfide), this indicates a total mass of sulfide of 6.19 x 10^7 kg sulfide. During the 1 year study period, 817 mt of sulfate was delivered from the SD033 discharge point, plus a possible extra 149 mt, which reports to the north, bypassing the SD033 discharge point. This means that about 970 mt was delivered from Area 5N in total. Using this current rate of delivery of sulfate from Area 5, and using a bracket of estimated percent sulfide from 0.24% to 2%, it would take on the order of 100 to 800 years to deplete the sulfide remaining at Area 5 (Table 4-10). This calculation assumes that all sulfide is available for oxidation at the same efficiency as currently, and that sulfate is efficiently flushed from the system. The availability of readily accessible sulfide can be expected to decrease over time, likely resulting in progressively lower sulfate concentrations in the discharge over time, and a corresponding lengthening of time before ultimate depletion of the sulfate source.

4.5 Conclusions and Recommendations

The most significant conclusions from the water quality sampling field study and subsequent sulfate mass balance exercise for the Area 5N pits are as follows:

- The geology and mineralogy of Area 5 are analogous to that at Area 6. Sulfide oxidation and subsequent neutralization by mixed cation carbonates is the source of sulfate and alkalinity in pit water at the Area 6 pit, and is the likely source of these constituents in the SD033 discharge and the Area 5N pits.

- A steady-state mass balance was constructed to allocate load from different parts of the site, based on the water balance presented in Section 3 and available data on sulfate concentrations in Area 5. Although several of the terms in the balance remain uncertain, the mass balance is acceptable for understanding the relative sulfate loads from different sources.

- Rock stockpiles appear to be the primary source for the sulfate load at SD033, with some minor contribution from pit wall exposures of the same materials. Based on the mass balance developed using mean observed concentrations, stockpile 5021 (21% of total load), stockpile 5027 (14%), stockpile 5026 (13%), the combined stockpile 5001-4003-5025-5024 (13%), the in-pit sulfate source at Area 5NE (11%), and stockpile 5031 (8%) are the most significant sources of load to SD033. Together, these sources make up an estimated 80% of the total sulfate load at SD033.

- Based on the current understanding of site hydrology and hydrogeology, some sulfate load bypasses SD033 and could potentially report to Spring Mine Creek downstream of SD033. Its fate along such a transport route is unknown.

- Based on assumptions regarding the sulfide content in the waste rock stockpiles, and the field-derived sulfide oxidation rate calculated for the Area 6 stockpiles, sulfide depletion cannot be expected prior to 100 years from now, and would likely take considerably longer.

The results of the water quality sampling field study and sulfate mass balance exercise lead to the following recommendations for potential follow-up investigation activities:

- Recent water quality study activities performed for the NorthMet Project in the Embarrass River watershed (including Spring Mine Creek) have indicated that sulfate reduction is occurring in the surface waterbodies (i.e., sulfate load tends to decrease in the downstream direction) . In order to better understand the potential need for long-term mitigation at Area 5 (related to sulfate), it is recommended that additional study be conducted into the fate of sulfate that is discharged at SD033. Additional discussion regarding this recommendation is provided in Section 9.

5.0 Stream Investigation

5.1 Background

A one year field study was conducted (July 2010 to June 2011) to characterize and assess the water quality and biological condition of streams directly adjacent and downstream of outfall SD033.

According to Minnesota State Water Rules (Chapter 7050), Spring Mine Creek is an unlisted water and is designated for the protection of aquatic life (Class 2B) as well as other use protections. In general, water quality standards for the protection of aquatic life, which are based upon toxicity tests with very sensitive aquatic organisms (e.g., zooplankton), serve as a conservative means to assess whether a given discharge could possibly have an effect on aquatic life. Therefore, if a given water quality standard is met in the discharge, it can be concluded with confidence that aquatic life is protected.

In addition to water quality standards, regulatory agencies may include Whole Effluent Toxicity (WET) testing requirements in permits to determine whether constituents in a discharge have additive toxicological effects, or if constituents lacking applicable water quality criterion (with respect to aquatic life, e.g., total dissolved solids or sulfate) may be toxic. WET testing was included in this study to follow this regulatory construct and to evaluate whether the groups of constituents originating from SD033 have toxic properties at the concentrations observed.

Biological monitoring, consisting of both aquatic invertebrates and fish, was also conducted to determine the effect of discharges from SD033. Biological monitoring is important because it highlights the true in-stream effect of a given discharge. Biological monitoring also separates the “chemical” effect from the “habitat” effect. For example, if water quality standards are not met, or if WET testing results show some perceptible difference from background, biological monitoring will provide an indication of whether these indicators really result in impacts to the biological communities downstream of the discharge. A habitat evaluation was also conducted as part of this study to quantify the difference in habitat quality between the downstream sites and the control sites.

The goal of this stream investigation was to determine whether the biota in streams downstream of outfall SD033 are “ecologically” better or worse than can be reasonably expected given the available habitat and compared to control streams that are not affected chemically by the discharge.

The overall composition and evaluation of biological communities including fish and macroinvertebrates, can provide valuable information about a site and allow investigators to draw conclusions about the system even without the availability of extrinsic abiotic information. Water chemistry and WET testing results should be viewed as indicators of potential effect, while the invertebrates provide an actual measurement of effect.

Fish also serve as good indicators of ecological health because the taxonomy of fishes is well established; extensive information is available on distributions and life histories of most North American species. Fish populations represent a broad spectrum of community tolerances and respond predictably to changes in abiotic factors such as habitat and water quality. The general public can easily relate to statements about the condition of a particular species or the fish community on the whole. Certain key indicators of severely degraded water quality conditions include measures such as the proportion of fish sampled that have deformities (e.g. eroded fins, lesions or tumors). The species composition in a particular habitat is also indicative of overall water quality conditions. For example, a high proportion of highly tolerant species or omnivorous species, especially in comparison to a reference condition site with minimal disturbance, would suggest poor water quality conditions. By comparison, sites with good water quality conditions and high overall ecological integrity, would contain top carnivorous species (e.g. northern pike, burbot), or a relatively high abundance of insectivorous fish such as perch or minnow species.

Study results provide the initial data to provide the assessment of the potential for effects from SD033 on aquatic life (in a laboratory setting and in the field).

5.2 Objectives

The objectives of the Stream Investigation Plan were to determine whether there is an effect from the existing SD033 discharge on Spring Mine Creek aquatic life (fish and macroinvertebrates).

5.3 Scope and Methods

The detailed scope of the Stream Investigation Plan was defined following the review of historical data and was provided in the MPCA-approved *NPDES Field Studies Plan – SD033*. The scope of work consisted of the following activities:

- **Literature review** on the relationship between dissolved solids/conductivity and aquatic life metrics. A preliminary review has been completed and is summarized in Section 5.4 below.
- **Aquatic life** (fish and macroinvertebrate) monitoring and WET testing at Spring Mine Creek and at a control site.
- **Data** analysis to evaluate the relationship between dissolved constituents and aquatic life (fish and macroinvertebrates) and assess ambient chronic toxicity in Spring Mine Creek. The analysis also includes a comparison of number, diversity, and relative abundance of species in Spring Mine Creek to the control site.

- **Summary report** that provides an evaluation of any impacts to aquatic life and ambient chronic toxicity associated with the SD033 discharge.

5.3.1 Study Sites

A reconnaissance visit to potential stream sites was conducted during the week of April 26, 2010 to identify sites that were suitable for both fish and macroinvertebrate sampling. Following MPCA Reconnaissance Procedures (Standard Operating Procedures; http://www.pca.state.mn.us/water/biomonitoring/bio-streams-fish.html; accessed on May 4, 2010), stream reaches were evaluated for such characteristics as substrate, morphology, and habitat so that selected reaches would have the potential to support macroinvertebrates and fish. Stream reaches included in the Stream Investigation are identified in Figure 5-1.

For Spring Mine Creek, the following sampling locations were identified:

- Macroinvertebrates.
  - Sampling Location #1: near the mouth of Spring Mine Creek, between County Road 615 (also known as Salo Road; sampling site PM12.1) and where Spring Mine Creek intersects with the Embarrass River.
  - Sampling Location #2: headwaters areas, just downstream of SD033 (within 0.25 miles downstream of SD033)
- Fish: one sampling location, near the mouth of Spring Mine Creek, between County Road 615 (also known as Salo Road) and where Spring Mine Creek intersects with the Embarrass River.

Note: the site reconnaissance found no fish habitat in the headwaters area just downstream of SD033.

A control stream was also identified: Bear Creek. The specific stream reach that is suitable for both macroinvertebrate and fish sampling is upstream of SW003 (alternatively known as site PM20). The control reach is approximately 0.1 miles to the west of the intersection of County Road 969 (Forrest Road) and County Road 960 (Hayland Road); approximately 2.4 miles north of the intersection of Bear Creek with State Highway 21 (Figure 5-1).

Macroinvertebrate community sampling was conducted at two separate time periods: spring-time (early June 2011) and late summer/early fall (mid-September 2010).

The fish community was sampled at Lower Spring Mine Creek (PM12.1) and at the control stream, Bear Creek, in July 2010.

Samples for water chemistry data analysis were collected at both Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1), as well as at the control stream, at the same time that macroinvertebrate sampling was conducted.

5.3.2 Physical Habitat Assessment

Each monitoring site was composed of a stream reach that was 150 meters in length. The respective mid-point, upstream and downstream ends of the reach were marked with surveyor tape and coordinates (NAD 83, Zone 15) were collected using a Global Positioning System (GPS) with submeter accuracy to provide consistency for future sampling efforts.

During the fish survey in July 2010, a physical habitat assessment was completed for the control stream and Lower Spring Mine Creek (PM12.1) using the MPCA's *Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites* (Appendix 5-A).

During the macroinvertebrate surveys in June 2011, a physical habitat evaluation was completed at the six monitoring sites, including the control stream, Lower Spring Mine Creek (PM12.1) and Upper Spring Mine Creek (SD033), to assess differences and/or similarities between sites using the *MPCA Stream Habitat Assessment Worksheet*, revised 03-07 (Appendix 5-B). Scores for the worksheet are based on a scale from -5 to 100, with higher numbers representing better quality habitat. This field worksheet provided information about the substrates, channel characteristics, riparian characteristics, and general area information.

The streambed gradient for each monitoring site was determined by reviewing ten-foot topographic contours using the digital raster graphic (DRG) developed by the USGS, which were overlain on the 2010 Farm Services Association (FSA) aerial imagery using ArcMap 9.3. Sinuosity was determined using the 2010 FSA imagery in ArcMap 9.3. The results were used in the MPCA's worksheets to assess the similarities and differences between the physical habitats of the sites.

Stream flow was measured during each biological sampling event at each respective site using a Marsh McBirney Flo-Mate 2000 flow meter.

5.3.3 Water Chemistry

Field measurements for water chemistry parameters were collected at Bear Creek, Upper Spring Mine Creek (SD033), and Lower Spring Mine Creek (PM 12.1) in July 2010, September 2010, October 2010, and June 2011. The parameters, measured using a YSI multiprobe unit, included dissolved oxygen (DO), temperature, pH, oxidation reduction potential (ORP), specific conductance and turbidity. The protocols for the water chemistry assessment presented in the MPCA document

Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites (see Appendix 5-A) were used as a guide for chemical measurement and sampling.

Water samples collected in the field were also processed in the laboratory to measure a suite of physico-chemical variables as well as concentrations of 23 metals (e.g., arsenic, chromium, manganese, zinc), nutrients (e.g., nitrogen) and anions (e.g., sulfate). All measured field and laboratory parameters have been summarized in Table 5-1.

Data Analysis

All water chemistry parameters (except pH) and metal concentration values were $\log_{10}$ (Y+1) transformed to improve homogeneity of variances and normality of the data. A spearman rank correlation matrix was used to identify redundancy among the set of variables. In the case where two variables were significantly correlated, only one of the two variables was chosen for further analysis (e.g. total suspended solids and total dissolved solids; Nitrate+Nitrite and Nitrogen (total kjeldahl)).

To determine if sites Upper Spring Mine Creek (SD033), Lower Spring Mine Creek (PM 12.1) and Bear Creek (control) were significantly different in terms of water chemistry, a randomized block Analysis of Variance (ANOVA) (blocking factor: season) was conducted for each of the measured parameters across sampling periods. For parameters that showed a significant difference among sites, a post-hoc test (Tukey's HSD (Honestly Significant Difference)) was conducted to determine which of the three sites were significantly different from each other.

Water chemistry parameter and concentration values from all biological sampling events were combined (July 26, 2010; September 15-17, 2010; October 26, 2010; June 2011), and the average values were compared to the Minnesota Water Quality Standards criteria for each individual parameter value or concentration (including metal concentrations).

Finally, as a further step in determining the overall surface water quality, a water quality index classification system (developed by Prati, et al. 1971) was used to categorize the sites into one of five different water quality classes, each of which corresponds to an implicit index of pollution (IIP), ranging from 1-8. The five classes correspond to conditions of 'excellent' (index value = 1), 'acceptable' (index value = 2), 'slightly polluted' (index value = 4), 'polluted' (index value = 8) and 'heavily polluted' (index value > 8) (terminology as prescribed by Prati, et al. 1971). The parameters evaluated were – dissolved oxygen, pH, 5-day biological oxygen demand (B.O.D.), chemical oxygen demand (C.O.D.), total suspended solids, ammonia, chlorides, iron and manganese. Parameter values were averaged across the four sampling periods. For each parameter, an explicit mathematical function was used to determine the value of each IIP and its corresponding classification.

5.3.4 Whole Effluent Toxicity (WET) Testing

WET testing is a commonly used technique to determine whether constituents in a discharge have additive toxicological effects, or if constituents lacking applicable water quality criterion (with respect to aquatic life, e.g., bicarbonate) may be toxic. This test is conducted in a controlled laboratory environment whereby test species are exposed to a range of effluent and receiving water mixtures. The test is typically conducted in a 125 milliliter cup and the effluent/receiving water mixtures are replaced daily during the test. The test species can vary, but for the purposes of this study the test species used was *Ceriodaphnia dubia* because it is commonly used and is regarded as one of the most sensitive test species. The test was conducted for seven days (a chronic test), and the testing endpoint was survival and reproduction.

WET testing with *C. dubia* is an indicator of the potential for a particular discharge to cause adverse effects to downstream biota. It is important to understand that WET testing is a "potential" indicator because of the sensitivity of the test and because the test results must be interpreted properly with respect to the severity of the test results. For example, mortality is a strong indicator of a potential effect. If there is mortality associated with a test solution that is only the discharge being evaluated, there is a potential to affect downstream aquatic life on some level, although there remains some uncertainty given the sensitivity of the test. However, if the effluent causes mortality with a highly diluted (e.g., 12 percent discharge and 82 percent receiving water) test solution, it can be interpreted that the discharge has a much greater potential to affect downstream aquatic life.

Reproduction is a more sensitive indicator than mortality because reproduction is much more easily disturbed by discharges that in some cases are not toxic but simply have a chemical composition that *C. dubia* are not accustomed to. The results of the WET tests discussed below must be interpreted with respect to the gradient of results that WET tests can provide.

WET testing was required for two discharge locations, SD033 and SD026 (seep area on the south side of the Tailings Basin). For efficiency and convenience, the water sampling and WET testing for SD033 and SD026 were conducted simultaneously and laboratory reports include the results from both SD033 and SD026.

Water was collected from SD033 and the control stream (Bear Creek) for WET testing on July 26, 2010, October 26, 2010, and June 2, 2011. For each WET test event, water was collected from outfall

SD033 and from a water body that is either unaffected by mining activity, can be considered as background, or the water body was downstream of the mining-affected outfall and hence consisted of a mixture of mining and background waters. For site SD033, the background (control water) water was collected at Bear Creek and at the Embarrass River upstream of the confluence of Spring Mine Creek and the Embarrass River (Site PM12).

For the October 2010 and June 2011 WET tests, water samples downstream of the respective discharge locations were also collected. Samples for WET testing and water chemistry were collected from Lower Spring Mine Creek (PM12.1).

Mixtures of permitted discharge waters (SD033) and background waters were prepared in the WET testing laboratory to evaluate whether there were biologically perceptible differences between the mining water and the background (Bear Creek) and receiving water (Embarrass River for SD033). The degree of difference can be determined using two statistics: (1) the NOEC (no observed effect concentration) is used for mortality to determine the concentration of effluent- receiving water mixtures which cause no mortality effects, and (2) the IC25 (concentration at which there is a 25 percent decrease in young production) which is based upon reproduction and is a more sensitive indicator. If the NOEC is > (greater than) 100 percent, then there is no statistically significant difference between the permitted discharge waters and the background or receiving water. If the IC25 is > 100 percent, this also means that there is no statistically significant difference between the receiving water and the effluent with respect to reproductive capacity. If the NOEC or the IC25 are less than 100 percent, then it can be concluded that the biological properties of the discharges are different from the receiving water.

Results of data collected and analysis performed are provided in this report. WET testing and chemical data for SD033 are provided in this report. However, in order to have a large enough data set that could be statistically analyzed (e.g., the number of response variables-survival and reproduction, had to be large enough to provide enough degrees of freedom), data were combined for outfalls SD033 and SD026; all background waters and all downstream waters. Using the entire data set, multivariate logistic regression (which is similar to linear regression but the curve has an S-shape) was used to identify those chemical constituents that appear to have the most influence on the WET testing results. Once the best logistic regression model was built, it was used to determine the importance of the monitored constituents on the WET testing outcomes.

5.3.5 Macroinvertebrates

Biological monitoring required an assessment of the status of the biota in terms of the physical, chemical and biological conditions of the water body. Biological monitoring in Bear Creek and Lower Spring Mine Creek (PM 12.1) utilized fish and macroinvertebrate communities. Biological monitoring for macroinvertebrate communities was also conducted in Upper Spring Mine Creek. The physical components of the respective stream reaches were measured utilizing stream geomorphology concepts and data, while parameter values and chemical concentrations were obtained from the analysis of water samples that were collected in July 2010, September 2010 and June 2011 (field analysis and laboratory analysis).

The MPCA Standard Operating Procedures (SOPs) were followed for this study.

Macroinvertebrate Sampling

Aquatic macroinvertebrates were sampled using the MPCA multi-habitat invertebrate sampling procedures (MPCA protocol EMAP-SOP4 (Appendix 5-C)). For each site, the relative proportion of available habitat was identified and the various habitats of Upper Spring Mine Creek were sampled according to their relative proportion to obtain similar samples of macroinvertebrates. A total of 20 samples was collected at each site. All macroinvertebrates were collected using D-frame dip nets.

The debris (large twigs, leaves, plants, rocks, etc.) was washed with stream water, visually inspected and discarded. Collected macroinvertebrates were composited in a sieve bucket, transferred into 500-ml plastic bottles, and preserved in 85 percent reagent alcohol. All containers were labeled (inside and outside) with information including site identification, habitat type and collection date.

Macroinvertebrates were sorted using the MPCA *Invertebrate Identification and Enumeration* (SOP BMIP03; Appendix 5-D) procedures as a reference. Macroinvertebrates were identified by Dr. Dean Hansen, and the MPCA procedures were provided to Dr. Hansen. Macroinvertebrates were identified to the genus level if at all possible for all organisms. Large macroinvertebrates were picked and identified for the entire sample.

Measures of Biological Diversity – Macroinvertebrate Community

Biological monitoring can be used to evaluate the relative condition of biological communities in streams. This monitoring is usually conducted in association with physical and chemical monitoring at the site to assess all aspects of the stream reach. Several metrics can be used to evaluate and compare the biological communities of streams.

Abundance

Abundance (n) for a site was determined as the total number of organisms collected in the sampling effort. Samples were subsampled to a minimum of 300 organisms as per MPCA's general guidelines for aquatic invertebrate monitoring in streams (http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/biological-monitoring/stream-monitoring/stream-monitoring-aquatic-invertebrates.html?menuid=&redirect=1#sops; Date Accessed: August 29, 2011).

Richness

For the macroinvertebrate data, the number of families and genera was used to determine richness.

Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index (H´) was used in conjunction with abundance and richness to detect environmental disturbances that may cause a decrease in diversity. H´ is calculated as:

$$H' = -\sum_{i=1}^{s} (n_i/n)\ln_2(n_i/n),$$

where n is the total number of individuals of all taxa, n_i is the number of individuals in the i^{th} taxon, and s is the total number of taxa in the community. The values of n and s were used as previously indicated for abundance and richness.

Evenness

Evenness was calculated to determine how equally abundant the species are among the families. Evenness (E) was calculated as:

$$E = H'/\ln s$$

where H´ is the calculated Shannon-Wiener Diversity Index and ln s is the natural logarithm (ln) of the total number of taxa in a community (s). High evenness occurs when species are equal or nearly equal in abundance and it is usually equated with high diversity. The maximum diversity would be possible if all species were equally abundant. By contrast, low evenness occurs when one or more species dominate the community which indicates low diversity.

Hilsenhoff Biotic Index (HBI) for Macroinvertebrates

The 2010 and 2011 macroinvertebrate data were evaluated using the Hilsenhoff Biotic Index (HBI). The Hilsenhoff Biotic Index (HBI) provides a method to assess water quality based on taxa pollution-tolerance (Hilsenhoff 1987). The HBI was developed from research on more than 1,000 small streams in Wisconsin (Hilsenhoff, 1982 and 1987). Small streams typically have a naturally low biological diversity, which is unrelated to their water quality. Small low-gradient streams in northeast Minnesota are also generally naturally low in DO without the introduction of nutrient or organic pollutants. Other water quality indices attribute biological diversity to stream condition and water quality. However, research indicates the HBI does an excellent job of ranking small streams in this region according to their stream condition.

The HBI was developed using macroinvertebrate populations in streams with a range of organic and nutrient levels, and therefore DO levels. The HBI is typically used to measure biodiversity in streams that may be affected by nutrient or organic pollution that causes excessive plant growth which reduces the DO and may affect the growth of other aquatic biota, e.g. macroinvertebrates. In general, species resident in streams with high organic levels and low DO levels were assigned high tolerance values and those species absent from these types of streams were given lower tolerance values. Using the tolerance values developed by Hilsenhoff and the EPA (*Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*, July 1999), every species or genus identified at the monitoring sites has been assigned an index value from 0-10, with 0 assigned to the most intolerant species and 10 assigned to the most tolerant species. Species with tolerance values that are less than or equal to 3 are considered to be sensitive (intolerant) and species with values greater than or equal to 7 are considered to be tolerant.

When evaluating water quality conditions at a site, only those taxa with assigned tolerance values are included in the analysis. The HBI is an average of tolerance values for all individuals collected from a site. The calculations result in a HBI value that is a tolerance score for the sample weighted by the number of individuals in each contributing taxon. The calculated HBI scores can range from 0 to 10.

An HBI score at the high end of the scale indicates the macroinvertebrate community is dominated by pollution-tolerant taxa and that the site has some amount of pollution or that conditions are stressing the resident populations. A score at the low end of the scale indicates the macroinvertebrate community is dominated by organisms intolerant of pollution or stressor conditions (i.e., sensitive taxa) and implies that the water quality is good.

It is noted that the stream evaluations based on the HBI may underestimate the biologic integrity of the streams discussed in this report. The HBI is generally a measure of organic or nutrient pollution which affects organisms resulting from low DO or fluctuating DO levels. The study streams may have naturally low DO levels because they generally flow through wetland complexes and may not have any relationship to "organic pollution". However, even with these limitations, the HBI values are presented as a method for comparing the streams included in this study.

Other Biotic Measures of Integrity for Macroinvertebrates

There are other metrics or measures of biological communities that are often used to provide some additional understanding of biological communities. The metrics that include composition and habitat include the percent Ephemeroptera, Plecoptera, and Tricoptera (% EPT); percent Ephemeroptera, Plecoptera, Tricoptera, and Odonata (% EPTO); and percent insecta versus percent non-insecta.

Composition metrics require identification of key genera and their associated ecological patterns. The presence of a nuisance genus, or notable lack of a preferred genus, relates to stream condition. Composition metrics also provide information on the relative contribution of the genera to the total assemblage. There is a high level of redundancy in the input values used to calculate various composition metrics when the pollution tolerant genera are dominant and there is low diversity, and estimated scores tend to be similar.

Habitat metrics explain the morphological adaptation of genera for feeding and movement in the aquatic habitat. Insects are clinger taxa and require adaptations for attachment in flowing water to maintain position. Typically, with increased pollution, the number of insect taxa decreases. These additional biotic metrics can be used to provide additional understanding of macroinvertebrate populations at each site.

The EPA Biological Indicators of Watershed Health (2007) identifies the benthic macroinvertebrate orders that indicate stream health. In a degraded stream, pollution tolerant organisms (midgeflies, worms, leeches, pouch snails) would dominate the population. In comparison, sites dominated by sensitive (stoneflies, riffle beetles, mayflies) and moderately tolerant (dragonflies, crayfish, scuds, blackflies, caddisflies) orders indicate good stream health.

5.3.6 Fish

Fish Sampling

Fish communities were sampled at Bear Creek and Lower Spring Mine Creek (PM 12.1) on July 26, 2010 using the MPCA *Fish Community Sampling Protocol for Stream Monitoring Site* (Appendix 5-E). A MDNR collection permit (Special Permit Number 16639) was obtained prior to fish sampling. As part of the permit requirement, the electro-fishing data and site figures were submitted to the MDNR - Fisheries Research on December 3, 2010.

For each stream reach, the fish community was sampled using a Smith-Root backpack electrofisher (135-245 volts), while walking 150 meters in an upstream direction and weaving between habitat types. Due to variable configurations of each of the stream reaches, the overall time fished was not consistent among streams. As such, abundances of fish species at each stream site were standardized based on time fished. All habitat types were sampled in the proportion that they existed in the stream reach.

Fish less than 25 mm in total length were excluded from the sampling effort. All specimens over 25mm were identified to the species level, measured for total length (mm) and weighed (to the nearest g) before being released into the stream. Any anomalies on a specimen (e.g. parasites, lesions, popeye) were recorded in the field. Unidentifiable fish were euthanized and preserved in 10% formalin for subsequent identification in the laboratory - specimens were sent to Dr. Andrew Simons in the Department of Fisheries and Wildlife, University of Minnesota, St. Paul, for detailed examination and were later retained for deposition in the Minnesota Bell Museum of Natural History.

Fish Community Assessment

The index of biotic integrity (IBI) approach is the most commonly used technique in fish community assessment and overall habitat assessment, particularly for streams and rivers (Karr 1981, Lyons et al. 1996, Mundahl and Simon 1999). Originally formulated specifically for the evaluation of fish communities, the IBI takes into account a variety of measures or attributes in connection with the stream reach under investigation. A metric is a calculated term or enumeration representing some aspect of biological assemblage structure, function, or other measurable characteristic that changes with increasing human disturbance, in a predictable manner (Fausch, et al. 1984). In an IBI, each metric is equally weighted and contributes to an overall IBI score, which signifies the “integrity” of a fish community at a site. In theory, the IBI reflects the degree to which the physical and chemical environment influences the fish community.

Development of an IBI requires fish community data at several reference condition (i.e. non-disturbed) sites in addition to data acquired from test sites (i.e., sites under investigation) because scoring of each metric is dependent upon variation in the metric response against some measure of anthropogenic disturbance. Due to limitations with suitable site availability for fish community sampling, only one reference condition site was benchmarked for inclusion in this study. Therefore, the IBI approach could not be used to calculate an overall index score and determine a qualitative measure of biological integrity; however, certain individual metrics within the index could still be evaluated against a composite measure of stream pollution and ultimately compared among sites to determine whether there are overall significant differences in the fish community between the reference condition site (i.e., Bear Creek) and Lower Spring Mine Creek (PM 12.1). Six of the original twelve IBI metrics (Karr et al. 1981) were selected for evaluation because they are the most comprehensive and informative measures of overall fish community health.

Measures of Fish Community Health

Total number of species

Total species richness is the most commonly used measure of fish community health and is defined as the total number of species sampled at the site under investigation (standardized by catch per unit effort) (Karr 1981). A decline of species richness can be indicative of degraded conditions as certain species can be intolerant to various types of stressors such as toxic metals (Lyons 1992).

Simpson's Diversity Index

Simpson's Diversity index is the simplest measure of the character of a biological community that takes into account both abundance and species richness. This is calculated by determining, for each species, the proportion of individuals that it contributes to the total abundance at a site (i.e. the proportion is P_i for the i^{th} species):

$$\text{Simpson's index, } D = \frac{1}{\sum_{i=1}^{S} P_i^2}$$

where S is the total number of fish species (i.e., the richness).

Proportion of individuals as tolerant species

This measure is most sensitive to changes in stream condition. A site with many tolerant species is indicative of degrading conditions (Karr 1981). As an example of species present in a degraded system, the more tolerant species in the Minnesota River Basin include white sucker, common carp, fathead minnow, creek chub and black bullhead (Bailey et al. 1993).

Proportion of individuals as insectivores

This measure evaluates the species that restrict their diet to benthic macroinvertebrates. Karr (1981) and Karr et al. (1986) used this measure in stream quality assessments. Typically, a decline in insectivorous species is indicative of degraded conditions.

Proportion of individuals as omnivores

Omnivores have a diet that includes ≥25% animal food and 25% plant food. Because the omnivore has a flexible diet, they generally can subsist in a range of stream conditions. The dominance of omnivores tends to suggest degradation in the trophic structure of a habitat (Karr 1981). Greater relative abundance of omnivores is thus considered to be an indication of poor habitat conditions.

Proportion of individuals with DELT (diseases, eroded fins, lesions and tumors) anomalies

This measure is widely used in stream quality assessments. The presence and especially abundance of fish with DELT anomalies is a sign of severe degradation at a site (Karr 1981), typically as a result of an environmental stressor (e.g., chemicals, overcrowding, improper diet, excessive siltation, etc.). It is important to mention that DELT anomalies do not include black spot since it may be a natural occurrence and is not a reflection of stream quality.

Each of the above fish community measures was compared among the fish sampling sites and further evaluated against a measure of pollution. When selecting a measure of pollution against which to compare a metric response, some degree of variability in the pollution measure among sites is necessary in order to assess the predicted response for a site with minimal disturbance (i.e., a background site) compared to a site with heavy disturbance. Non-essential metals such as mercury, cadmium, lead and arsenic are known to cause significant toxic effects in aquatic organisms and their respective concentration can be used as a measure of pollution. Arsenic concentration showed the most variability among all sites where water chemistry data was collected for this study, and was thus chosen as one measure of metal pollution against which each fish community metric was evaluated.

5.4 Results and Discussion

Results for the stream habitat surveys, surface water samples (chemistry), WET testing, macroinvertebrate sampling and fish sampling are presented and discussed in the following sections.

5.4.1 Physical Habitat

The physical and chemical measurements that were taken in the field during the macroinvertebrate surveys are presented in Table 5-2. The water level for each stream reach was within normal levels, based on observations of vegetation along the bank. The water level was within the banks of all streams when the macroinvertebrate samples were collected.

With regard to precipitation, the following is noted:

- There was 0.24 inches of rainfall in the seven days prior to sampling on September 15 and 17, 2010, with the 0.24 inches occurring on September 11 (precipitation data from state climatologist network, Station: 210390 Babbitt 2SE, http://climate.umn.edu/HIDradius/radius.asp). In addition, during the day on September 16 there was 0.17 inches of rain.

- In the seven days prior to the June 2, 2011 sampling there was 0.73 inches of rain, occurring on May 28 (0.15 inches) , 29 (0.53 inches) and 31 (0.05 inches).

- Recent precipitation data were compared to historic data for evaluating annual and monthly deviations from normal conditions, and to determine if the macroinvertebrate sampling and water chemistry were representative of "normal" conditions. Precipitation data were obtained from the Minnesota Climatology Working Group, Wetland Delineation Precipitation Data Retrieval from a Gridded Database (http://climate.umn.edu/wetland/) for St. Louis County, Township 60N, Range 13W, Section 1. Precipitation during the 2 months prior to the mid-September 2010 macroinvertebrate sampling was above normal in July and August. In 2011, the previous 2 months prior to sampling were above the normal range in April and within the normal range in May.

The precipitation data suggests that the macroinvertebrate sampling in September 2010 and June 2011 was conducted during a wet time period. However, water levels in the streams were within the banks and do not indicate sampling was conducted during high flow or flooding conditions. Therefore, the biological sampling is considered to have been completed under relatively normal precipitation conditions.

Reference Stream Habitat – Bear Creek

For the stream reach assessed, available habitat types at Bear Creek included undercut banks/overhanging vegetation, woody debris, emergent vegetation and sediment (Table 5-2). The riparian zone was characterized by reed canarygrass, alders and willows. The substrate included muck and detritus. The Qualitative Habitat Evaluation Index (QHEI) for the MPCA worksheet was 44/100. The lower Index value reflects the low diversity of habitat types, substrate and in-stream cover. Discharge (in cubic feet per second, cfs) was higher in 2011 compared to 2010, with a maximum water depth of 1.8 feet. The stream shading was similar in 2010 and 2011 for the reach. The water temperature ranged from 10.2 ºC (2010) to 15.7 ºC (2011). Specific conductivity ranged from 105 µmhos (2010) to 62 µmhos (2011). The pH ranged from 6.9 (2010) to 6.4 (2011). Dissolved oxygen values were 6.4 ppm in 2010 and 6.8 ppm in 2011.

Area 5 Habitat – Lower Spring Mine Creek (PM 12.1) and Upper Spring Mine Creek (SD033)

Available habitat types at Lower Spring Mine Creek (PM12.1) included undercut banks/overhanging vegetation, emergent vegetation and woody debris (Table 5-2). The riparian zone was characterized by reed canarygrass, willows and alder. The substrate included sand and detritus. The QHEI for Lower Spring Mine Creek using the MPCA worksheet was 44/100. The lower index value reflects the low diversity of habitat types, substrate and in-stream cover. Discharge (in cfs) was higher in 2011 compared to 2010, with a maximum water depth of 0.8 to 1.1 feet. The stream shading was similar in 2010 and 2011 for the reach. The water temperature ranged from 10.1 ºC (2010) to 16.5 ºC (2011). Specific conductivity ranged from 1,062 µmhos (2010) to 664 µmhos (2011). The pH ranged from 7.7 (2010) to 7.8 (2011). Dissolved oxygen values were 8.9 ppm in 2010 and 9.5 ppm in 2011.

Available habitat types at Upper Spring Mine Creek (SD033) included riffles, woody debris and sediment (Table 5-2). The riparian zone was characterized by willows and alder shrubs and saplings/trees such as birch, aspen, etc. The substrate included cobbles, gravel, sand and detritus. The QHEI for Upper Spring Mine Creek using the MPCA worksheet was 73/100. The higher score reflects the higher diversity of habitat types, substrate and in-stream cover. Discharge (cfs) was slightly higher in 2011 compared to 2010, with a maximum water depth of 0.7 to 0.8 feet. Discharge is controlled at the upstream end of the reach by a beaver dam. The stream shading was similar in 2010 and 2011 for the reach. The water temperature ranged from 13.6 ºC (2010) to 8.3 ºC (2011). Specific conductivity ranged from 2,340 µmhos (2010) to 2,006 µmhos (2011). The pH value was 8.2 in 2010 and 2011. Dissolved oxygen values were 11.3 ppm in 2010 and 11.7 ppm in 2011.

5.4.2 Water Chemistry

Water chemistry data collected from July 2010, September 2010, October 2010, and June 2011 were evaluated.

General Comparison and Evaluation

Bear Creek, Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) were significantly different based on 13 of the 41 measured water chemistry parameters (Table 5-3). The following is noted.

- Of the general chemistry parameters, alkalinity, hardness, pH, total dissolved solids, specific conductance and sulfate were significantly higher in Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) compared to Bear Creek.

- Of the metal concentrations, calcium, magnesium, potassium and sodium were significantly higher in Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) compared to Bear Creek (Table 5-3).

- Barium concentration, on the other hand, was significantly higher in Bear Creek compared to Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1).

- Molybdenum was significantly higher in Upper Spring Mine Creek (SD033), but there was no significant difference between Lower Spring Mine Creek (PM 12.1) and Bear Creek.

Comparison to Surface Water Standards and Criterion

The average parameter values were compared against the Minnesota Water Quality (WQ) Standards and Aquatic Life Criteria for surface waters. Of the 18 parameters for which standards criterion values are available for comparison, Bear Creek, Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) met the criteria for 14 parameters (Table 5-4). No aquatic life criteria were exceeded.

For those parameters that did not meet the relevant surface water standard, the following is noted.

- Average dissolved oxygen (DO) concentration of 4.8 mg/L in Bear Creek was slightly lower than the daily minimum standard of 5.0 mg/L; however, this was not surprising because Bear Creek is a low gradient and slow moving stream that drains a wetland complex. Low dissolved oxygen is typical of these types of stream reaches in the region.

- Average total hardness value of 1,278 mg/L for Upper Spring Mine Creek (SD033) and 393 mg/L for Lower Spring Mine Creek (PM 12.1) exceeded the standard of 305 mg/L.

- Average total dissolved solids concentration of 1,828 mg/L in Upper Spring Mine Creek (SD033) exceeded the water quality criterion of 700 mg/L.

- Average specific conductance at Upper Spring Mine Creek was 2,350 µmhos/cm, exceeding the surface water quality standard of 1,000 µmhos/cm. Specific conductance at Lower Spring Mine Creek (PM 12.1), however, was below the WQ standard.

Water Quality Classification Index

Based on the water quality classification index (Prati, et al. 1971), results were variable and dependent upon specific parameters evaluated. The following is noted with regard to the index values calculated for Bear Creek, Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1):

- All three sites were rated as 'excellent' for the following parameters: biological oxygen demand, chlorides, pH and total suspended solids (Table 5-5).

- Dissolved oxygen values ranged from 3.3 mg/L to 9.4 mg/L (Table 5-1), resulting in a classification for all three sites as 'acceptable' to 'slightly polluted' (Table 5-5).

- Chemical oxygen demand (C.O.D.) and iron concentrations were highest at Bear Creek, classifying that water as 'slightly polluted-polluted' and 'heavily polluted' respectively. By comparison, C.O.D. values and iron concentration at Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM12.1) resulted in those waters being classified as 'excellent' and 'acceptable-slightly polluted', respectively (Table 5-5).

- Based on measured manganese concentrations, Upper Spring Mine Creek (SD033) was classified as slightly polluted-polluted, while Bear Creek and Lower Spring Mine Creek (PM 12.1) were classified as 'acceptable-slightly polluted' (Table 5-5).

Overall, in comparison to the reference site (Bear Creek), Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) were generally classified as 'excellent' or 'acceptable' for most of the parameters in the index.

5.4.3 Whole Effluent Toxicity (WET) Testing

Literature Review

The available literature indicates that toxicity can occur over a range of dissolved solids concentrations: acute toxicity can occur over a range of ~ 325 mg/L to ~ 5,100 mg/L and chronic toxicity has been shown to occur over a narrower range of values, approximately 29 mg/L up to ~ 2,000 mg/L. It is suspected that some other toxicant may have been influencing the study that produced the chronic toxicity value of 29 mg/L, but the study in question did not identify other potential sources of toxicity in the effluent being tested. The difference in toxicity is due largely to the ions that compose the dissolved solids (i.e., sodium, calcium, magnesium, potassium, sulfate, chloride bicarbonate). In general, the most toxic ions to freshwater organisms are potassium and bicarbonate. Several studies have identified that potassium and magnesium can be more toxic than sulfate. However, the mixture of ions is very important in determining the toxicity of any discharge water and the potential contribution of sulfate to toxicity is an important consideration in any WET testing to be conducted. Because the ion composition of the discharge water is important to assessing potential toxicity, samples of the discharge water from Upper Spring Mine Creek (SD033) were collected and analyzed for a number of specific ions to support the Stream Investigation work and the WET testing.

General Toxicological Results

A summary of the chronic WET testing results for outfall SD033 and for tests with Spring Mine Creek (PM12.1) and Embarrass River (PM12) water are provided in Table 5-6. Mixtures of SD033 water with Bear Creek, Embarrass River, and synthetic laboratory water were tested (mixtures were zero, 12.5, 25, 50, 75 and 100 percent SD033 water). Test statistics in Table 5-6 include survival in 100 percent effluent, IC25, and NOEC. It can be seen that *C. dubia* survival was 100 percent in 100 percent SD033 water for June 2010, October 2010, and June 2011 tests. Overall, there appears to be little potential for SD033 water to cause mortality to zooplankton and other invertebrates of similar sensitivity to *C. dubia*. It should also be noted that there was 100 percent survival for water collected downstream of SD033 (Lower Spring Mine Creek at Site PM 12.1).

WET testing endpoints which are based upon reproduction (see IC25 and NOEC values in Table 5-6) provide more sensitive indicators of the potential for SD033 to affect biota in the downstream receiving water (Lower Spring Mine Creek and Embarrass River further downstream). Summary results include the following:

- For the first test in July 2010 the IC25 and NOEC for that test were 72.5 and 50 percent, respectively. This indicates that the reproductive potential of *C. dubia* and species of similar sensitivity to *C. dubia* would be hindered by 25 percent compared to Bear Creek water, until SD033 water is diluted below a concentration of 50 to 72.5 percent.

- For the October 2010 test the IC25 was 100 percent and the NOEC 100 percent when compared to Embarrass River water (Embarrass River was the source of the diluent). In this test, the reproductive potential of *C. dubia* and species of similar sensitivity would not be hindered by SD033 water.

  It is noted that the number of young produced per adult *C. dubia* for SD033 water in the October 2010 test was 17.0, while in the July 2010 test it was 20.2 (Table 5-6). However, the lower reproduction in the October 2010 test indicates no hindrance of reproduction while the July 2010 test did indicate a hindrance to reproduction.

One factor affecting the different results for the July 2010 test and the October 2010 test is the reproduction of *C. dubia* in the dilution water. In the July 2010 test, Bear Creek water was used as the diluent and *C. dubia* reproduction was 30.3 young per adult (very high). In that July 2010 test, the C. dubia reproduction was 20.2 for SD033 water (Table 5-6). When the WET test statistics were calculated they showed reproduction was hindered in the SD033 water. In the October 2010 test, laboratory reconstituted water was used as the diluent and *C. dubia* reproduction was 18.3 young per adult. The number of young per adult *C. dubia* was 17.0 for SD033 water and 22.2 for Bear Creek water, respectively. The WET test statistics for the October 2010 test indicate no hindrance of C. dubia reproduction in SD033 waters and reproduction was similar to the background stream (Bear Creek).

The dilution water plays an important role in the WET test statistics. The high reproduction rate in the Bear Creek water in the July 2010 test (30.3 young per adult C. dubia) resulted in reproduction in SD033 (20.2 young per adult) to be considered “hindered”. Yet, a reproduction rate of 17.0 young per adult in SD033 water for the October 2010 test indicated no hindrance of reproduction when compared to the dilution water or to Bear Creek (22.2 young per adult). Therefore, there is uncertainty as to whether there was an actual toxicity effect or that reproduction was truly hindered in SD033 water for the July 2010 test.

- For the June 2011 test, the IC25 and NOEC were 83 and 75 percent (Embarrass River water was the diluent). The number of young produced per adult C. dubia was 8.0 for SD033 water, notably lower than in the other two WET tests.

The full laboratory report for each WET Test is provided in Appendix 5-F to this report. Because the results for the three WET tests were variable, and in particular because the reproduction rate for SD033 water in the spring 2011 test was lower than in the previous two tests, an additional assessment of the WET test data was conducted.

Evaluation of Chemical Drivers of WET Testing Results

For this analysis, water chemistry data and WET test results for SD033 and SD026 were combined to provide a more robust assessment and to provide a better opportunity to identify the chemicals likely influencing the WET test results.

For each WET test, the number of young produced per adult *C. dubia* were counted for the seven day duration of the test. There are some differences in young production for both SD033 and SD026 water compared to all of the receiving waters considered to be background (Bear Creek, Embarrass

River at PM12, and Partridge River). If all of the WET testing and chemical data collected as part of this study are considered as one group, a statistical analysis can be conducted in an attempt to understand why the receiving waters may behave differently than the outfall waters.

The WET testing results and chemical analytical data were organized as shown in Table 5-7 for waters corresponding to outfall SD033. WET results for SD026 and corresponding background (Bear Creek) and downstream waters (Second Creek, PM17; Lower Spring Mine Creek, PM12.1) were also organized as presented in Table 5-7. A regression analysis was then conducted to formulate a relationship between water chemistry and WET test results (i.e., relationship between water chemistry and the number of young produced per adult *C. dubia)*. Four different models were built and the goodness of fit for each model was then evaluated by comparing the observed to the model-predicted young production (see Figure 5-2). These models were then used to identify the relative importance of the different chemical constituents for young production.

There is a clear difference between the chemical composition of outfall SD033 water and the various receiving waters (Figure 5-3, Table 5-8). From Table 5-8 it can be seen that outfall water (SD026 and SD033 are averaged in Table 5-8) is elevated compared to background for alkalinity, magnesium and calcium (note: magnesium and calcium are displayed in Table 5-8 as the ratio of magnesium to calcium), sulfate, and potassium. Several constituents are lower in the outfall waters compared to background, for example, barium, cobalt, copper, iron, dissolved or total organic matter, total phosphorus, and total nitrogen.

It is noted that the best regression model with the fewest parameters includes the variables described above that are lower in the outfall water (e.g., iron, dissolved organic matter, etc.) plus nickel (r^2 = 0.79). This finding is supported by simple regression analysis of individual chemical constituents and young production (Figure 5-4 and 5-5, respectively).

Model 4 (r^2 = 0.86; see Figure 5-2) includes constituents that are both higher and lower in the outfall water compared to the background waters – this model was used to evaluate the relative effect of constituents higher in the outfall water compared to constituents that are lower. Table 5-9 shows the results of this analysis. The table shows that if the parameters with lower concentrations in the outfall waters (SD026, SD033) are held constant at monitored concentrations, and the other parameters found to be elevated in the mining water (e.g., sulfate) are reduced to approximately background concentrations, there is no predicted effect on young production. What this indicates is that the parameters at elevated levels in the mining outfall water (e.g., sulfate, Mg/Ca ratio) are not likely responsible for the observed differences in WET testing results (with respect to *C. dubia* young production) between outfall waters and receiving water. Rather, the regression analysis indicates that the chemicals likely having the most effect on WET test results are those parameters at low levels in the outfall discharges (barium, cobalt, copper, iron, dissolved or total organic carbon, total phosphorus, and total nitrogen).

It is noted that copper, phosphorus, and nitrogen are micronutrients for zooplankton and low concentrations of these parameters in SD033 and SD026 water may be influencing the WET test results. If one or more of these low-concentration parameters (e.g., dissolved organic carbon) are increased in the Model 4 inputs there would be a notable increase in predicted number of young. Dissolved organic carbon is singled out here because Figure 5-5 identifies that there is a relatively strong relationship between dissolved organic carbon concentration and number of young produced per adult *C. dubia*.

Mining-related waters have very little dissolved organic carbon (approximately 5 mg/L for SD033 and SD026 water compared to 22 mg/L for background waters; Table 5-8). The relationship of dissolved organic carbon and young produced (Figure 5-5) is assumed to be influenced by higher concentrations of dissolved organic carbon in background waters (e.g., Embarrass River, Partridge River, Bear Creek) and downstream waters (e.g., Lower Spring Mine Creek, PM12.1; Second Creek, PM17). As dissolved organic carbon concentrations increase, the number of young produced increases (Figure 5-5). This relationship is consistent with other data and evaluations conducted for other mining projects in the Aurora-Hoyt Lakes area and it suggests that the WET test results for SD033 and SD026 may be influenced by a lack of nutrients (i.e., lack of a carbon source for energy).

Studies have shown that higher dissolved or total organic carbon improves growth and reproduction of aquatic life. The analysis results indicate that the mining-related discharge water is low in these important micronutrients, and low in an energy source (such as total organic carbon or dissolved organic carbon). Therefore, the lower number of young produced in the spring (June 2011) test may be more related to oligotrophic conditions in the Area 5NW Pit (source of water to SD033) or the Tailings Basin (source of the water to SD026) than representing a “toxic effect” from a high dose of a particular parameter. The WET tests suggest a potential seasonality in the data, with lower number of young produced in the spring (June 2011) test as compared to the summer (July 2010) and fall (October 2010) tests (Table 5-6; Table 5-7). Dilution of mining-related water may be more pronounced in spring time due to further dilution with snowmelt water.

Assuming that the response of WET test species *C. dubia* can act as a surrogate for the expected response of aquatic life in the actual receiving stream, this analysis suggests that a simple reduction in the constituents that currently have elevated concentrations in the Area 5 pits (sulfate, alkalinity, potassium, calcium, and magnesium) to background or near background levels will not improve the suitability of water from outfall SD033 for aquatic life. Rather, the analysis is suggesting that a lack of nutrients in the mining-related discharge water may be playing a greater role than previously expected.

Overall, because the chronic WET test results do not indicate mortality of C. dubia, it is unlikely that water from SD033 has, or will, adversely affect aquatic life in downstream waters. Reproduction (which is a much more sensitive indicator than mortality) of the test species *C. dubia* was reduced in two tests compared to the reference site Bear Creek and the Embarrass River (PM12). However, reproduction was not severely reduced in SD033 water compared to the reference sites and for one test there was no significant difference between SD033 and the reference sites. Therefore, the WET test results indicate that the potential for actual adverse effect to aquatic life is low.

5.4.4 Macroinvertebrate Survey Data and Assessment

The total number of macroinvertebrates sampled in each stream segment is provided in Table 5-10. The data presented in Table 5-10 was then used to prepare other tables discussed in this section and related to macroinvertebrate survey results.

Taxa

Reference Stream – Bear Creek

Taxa collected at Bear Creek in 2010 and 2011 represented 6 classes and 14 orders (Tables 5-11 and 5-12). There were 32 families collected in 2010 and 34 families collected in 2011 (Table 5-2). The **classes** and orders collected in 2010 and 2011 included: **Insecta (insects) –** Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Odonata (dragonflies), Megaloptera (alderflies and dobsonflies), Lepidoptera (moths and butterflies), Plecoptera (stoneflies) and Trichoptera (caddisflies); **Crustacea (crustaceans) –** Amphipoda (scuds) and Decapoda (crayfish); **Entoprocta (brozoans)**; **Annelida (segmented worms) –** Oligochaeta (aquatic worms), Arhynchobdellida (leeches) and Rhynchobdellida (leeches); **Gastropoda (snails)** – Basommatophora (snails); **Bivalvia (bivalve clams)** – Veneroida (clams); **Malacostraca (crustaceans) –** Isopoda (pillbugs and sowbugs); **Hydrozoa (hydrozoans) –** Hydroida (hydra)**;** and **Nematoda (roundworms)**.

Classes identified at the site in 2010 and 2011 included insects, crustaceans, segmented worms, snails, and clams. Classes only identified in 2010 and 2011 were bryozoans and hydrozoans, respectively. Dominant classes in 2010 and 2011 were insects, segmented worms and crustaceans.

Orders that were identified at the site in 2010 and 2011 included beetles, true flies, mayflies, dragonflies, moths and butterflies, caddisflies, scuds, aquatic worms, leeches, snails and clams. Orders only identified in 2010 included crayfish, bryozoans and alderflies, dobbonflies and fishflies. Orders only identified in 2011 included stoneflies and hydra. Dominant orders in 2010 were true flies, caddisflies, aquatic worms and scuds; and in 2011 were mayflies, true flies, scuds and aquatic worms.

Lower Spring Mine Creek (PM 12.1)

Taxa collected at Lower Spring Mine Creek in 2010 and 2011 represented 5 classes and 11 orders (Tables 5-11 and 5-12, respectively). There were 33 families collected in 2010 and 26 families collected in 2011 (Table 5-2). The **classes** and orders collected in 2010 and 2011 included: **Insecta (insects) –** Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Odonata (dragonflies), Lepidoptera (moths and butterflies), Plecoptera (stoneflies) and Trichoptera (caddisflies); **Crustacea (crustaceans) –** Amphipoda (scuds); **Annelida (segmented worms) –** Oligochaeta (aquatic worms; **Gastropoda (snails)** – Basommatophora (snails); and **Bivalvia (bivalve clams)** – Veneroida (clams);.

Classes identified at the site in 2010 and 2011 included insects, crustaceans, segmented worms, snails, and clams. Classes only identified in 2010 were segmented worms. Dominant classes in 2010 were insects and snails; in 2011 were insects, snails and clams.

Orders that were identified at the site in 2010 and 2011 included beetles, true flies, mayflies, dragonflies, moths and butterflies, stoneflies, caddisflies, scuds, aquatic worms, snails and clams. Orders only identified in 2010 included aquatic worms and moths and butterflies. Dominant orders in 2010 were mayflies, snails, true flies and caddisflies; and in 2011 were mayflies, true flies, caddisflies, snails and clams.

Upper Spring Mine Creek (SD033)

Taxa collected at Upper Spring Mine Creek (SD033) in 2010 and 2011 represented 4 classes and 8 orders (Tables 5-11 and 5-12, respectively). There were 20 families collected in 2010 and 19 families collected in 2011 (Table 5-2). The classes and orders collected in 2010 and 2011 included: **Insecta (insects) –** Coleoptera (beetles), Diptera (true flies), Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies); **Annelida (segmented worms) –** Oligochaeta (aquatic worms; **Gastropoda (snails)** – Basommatophora (snails); and **Bivalvia (bivalve clams)** – Veneroida (clams).

Classes identified at the site in 2010 and 2011 included insects, crustaceans, segmented worms, snails, and clams. Classes only identified in 2010 were clams. Dominant classes in 2010 and 2011 were insects.

Orders that were identified at the site in 2010 and 2011 included beetles, true flies, mayflies, stoneflies, caddisflies, aquatic worms, snails and clams. Orders only identified in 2010 and 2011 included clams and mayflies, respectively. Dominant orders in 2010 and 2011 were true flies, caddisflies and stoneflies.

Abundance and Richness

For Bear Creek (reference stream), the abundance of macroinvertebrates in September 2010 and June 2011 was 2,787 and 1,113, respectively (Table 5-11). In comparison, in Lower Spring Mine Creek (PM12.1) the abundance of macroinvertebrates in September 2010 and June 2011 was 8,648 and 1,932, respectively (Table 5-11). In Upper Spring Mine Creek, the abundance of macroinvertebrates in September 2010 and June 2011 was 2,494 and 3,605, respectively (Table 5-11).

The abundance was lower in the spring sampling compared to the fall sampling, except for Upper Spring Mine Creek. The difference in abundance reflects the seasonal emergence of adults such as caddisflies, mayflies and black flies. In Upper Spring Mine Creek, the higher spring abundance was the result of higher numbers of chironomid (bloodworms) present at the site.

Richness describes the number of families or genera present within a sampled group.

- For Bear Creek (reference stream), in 2010 there were 32 families and 46 genera collected; in 2011, there were 34 families and 43 genera collected from the site (Table 5-2 and Table 5-11, respectively).

- For Lower Spring Mine Creek (PM 12.1) in 2010 there were 33 families and 42 genera collected; in 2011, there were 26 families and 35 genera collected from the site (Table 5-2 and Table 5-11).

- For Upper Spring Mine Creek (SD033), in 2010 there were 20 families and 25 genera collected; in 2011, there were 19 families and 29 genera collected from the site Table 5-2 and Table 5-11).

Shannon-Wiener Diversity Index (H´) and Evenness

For all three streams, the H' scores were similar in 2010 and in 2011, and scores for each stream were similar to each other.

- Bear Creek (reference stream): 2010 H´ = 2.91; and 2011 = 2.42 (Table 5-2)
- Lower Spring Mine Creek (PM 12.1): 2010 H' = 2.31; and 2011 = 2.43 (Table 5-2)
- Upper Spring Mine Creek (SD033): 2010 H' = 2.23; and in 2011 = 2.83 (Table 5-2)

Evenness scores were also similar between years for each stream, and were similar for the three streams.

- Bear Creek: Evenness scores were 0.75 in 2010 and 0.64 in 2011
- Lower Spring Mine Creek (PM 12.1): Evenness scores were 0.61 in 2010 and 0.66 in 2011
- Upper Spring Mine Creek (SD033): Evenness scores were 0.66 in 2010 and 0.82 in 2011.

The Shannon-Wiener Diversity index is increased either by having additional unique species or by having a greater evenness. Typically, the value of the index ranges from 1.5 (low species richness and evenness) to 3.5 (high species richness and evenness).

For Upper Spring Mine Creek (SD033), in 2011 the individuals were distributed among the blackflies, mayflies and stoneflies, which resulted in higher H´ and evenness scores compared to 2010.

Overall, the H' and evenness scores indicate similarity between the stream sites.

Hilsenhoff Biotic Index (HBI)

Reference Stream – Bear Creek

The HBI score for 2010 was 6.36 ("fairly poor") and the score increased to 5.94 ("fair") in 2011 (Tables 5-2 and 5-15). The HBI values are scaled to **indicate improving biotic condition with**

decreasing values (Table 5-14). In 2011, the number of tolerant taxa (tolerance score ≥ 7) decreased slightly which slightly improved the HBI rating from "fairly poor" to "fair".

Lower Spring Mine Creek (PM 12.1)

The HBI score for 2010 was 5.33 ("good") and the score increased to 5.10 ("good") in 2011 (Tables 5-2 and 5-15). The HBI values are scaled to **indicate improving biotic condition with decreasing values** (Table 5-14). In 2011, the number of tolerant taxa (tolerance score ≥ 7) decreased nearly 20 percent which increased the HBI value, although the rating remained "good".

Upper Spring Mine Creek (SD033)

The HBI score for 2010 was 5.82 ("fair") and the score increased to 5.60 ("fair") in 2011 (Tables 5-2 and 5-15). The HBI values are scaled to **indicate improving biotic condition with decreasing values** (Table 5-14). In 2010 and 2011, the number of tolerant taxa (tolerance score ≥ 7) and sensitive taxa (tolerance score ≤ 3) remained constant. Changes in the HBI score are the result of how the individuals are distributed among the different taxa (with different tolerance scores).

Other Measures of Biotic Integrity

The percentage composition of Ephemeroptera, Plecoptera and Trichoptera (% EPT) and Ephemeroptera, Plecoptera, Trichoptera and Odonata (% EPTO) are other methods used to evaluate macroinvertebrate data. These species are generally considered to be in more environmentally sensitive Orders so are better indicators of the stream quality or are more sensitive to stress.

Another composition metric used to evaluate macroinvertebrate data includes percentage composition of black flies (Simulidae), non-insects (Non-Insecta), true flies (Diptera) and midges (Chironomids).

Results for the other measures of biotic integrity for each stream site are presented below

Reference Stream – Bear Creek

In 2010, there were 14 EPT and 19 EPTO genera collected in the stream; in 2011, there were 9 EPT and 12 EPTO genera (Table 5-2).

The % EPT and EPTO ranges from 24 percent to 37 percent over the two sampling events (Table 5-2). In 2010 caddisflies were one of the dominant orders, while in 2011; mayflies were a dominant order (Table 5-13). Most of the caddisfly and dragonfly species present at the site tend to be the more tolerant species that can adapt to a wide range of environmental conditions, however there are species present with tolerance values ≤ 3 (Table 5-15). No riffles were present at the site, so most of these organisms were either found on overhanging vegetation or woody debris.

The abundance of black flies (moderately sensitive) was 11 percent in 2010 and 15 percent in 2011 (Table 5-2). The percentage composition of non-insect individuals was lowest at the reference site, Bear Creek, compared to all other sites (Table 5-2). True flies comprised about one-third of the macroinvertebrates at the site, with chironomids (bloodworms) accounting for 20 to 30 percent of the true flies. The higher percentage of chironomids is typically found in slow-moving, low DO streams typically found in this area.

Lower Spring Mine Creek (PM 12.1)

In 2010, there were 19 EPT and 22 EPTO genera collected in the stream; in 2011, there were 15 EPT and 20 EPTO genera present (Table 5-2).

The % EPT and EPTO ranges from 44 percent to 46 percent over the two sampling events (Table 5-2). In 2010 and 2011 caddisflies and mayflies accounted for over 40 percent of the individuals present at the site (Table 5-13). Most of the caddisfly and mayfly species present at the site tend to be the more tolerant species (tolerance scores 4-6) that can adapt to a wide range of environmental conditions (Table 5-15). No riffles were present at the site, so most of these organisms were either found on overhanging vegetation or woody debris.

The abundance of black flies (moderately sensitive) was 16 percent in 2010 and 20 percent in 2011 (Table 5-2). The percentage composition of non-insect individuals was 32 percent at the site in 2010 and 23 percent in 2011 (Table 5-2). True flies comprised about less than 25 percent of the macroinvertebrates at the site, with chironomids (bloodworms) accounting for 15 percent of the true flies in 2010 and 2011.

Upper Spring Mine Creek (SD033)

In 2010 and 2011, there were 7 and 9 EPT genera collected in the stream; no Odonata were collected at the site (Table 5-2).

The % EPT ranges from 11 percent to 22 percent over the two sampling events (Table 5-2). Another composition metric used to evaluate macroinvertebrate data includes percentage composition of black flies (Simulidae), non-insects (Non-Insecta), true flies (Diptera) and midges (Chironomids).

The black flies (moderately sensitive) accounted for 64 percent of the abundance in 2010 and 47 percent in 2011 (Table 5-2). The percentage composition of non-insect individuals was 17 percent at the site in 2010 and 4 percent in 2011 (Table 5-2). True flies comprised about 20 to 25 percent of the macroinvertebrates at the site, with chironomids (bloodworms) accounting for about 20 percent of the true flies in 2010 and 2011.

5.4.5 Fish Community Assessment

A total of 20 individuals, represented by 5 species, were sampled at Bear Creek (Table 5-16). The most abundant species captured were white sucker (*Catostomus commersonii*) and Johnny darter (*Etheostoma nigrum*). At Lower Spring Mine Creek, 21 individuals, represented by 8 species, were sampled (Table 5-16). Burbot (*Lota lota)* and Creek chub (*Semotilus atromaculatus*) were the most abundant species in the catch at Lower Spring Mine Creek (PM12.1). Overall, at least one species from each of the major trophic guilds (piscivore, insectivore and omnivore) was present at both Bear Creek and Lower Spring Mine Creek (PM12.1) (Table 5-16).

Measures of Fish Community Health

Total number of species

The total number of species sampled at Bear Creek and Lower Spring Mine Creek (PM12.1) was 5 and 8, respectively (Figure 5-6a). Generally, overall species richness tends to decrease with increasing disturbance or stress. When comparing the metric response to arsenic concentration (across all sites where fish were sampled), Bear Creek had the highest arsenic concentration and lower species richness, compared to Lower Spring Mine Creek (PM12.1) where arsenic concentration was below 0.6 µg/L (Figure 5-7a).

Simpson's Diversity Index

Simpson's diversity index at Bear Creek was 3.22. By comparison, the diversity index value at Lower Spring Mine Creek was higher at 5.4 (Figure 5-6b). Across all sites, as expected, Simpson's diversity was negatively correlated with arsenic concentration. Lower Spring Mine Creek (PM 12.1) had the lowest arsenic concentration and the highest Simpson's diversity, whereas the background site, Bear Creek, had the highest arsenic concentration and thereby, the lowest Simpson's diversity value (Figure 5-7b).

Proportion of individuals as tolerant species

Tolerant individuals are generally present at a higher abundance in habitats that are degraded or indicative of poor water quality conditions. Lower Spring Mine Creek (PM 12.1) had the lowest proportion of tolerant individuals at 0.47 (Figure 5-6c). Across all sites, as expected, a positive, albeit weak relationship was found between proportion of individuals that were tolerant and arsenic concentration (Figure 5-7c).

Proportion of individuals as insectivores

Bear Creek had the highest proportion of insectivores, at 0.5, compared to Lower Spring Mine Creek (PM 12.1) at 0.33 (Figure 5-6d). Contrary to predictions, across all sites, there was a positive, albeit, weak relationship between the proportion of insectivores and arsenic concentration (Figure 5-7d). Based on this metric, however, Bear Creek had relatively better water quality conditions for insectivores followed by Lower Spring Mine Creek (PM 12.1).

Proportion of individuals as omnivores

Lower Spring Mine Creek (PM 12.1) had a lower proportion of omnivores at 0.14, compared to Bear Creek at 0.45 (Figure 5-6e). The proportion of omnivores in a community is expected to increase with increasing habitat deterioration (Karr 1986). Across all sites, as expected, there was a strong positive relationship between the proportion of individuals as omnivores and arsenic concentration (Figure 5-7e). In comparison to the reference condition site (Bear Creek), Lower Spring Mine Creek (PM 12.1) had a relatively lower arsenic concentration and proportion of omnivorous individuals, and therefore, represents ‘good’ habitat conditions.

Proportion of individuals with DELT (diseases, eroded fins, lesions, tumors) anomalies

None of the individuals sampled at Bear Creek and Lower Spring Mine Creek (PM 12.1) had any DELT anomalies. This metric is one of the strongest indicators of conditions of severe degradation and poor water quality conditions at a site. The absence of fish with anomalies suggests that both Lower Spring Mine Creek (PM 12.1) and Bear Creek represent ‘good’ habitat conditions.

5.5 Conclusions

Chemistry

The chemical composition of water from the permitted outfall SD033 is different from the composition of the receiving water—Lower Spring Mine Creek, and is different from waters that served as reference or background sites for this field investigation (e.g., Embarrass River, PM12). Samples from SD033 had elevated concentrations of total dissolved solids, bicarbonate (measured as alkalinity), chloride, hardness, sulfate, potassium, sodium, molybdenum, and nickel with respect to the reference or background sites. Copper was also slightly elevated for SD033 compared to background. Water samples from SD033 were also lower for several constituents compared to background waters, including: organic carbon, total nitrogen, total phosphorus, total suspended solids, barium, and iron. Other than the possible exceptions of copper and chloride, constituents found to be elevated at SD033 are not traditionally viewed as “toxicants” and do not have applicable water quality criterion for aquatic life. No water quality criteria for aquatic life were exceeded at outfall SD033.

Whole Effluent Toxicity (WET) Tests

The chronic WET test results strongly suggest that it is unlikely that the constituents observed and the concentration of the constituents observed will cause any mortality of aquatic life in Spring Mine Creek (the receiving stream). Reproduction (which is a much more sensitive indicator than mortality) of the test species *C. dubia* was reduced in two tests compared to the reference site Bear Creek and the Embarrass River. It should be noted that reproduction was not severely reduced in SD033 compared to the reference sites and for one test there was no significant difference between SD033 and the reference sites.

WET testing (particularly chronic tests with *C. dubia*) is a sensitive methodology and the results suggest that the SD033 discharge water is lacking any notable toxicant and the additive or cumulative effects of the constituents present are not significant. A statistical analysis of outfall SD033 water and the receiving waters suggest that reduced reproduction for *C. dubia* in some tests is not due to toxicity, but rather is largely due to constituents that are lacking in the SD033 water, including organic carbon, phosphorus, nitrogen, and possibly some trace metals. It does not appear that bicarbonate, hardness, sulfate, and potassium, which are elevated in SD033, are responsible for the WET test results that indicate reproductive differences between water from SD033 and the reference sites.

Macroinvertebrates

Overall, the macroinvertebrate community in Spring Mine Creek just downstream of outfall SD033 is comparable to the invertebrate community in Bear Creek (the chosen reference site) and there is no evidence that the macroinvertebrate community in Spring Mine Creek is being notably impacted by the discharge as SD033.

In Lower Spring Mine Creek (PM12.1) there are more sensitive species. It should be noted that the habitat in Upper Spring Mine Creek has better habitat quality (according to the QHEI) compared to Bear Creek. Also, some of the more subtle metrics calculated (e.g., percent Simuliidae and percent Diptera, percent Ephemeroptera, Plecoptera, and Tricoptera) suggest that Upper Spring Mine Creek (SD033) has more tolerant species. However, the stream segment assessed at Upper Spring Mine Creek has a much smaller watershed and flow, and hence it is expected that there will be less diversity simply due to the stream size and order. Again, due to the similarity of the macroinvertebrate communities in Bear Creek and Upper Spring Mine Creek, it can be concluded that there is no measurable or noticeable effects on the macroinvertebrate community in Spring Mine Creek due the SD033 discharge.

Fish

Upper Spring Mine Creek (SD033) did not have fish habitat and was therefore not sampled. The fish community at Lower Spring Mine Creek (PM 12.1) was comparable to the fish community at the reference site, Bear Creek; Lower Spring Mine Creek (PM 12.1) fared better than Bear Creek for 4 of the 5 comparable fish community metrics. Overall, Lower Spring Mine Creek (PM 12.1) had higher species richness and Simpson’s diversity and lower proportions of tolerant species and omnivorous species, compared to Bear Creek. The difference in the proportion of insectivorous individuals between Bear Creek and Lower Spring Mine Creek (PM 12.1) was not considerably high and given that 50% of the species caught at Lower Spring Mine Creek (PM 12.1) were insectivores and only 20% were omnivores, the overall trophic structure and composition at Lower Spring Mine Creek (PM 12.1) was reflective of a stream with minimal disturbance. The absence of any fish individuals with anomalies such as lesions, tumors or eroded fins, further corroborates the finding of no measurable or notable disturbance to the biological community in Lower Spring Mine Creek.

Summary

Overall, the results from the Stream Investigation indicate that while the SD033 discharge water has elevated concentrations of some parameters (e.g., sulfate, alkalinity, magnesium, calcium), the biological monitoring data for fish and macroinvertebrates indicate no measurable or notable effects in the upstream or downstream portions of Spring Mine Creek, compared to the data from the reference stream (Bear Creek).

5.6 Recommendations for Future Work

Based on the biological monitoring data collected for the 2010-2011 Stream Investigation Study, the following is recommended.

1) No additional fish monitoring. Upper Spring Mine Creek does not have fish habitat as identified in the initial site reconnaissance that followed MPCA guidance. Low gradient streams draining wetlands have limited biological diversity. The fish-related indices indicate that Lower Spring Mine Creek is similar to the reference stream (Bear Creek). Because this discharge has been part of the environment for decades and there has been no notable effect to date, there is no need to conduct additional fish monitoring data.

2) No additional macroinvertebrate monitoring. The available data indicates that the macroinvertebrate community inhabiting Upper Spring Mine Creek (i.e., the stream reach just below the SD033 discharge area) is similar to the reference stream (Bear Creek). The various indices calculated from the macroinvertebrate data indicate that both Upper Spring Mine Creek and Lower Spring Mine Creek are similar to the reference stream. Because this discharge has been part of the environment for decades and there has been no notable effect to date, there is no need to conduct additional macroinvertebrate studies.

3) Additional WET testing. Because of the variability in the WET test results, and in particular the potential seasonality effects on results, additional WET tests are recommended prior to the development of site specific standards. The additional WET tests are recommended for late spring/early summer. Samples for water chemistry analyses and flow data should be collected at the same time water is collected from SD033 for the WET tests, to provide support information to better assess WET test results. The additional tests can include some nutrient-related dosing to further elucidate whether the previous WET test results were more influenced by potential nutrient deficiency or by a high dose of a particular chemical constituent. A work plan would be developed prior to any additional WET testing.

4) Develop site specific standards after additional WET testing is completed.

6.0 Methylmercury Investigation

As described in the *NPDES Field Studies Plan – SD033* (approved by the MPCA on June 16, 2010), it is unlikely that continued discharge from SD033 will have an effect on the sulfate and methylmercury dynamics in the Embarrass River watershed. Therefore, no additional sampling for methylmercury and sulfate was conducted as part of the Field Studies.

7.0 Wild Rice and Sulfate Monitoring

7.1 Background

In 2009, the MPCA requested PolyMet and Mesabi Mining, LLC (Mesabi) provide information and data regarding wild rice stand locations, densities, and surface sulfate levels in waters potentially affected by their projects (correspondence May 28, 2009 regarding the PolyMet - NorthMet and Mesabi Nugget Phase II Projects (study areas)). The request included: 1.) conducting a literature search for the presence of wild rice in downstream receiving waters, 2.) cooperating with tribes in the study areas, 3.) conducting field surveys to determine the presence of wild rice in the study areas, and 4.) determining surface sulfate levels in waters where wild rice is identified. Following the 2009 request, PolyMet and Mesabi carried out multi-phase studies in summers 2009 and 2010. PolyMet and Mesabi carried out the following activities. First, they consulted literature sources as part of determining the study areas. Second, they analyzed historic aerial photographs of the project areas and compared them to results from field surveys. Third, they determined wild rice stand density and calculated average plant height. Finally, they collected and analyzed water samples for sulfate concentrations in the project areas. The study results are documented in *2009 Wild Rice Survey and Sulfate Monitoring Prepared for Steel Dynamics, Inc. and Mesabi Mining, LLC*, October 2009, *2009 Wild Rice and Sulfate Monitoring Prepared for PolyMet Mining Inc. – NorthMet Project*, September 2009, *2010 Wild Rice Survey and Sulfate Monitoring Prepared for Mesabi Mining, LLC*, March 2011, and *2010 Wild Rice and Water Quality Monitoring Report, Prepared for PolyMet Mining Inc. – NorthMet Project*, January 2011.

7.2 Objective

The purpose of the Wild Rice Survey is to determine the presence of wild rice (*Zizania palustris* L.), an annual grass, in waterbodies potentially affected by the SD033 discharge in the study areas. The study's purpose is also to determine sulfate levels at the locations where wild rice is found and whether sulfate affects wild rice growth and production in the study areas. In particular, the objective of the Wild Rice Survey conducted under the Consent Decree was to evaluate the presence of wild rice along Spring Mine Creek and the Upper Embarrass River.

7.3 Scope and Methods

Waterbodies potentially affected by the SD033 seepage include the Embarrass River and Spring Mine Creek. As discussed in Section 7.1, Spring Mine Creek and the Embarrass River were surveyed for the presence of wild rice and surface water samples were analyzed for sulfate in response to the MPCA request. The results of the multi-phase studies (submitted to the MPCA in 2009 and 2011), and the findings from the MDNR's 2008 Legislative Report on wild rice (February 2008), will form the basis for the MPCA's determination of wild rice waterbodies potentially affected by the SD033 discharge.

Most of Spring Mine Creek was unnavigable by canoe or kayak. It was possible to drive or walk alongside the lower portion of the creek. Field staff determined that it was difficult to identify a good access point along the southern (upstream) stream reach. The stream channel was between 6 to 12 feet wide with flowing water. The upstream portion cascades through rocks and boulders, and has dense forest canopy. The downstream portion flows alongside a road, where the streambed is a mix of sand/gravel/silt and the banks are overhanging grass.

7.4 2009 Survey Results and Discussion

In the Upper Embarrass River, sparse stands of wild rice with density rating 1 were identified from its headwaters to the north end of Embarrass Lake (Figure 7-1). From Embarrass Lake to south of Lake Esquagama, wild rice densities ranged from 1 to 4. Wild rice was not found in Spring Mine Creek. No water samples were collected in Spring Mine Creek. Based on this information, it is not possible to determine the effects of sulfate on wild rice growth and populations.

7.5 2010 Survey Results and Discussion

The results in 2010 (Figure 7-2) were the same as those in 2009. Wild rice was not found (and no water samples were collected) in Spring Mine Creek. Based on this information, it is not possible to determine the effects of sulfate on wild rice growth and populations.

7.6 Recommendations

Based on findings that sparse wild rice was identified along the upper Embarrass River and no wild rice was identified in Spring Mine Creek in 2009 and 2010, no additional wild rice survey work is recommended for the Consent Decree Field Studies. A number of ongoing and potential future studies are being undertaken to address questions regarding sulfate and wild rice. None of these studies are related directly to the Consent Decree.

8.0 Summary

The Field Studies for SD033 were intended to provide a better understanding of the sources, flow paths, and potential impacts of constituents that have been detected at elevated concentrations at SD033. The results from the Field Studies were also intended to be used to support either the development of recommendations for long-term mitigation alternatives or the development of site specific standards for SD033.

Briefly, the Field Studies results indicate the following:

- The water balance conducted for the Field Studies indicates that discharge flow at SD033 is significantly lower than previous estimates. The computed average watershed yield of 8.7 inches per year at SD033 is more similar to the expected range for the Embarrass River watershed than the previously-estimated value of 21 inches per year, which was developed from the instantaneous data collected from 2003 to 2009.

- Sulfide oxidation and subsequent neutralization by mixed cation carbonates is the likely source of sulfate and alkalinity in the SD033 discharge and the Area 5N pits.

- Rock stockpiles appear to be the primary source for the sulfate load at SD033, with some minor contribution from pit wall exposures of the same materials. Based on the mass balance developed using mean observed concentrations, stockpile 5021 (21% of total load), stockpile 5027 (14%), stockpile 5026 (13%), the combined stockpile 5001-4003-5025-5024 (13%), the in-pit sulfate source at Area 5NE (11%), and stockpile 5031 (8%) are the most significant sources of load to SD033. Together, these sources make up an estimated 80% of the total sulfate load at SD033.

- Based on the current understanding of site hydrology and hydrogeology, some sulfate load bypasses SD033 and could potentially report to Spring Mine Creek downstream of SD033. Its fate along such a transport route is unknown.

- Based on assumptions regarding the sulfide content in the waste rock stockpiles, and the field-derived sulfide oxidation rate calculated for the Area 6 stockpiles, sulfide depletion cannot be expected prior to 100 years from now, and would likely take considerably longer.

- Overall, the results from the Stream Investigation indicate that while the SD033 discharge water has elevated concentrations of some parameters (e.g., sulfate, alkalinity, magnesium, calcium), the biological monitoring data for fish and macroinvertebrates indicate no measurable or notable effects in the upstream or downstream portions of Spring Mine Creek, compared to the data from the reference stream (Bear Creek).

- The chronic WET test results strongly suggest that it is unlikely that the constituents observed and the concentration of the constituents observed will cause any mortality of aquatic life in Spring Mine Creek (the receiving stream). Reproduction (which is a much more sensitive indicator than mortality) of the test species C. dubia was reduced in two tests compared to the reference site Bear Creek and the Embarrass River. It should be noted that reproduction was not severely reduced in SD033 compared to the reference sites and for one test there was no significant difference between SD033 and the reference sites.

- WET testing (particularly chronic tests with C. dubia) is a sensitive methodology and the results suggest that the SD033 discharge water is lacking any notable toxicant and the additive or cumulative effects of the constituents present are not significant. A statistical analysis of outfall SD033 water and the receiving waters suggest that reduced reproduction for C. dubia in some tests is not due to toxicity, but rather is largely due to constituents that are lacking in the SD033 water, including organic carbon, phosphorus, nitrogen, and possibly some trace metals. It does not appear that bicarbonate, hardness, sulfate, and potassium, which are elevated in SD033, are responsible for the WET test results that indicate reproductive differences between water from SD033 and the reference sites.

- No wild rice was found in the portion of Spring Mine Creek surveyed for this study.

9.0 Recommendations

The following recommendations are based on the results of the Field Studies for SD033:

- Because the results from the Field Studies indicate that the aquatic life in Spring Mine Creek downstream of SD033 has not been adversely impacted by the discharge at SD033, no additional fish monitoring or macroinvertebrate monitoring is recommended.

- Because of the variability in the WET test results, and in particular the potential seasonality effects on results, additional WET tests are recommended prior to the development of site specific standards. The additional WET tests are recommended for late spring/early summer. Samples for water chemistry analyses and flow data should be collected at the same time water is collected from SD033 for the WET tests, to provide support information to better assess WET test results. The additional tests can include some nutrient-related dosing to further elucidate whether the previous WET test results were more influenced by potential nutrient deficiency or by a high dose of a particular chemical constituent. A work plan would be developed prior to any additional WET testing.

- It is recommended that site specific standards be developed (for parameters other than sulfate) after the additional WET test testing is completed.

- Wild rice is found in Embarrass Lake. There are other sulfate sources between SD033 and the rice, including the former LTVSMC Tailings Basin. A potential compliance point for SD033 and the Tailings Basin should be downstream of SD033 and the Tailings Basin and upstream of the rice and any other sulfate sources. Compliance to wild rice standard is emerging and at the present time, source mitigation has not been developed for sulfate sources to SD033. Options for source mitigation that could be applied at Area 5 will be developed in the Long Term Mitigation Plan. Options for passive treatment that could be applied at SD033 are also being developed. Recent water quality study activities performed for the NorthMet Project in the Embarrass River watershed (including Spring Mine Creek) have indicated that sulfate reduction is occurring in the surface waterbodies downstream from SD033 (i.e., sulfate load tends to decrease in the downstream direction). In order to better understand ramifications of this reduction related to potential long-term mitigation at Area 5 (related to sulfate), it is recommended that additional study be conducted into the fate of sulfate that is discharged at SD033. The scope of such a study has not been developed at this time. A detailed work plan would be developed prior to conducting the study into the fate of sulfate in the SD033 discharge.

10.0 References

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Tables

Table 3-1 Area 5 Watershed Areas and Land Use/Land Cover

Land Use/Land Cover	Surface Watersheds			Ground Watersheds			Calibrated Runoff Fraction[1]	Calibrated Shallow GW Fraction[2]
	Area 5NE (acres)	Area 5NW (acres)	SD033 (acres)	Area 5NE (acres)	Area 5NW (acres)	SD033 (acres)		
Undisturbed (non-wetland)	50.7	96.5	105.0	62.4	92.0	107.8	10%	5%
Undisturbed (wetland)	--	3.1	2.4	--	8.3	3.2	10%	5%
In-pit stockpiles	34.2	14.4	--	48.6	--	--	40%	0%
Out-of-pit stockpiles	62.5	60.6	80.3	87.9	40.0	91.7	5%	35%
Haul roads, barren (non-pit)	10.5	11.7	36.4	11.7	9.6	37.8	5%	35%
Pit bare rock (incl. water)	150.7	96.0	--	161.7	85.1	--	35%	0%
Total	308.5	282.2	224.1	372.3	235.1	240.6	--	--

[1] Runoff fraction is the portion of monthly precipitation that reports as monthly runoff to the receiving waterbody (pit lake or stream)

[2] Shallow groundwater fraction is the portion of average annual precipitation that reports as constant inflow to the receiving waterbody (pit lake or stream)

Table 3-2 Refined Water Balance Results for SD033

Month	Observed Outflow (cfs)	Observed Outflow (gpm)	Predicted Outflow (cfs)	Predicted Outflow (gpm)	Difference (pred. - obs.) (cfs)	Difference (pred. - obs.) (gpm)	Difference (pred. - obs.) (%)
August, 2010	0.88	395	0.83	374	-0.05	-21	-5%
September, 2010	1.17	525	1.25	562	0.08	38	7%
October, 2010	0.63	285	0.96	431	0.33	146	51%
November, 2010	0.49	221	0.61	272	0.11	51	23%
December, 2010	0.42	189	0.45	203	0.03	14	7%
January, 2011	0.44	199	0.42	188	-0.02	-11	-6%
February, 2011	0.35	158	0.48	217	0.13	59	37%
March, 2011	0.39	177	0.42	188	0.02	11	6%
April, 2011	2.48	1115	2.48	1113	0.00	-2	0%
May, 2011	1.39	626	0.69	310	-0.70	-316	-50%
June, 2011	1.14	509	1.25	561	0.11	51	10%
Study Period Average Flow	**0.89**	**401**	**0.89**	**400**	**0.00**	**1**	**0.2%**

Table 3-3 Flow Contributions by Source to SD033

Source	Area 5NE	Area 5NW	SD033 Direct	Total*
Net Precipitation (open water)	4%	8%	--	12%
Undisturbed Runoff	2%	3%	3%	8%
Undisturbed Shallow GW	1%	2%	2%	5%
Stockpile/Road Runoff	5%	3%	2%	10%
Stockpile/Road Shallow GW	12%	6%	15%	32%
Pit Wall Runoff	13%	3%	--	16%
Deep Groundwater (GW)	8%	8%	--	16%
Total*	45%	33%	22%	100%

* Values may not sum exactly due to rounding

Table 4-1
Monitoring Station Location Descriptions and Sampling Activity Summary

			Observed Flow Condition						Sampling Event Activities			
Station	**Description**	**Type**	**Apr, 2009** [1]	**Apr, 2010** [2]	**Aug, 2010** [3]	**Oct, 2010** [4]	**Apr-May, 2011** [5]	**Jun. 2011**	**Aug-10**	**Oct-10**	**Apr/May-2011**	**Jun-11**
SD033	Discharge	Surface	Flowing	Flowing	Flowing	Flowing	Flowing	Flowing	FLM	FLM	FLM	FLM
MS001	Former channel into Spring Mine Lake	Surface	N/O	Dry	Dry	Dry	slight flow, <0.2 gpm	Dry	FL	F	FL	FL
MS002	Spring Mine Lake	Surface	N/A	N/A	N/A	N/A	N/A	N/A	FL	F	FL	FL
MS003	Ditch where passes under road	Surface	water flowing	water flowing	water flowing, ~14 gpm	steady flow, ~14 gpm	strong flow, 190 gpm	steady flow, 16 gpm	FL	F	FL	FL
MS004	Former Spring Mine Creek Channel, where water may report beneath stockpile 5031	Surface	significant flow	standing water	Dry, no standing water next to stockpile	Dry	Dry	Dry	FL	FL	FL	FL
MS005	Seep from stockpile 5029/5004	Surface	N/O	standing water, SC > 1000	standing water, SC = 1799 uS/cm	stagnant water	stagnant water	stagnant water	FL	F	FL	FL
MS006	Seep from stockpile 5029/5004	Surface	N/O	N/O	No water or low area at location.	Not visited	Not visited	Not visited	FL	F	--	--
MS007	Seep from stockpile 5029/5004	Surface	N/O	standing water, SC > 1000	gentle flow, ~0.8 gpm	slight flow, too slow to measure	frozen/flowing	very slight flow, too slow to measure	FL	F	FL	FL
MS008	Seep from stockpile 5029/5004	Surface	N/O	N/O	No water or low area at location.	Not visited	Not visited	Not visited	FL	F	--	--
MS009	5NW Pit Lake	Surface	N/A	N/A	N/A	N/A	N/A	N/A	--	FL	--	FL
MS010-A	Apparent seep from overburden (?) in 5SW	Surface	N/O	Dry	Dry	heavy flow in channels and sheets of runoff	Dry	Dry	FL	FL	FL	FL
MS010-B	Apparent seep from overburden (?) in 5SW	Surface	N/O	Dry	gentle flow, ~0.03 gpm	Not visited	very slight flow, immeasurabe	Dry	--	--	FL	FL
MS010-C	Channelized flow during runoff	Surface	--	--	N/O	heavy flow from runoff, at least 100 gpm (?)	Dry	Dry	--	--	FL	FL
MS011	Seep from 5NE to 5NW	Surface	water flowing	significant water flowing	significant water flowing, unmeasurable	significant water flowing, unmeasurable	significant diffuse water flow, unmeasurable	significant diffuse water flow, unmeasurable	FL	FL	FL	FL
MS012	Seep from stockpile5024/5025	Surface	slight flows	Dry	Dry	Dry, small puddle from rain	Frozen/ground moist, but no flow	Dry	FL	F	FL	FL
MS013	Seep from stockpile5024/5025	Surface	slight flows	Dry	standing water, SC - 2209 uS/cm	Very slight flow, not measureable	Frozen/ground moist, but no flow	Very slight flow, not measureable	FL	F	FL	FL
MS013-B	Seep from stockpile5024/5025, closer to pond	Surface				Diffuse, very slight flow, not measureable	Frozen/ground moist, but no flow	Diffuse, very slight flow, not measureable	--	--	FL	--
MS014	Seep reporting to pond above SD033	Surface	stream of water embedded in ice and snow	significant water flowing; white and green slime observed	gentle flow, ~0.3 gpm	slight diffuse flow, not measureable	Slight diffuse flow, <0.1 gpm	slight diffuse flow, not measureable	FL	FL	FL	FL
MS015	Standing water north of stockpile 5020	Surface	N/O	standing water observed	standing water, SC = 44 uS/cm	standing water, SC = 35 uS/cm	Frozen/standing water	standing water	FL	F	FL	FL
MS016	Standing water north of stockpile 5020	Surface	N/O	standing water observed	standing water, SC = 68 uS/cm	standing water, SC = 47 uS/cm	Frozen/standing water	standing water	FL	F	FL	FL
MS017	Standing water north of stockpile 5020	Surface	N/O	standing water observed	standing water, SC = 566 uS/cm	standing water, SC = 870 uS/cm	Frozen/standing water	standing water	FL	F	FL	FL
MS018	Standing water north of stockpile 5021	Surface	N/O	N/O	standing water, moved location due to unsafe access, SC = 1788 uS/cm	standing water, SC = 2130 uS/cm	Frozen/not visited again	Dry	FL	F	FL	FL
MS019	Seep reporting from stockpile 5021	Surface	N/O	N/O	steady flow, ~ 5 gpm	steady flow, ~10 gpm	Steady diffuse flow, not measureable	steady flow, ~ 6 gpm (minimum)	FL	F	FL	FL
MS020	Surface water between stockpiles 5020 and 5021	Surface	N/O	Flowing water observed	steady flow, ~11 gpm	steady flow, ~16 gpm	steady flow, ~16 gpm	strong flow, ~ 55 gpm	FL	FL	FL	FL
MS021	Topographic low area north of stockpile 5021	Surface	N/O	N/O	Unsafe access route.	Route was established. Flow audible beneath boulders, not visible	Flow audible beneath boulders, only visible when boulders moved	Flow audible beneath boulders, only visible when boulders moved	FL	F	FL	FL
MS022	Topographic low area east of stockpile 5021	Surface	N/O	N/O	Located off of property.	Not visited	Not visited	Not visited	FL	F	--	--
MS023	Seep which discharges to 5NE	Surface	flow observed	Dry	standing water, SC = 1330	Dry	Steady flow, diffuse and immeasurable	Gente flow, diffuse and immeasurable	FL	FL	FL	FL
MS024	5NE Pit Lake	Surface	N/A	N/A	N/A	N/A	N/A	N/A	FL	FL	FL	FL
MS025	5NE Pit Lake, possibly separate basin	Surface	N/A	N/A	N/A	N/A	N/A	N/A	FL	FL	FL	FL
MS026	5NE Pit Lake, possibly separate basin	Surface	N/A	N/A	Pit 5NE locations MS025 and MS026 were in the same basin during this event	Same basin as MS025	Same basin as MS025	Same basin as MS025	--	--	--	--
MS027	5NE Pit Lake, possibly separate basin	Surface	N/A	N/A	N/A	N/A	N/A	N/A	--	FL	--	FL
MS028	5NE Pit Lake	Profile	N/A	N/A	N/A	N/A	N/A	N/A	F, FL	--	F, FL	--
MS029	5NW Pit Lake	Profile	N/A	N/A	N/A	N/A	N/A	N/A	F, FL	--	F, FL	--
Well A		Groundwater	N/A	N/A	N/A	N/A	N/A	N/A	FL	--	FL	--
Well B		Groundwater	N/A	N/A	N/A	N/A	N/A	N/A	FL	--	FL	--

1 Observations catalogued in memorandum dated April 30, 2009 from Mr. Bruce Trebnick (NTS, Inc.) to Mr. Dave Skolasinski (CNR).
2 Observations during Barr on-site reconnasaince, April 5-7, 2010.
3 Observations during August, 2010 sampling event, August 2-5, 2010.
4 Observations during October, 2010 sampling event, October 25-27, 2010 (this sampling was conducted during light-heavy rainfall).
5 Observations during April-May, 2011 sampling event, April 19-20. Some seeps were partially or completely frozen. Another event took place May 24th to revisit the frozen sites.
6 Observations during June, 2011 sampling event, June 13-14, 2011.
N/O The monitoring station was Not Observed during the site reconnaissance event.
N/A Not Applicable; no flow observations made at pit lakes or groundwater monitoring wells.
SC Specific Conductivity (in uS/cm)

<u>Parameter Key</u>
F, FL, FLM **F**ield parameters only, **F**ield parameters and **L**aboratory analysis for selected parameters of interest, **F**ield parameters, **L**aboratory analysis for selected parameters of interest and **M**itigation evaluation parameters
-- No field paramter or laboratory sampling conducted.

Table 4-2
Water Quality Monitoring Station and Groundwater Quality Data

Chemical Name / Total or Dissolved / Units: Sys Loc Code	Sample Date	Sample Type Code	Alkalinity, total, lab NA mg/l	Alkalinity, total, field NA mg/l	Chloride NA mg/l	Dissolved oxygen, field NA mg/l	pH, lab NA pH units	pH, field NA pH units	Redox (oxidation potential), field NA mV	Specific Conductance, field NA umhos/cm	Temperature, field NA deg C	Hardness, total as CaCO3 NA mg/l	Solids, total dissolved NA mg/l	Sulfate NA mg/l	Calcium Dissolved ug/l	Calcium Total ug/l	Iron Dissolved ug/l	Iron Total ug/l	Magnesium Dissolved ug/l	Magnesium Total ug/l	Potassium Dissolved ug/l	Potassium Total ug/l	Sodium Dissolved ug/l	Sodium Total ug/l
MS001	04/19/2011	N	15.6	--	< 0.5	12.26	6.6	6.63	59.1	39	-0.02	18.4	33	3.86	--	4140	--	1030	--	1970	--	1440	--	< 2000
MS003	08/02/2010	N	24.5	< 100	< 2	5.95	--	8.15	-22.6	130	21.55	52.2	131	38	--	10800	--	5230	--	6120	--	1160	--	6970
MS003	10/26/2010	N	--	--	--	5.16	--	6.3	-27.5	160	9.81	--	--	--	--	--	--	--	--	--	--	--	--	--
MS003	04/19/2011	N	10.3	--	< 0.5	5.39	6.4	6.99	-0.8	89	0.65	23	74	14.6	--	4600	--	869	--	2800	--	2070	--	3770
MS003	06/13/2011	N	36.4	--	< 0.5	2.76	6.4	6.6	105.1	152	11.9	46.4	167	9.43	--	10400	--	5500	--	4970	--	1750	--	7500
MS005	08/02/2010	N	914	500	3.3 j	6.35	--	8.9	-39.6	1799	18.71	715	1300	263	--	29000	--	278	--	156000	--	97000	--	224000
MS005	10/26/2010	N	--	--	--	2.42	--	8.5	-99.0	1970	9.8	--	--	--	--	--	--	--	--	--	--	--	--	--
MS005	04/19/2011	N	427	150	0.84	3.97	8.7	9.64	-290.0	2123	2.35	210	558	89.9	--	10800	--	364	--	44400	--	29600	--	55300
MS005	06/13/2011	N	1070	500	1.45	8.6	8.7	8.8	112	2123	12.7	803	1326	247	--	27900	--	< 50	--	178000	--	96600	--	230000
MS007	08/02/2010	N	1990	700	4.0 j	7.54	--	9.4	-49.8	1211	3.74	820	1270	153	--	11800	--	66.3	--	192000	--	121000	--	202000
MS007	10/26/2010	N	--	--	--	7.36	--	8.5	-44.3	1625	2.8	--	--	--	--	--	--	--	--	--	--	--	--	--
MS007	04/19/2011	N	200	--	--	11.92	--	9.20	-77.5	1946	0.61	--	--	--	--	--	--	--	--	--	--	--	--	--
MS007	05/24/2011	N	1200	--	1.32	16.23	9	9.00	--	2163	0.64	879	1430	149	--	8880	--	68.4	--	208000	--	114000	--	195000
MS007	06/13/2011	N	500	--	--	10.1	8.8	8.8	116	3163	10	--	--	--	--	--	--	--	--	--	--	--	--	--
MS010	08/02/2010	N	--	--	--	6.49	--	11.27	-50.8	428	28.21	--	--	--	--	--	--	--	--	--	--	--	--	--
MS010	04/19/2011	N	--	--	--	--	--	8.3	--	54	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MS010A	10/26/2010	N	28.4	--	< 0.5	9.54	--	7.65	-66.0	57	11.57	32.3	12	1.88	--	9970	--	399	--	1810	--	250	--	< 2000
MS010B	04/19/2011	N	--	--	--	--	--	8.3	--	54	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MS010C	10/26/2010	N	42.9	--	< 0.5	9.0	--	7.97	-62.5	95	11.69	48.2	45	2.79	--	12500	--	310	--	4130	--	400	--	< 2000
MS011	08/03/2010	N	289	250	4 j	1.3	--	8.02	-22	1591	8.62	1300	1730	1350	--	73900	--	< 50	--	272000	--	86800	--	90600
MS011	10/25/2010	N	293	--	2.18	4.83	--	3.8 **	-9.6	2290	9.97	1310	1970	1180	--	82500	--	< 50	--	268000	--	84800	--	83000
MS011	04/19/2011	N	335	--	2.48	3.62	7.5	7.77	-28.7	2249	8.83	1290	1860	1080	--	94600	--	< 50	--	257000	--	71200	--	74900
MS011	06/13/2011	N	286	--	1.92	5.4	7.6	7.6	95	2170	8.5	1190	1797	1050	--	73100	--	< 50	--	245000	--	70500	--	83000
MS013	08/04/2010	N	--	--	--	8.85	--	8.48	-31.7	2209	26.08	--	--	--	--	--	--	--	--	--	--	--	--	--
MS013	06/13/2011	N	--	--	--	7.7	8.3	8.3	115	6770	10	--	--	--	--	--	--	--	--	--	--	--	--	--
MS013B	10/26/2010	N	73	--	2.24	7.3	--	7.8	-42.2	1313	10.5	586	741	521	--	18800	--	53.7	--	131000	--	18300	--	10100
MS014	08/04/2010	N	403	270	9.41	1.04	--	5.77	-19.0	2605	5.53	2920	3990	2610	--	293000	--	< 50	--	532000	--	21800	--	92700
MS014	08/04/2010	FD	413	--	9.31	--	--	--	--	--	--	2880	3950	2600	--	291000	--	< 50	--	524000	--	20700	--	93500
MS014	10/26/2010	N	31.2	--	0.9	7.32	--	6.48	-44.6	1820	8.47	109	140	85.1	--	12400	--	500	--	18900	--	3200	--	3180
MS014	04/19/2011	N	--	--	--	4.43	--	6.87	-43.0	4180	1.55	--	--	--	--	--	--	--	--	--	--	--	--	--
MS014	05/24/2011	N	429	--	8.68	0.72	6.5	6.28	--	4172	1.61	2960	4110	2480	--	306000	--	< 50	--	534000	--	21600	--	89600
MS014	06/13/2011	N	432	--	8.45	2.8	6.4	6.4	159	4440	3	3130	4244	2460	--	307000	--	< 50	--	573000	--	23600	--	90600
MS015	08/03/2010	N	60.4	< 100	< 2	3.16	--	9.68	-34	44	21.39	20.7	111	< 5	--	4610	--	2470	--	2230	--	310	--	< 2000
MS015	10/27/2010	N	--	--	--	5.3	--	6.3	115.0	35	5.26	--	--	--	--	--	--	--	--	--	--	--	--	--
MS015	05/24/2011	N	25.4	--	< 0.5	3.05	6.9	6.82	--	47	13.00	22.4	82	1.28	--	5100	--	2430	--	2350	--	1900	--	< 2000
MS015	06/13/2011	N	25.5	--	< 0.5	3.8	7.1	6.9	27	61	16.5	23.8	82	1.22	--	5400	--	2340	--	2510	--	1580	--	< 2000
MS016	08/03/2010	N	63.2	< 100	< 2	2.1	--	9.02	-26	68	18.82	37.6	72	< 5	--	10100	--	5760	--	3010	--	1100	--	< 2000
MS016	10/27/2010	N	--	--	--	2.57	--	5.68	112.2	47	4.19	--	--	--	--	--	--	--	--	--	--	--	--	--
MS016	05/24/2011	N	40.6	--	< 0.5	1.89	6.8	6.6	--	80	11.91	22.4	129	< 1	--	5120	--	2440	--	2330	--	1960	--	< 2000
MS016	06/13/2011	N	41.8	--	< 0.5	4.4	7.1	6.6	76	116	14.1	49.7	94	< 1	--	12700	--	4790	--	4380	--	730	--	< 2000
MS017	08/03/2010	N	165	160	< 2	1.3	--	9.3	-32	566	18.64	234	412	181	--	16900	--	268	--	46500	--	42900	--	35600
MS017	10/27/2010	N	--	--	--	4.86	--	7.31	85.9	870	5.67	--	--	--	--	--	--	--	--	--	--	--	--	--
MS017	05/24/2011	N	130	--	0.67	1.58	7.6	7.21	--	456	12.4	144	317	90.5	--	10600	--	439	--	28600	--	32300	--	25900
MS017	06/13/2011	N	155	--	0.9	2.7	7.5	7.1	60	538	9.4	188	372	102	--	15000	--	852	--	36700	--	31500	--	27200
MS018	08/03/2010	N	266	250	2 j	3.88	--	9.01	-40.7	1788	13.34	749	1000	670	--	52600	--	570	--	150000	--	127000	--	64000
MS018	10/27/2010	N	--	--	--	1.16	--	7.08	32.9	2130	5.06	--	--	--	--	--	--	--	--	--	--	--	--	--
MS019	08/03/2010	N	485	400	7	5.9	--	9.13	-35	3702	5.78	4220	5630	4560	--	153000	--	243	--	932000	--	280000	--	190000
MS019	08/03/2010	FD	484	--	7	--	--	--	--	--	--	4280	5640	4570	--	154000	--	223	--	946000	--	286000	--	192000
MS019	10/27/2010	N	--	--	--	5.63	--	7.1	110.6	5285	4.45	--	--	--	--	--	--	--	--	--	--	--	--	--
MS019	04/19/2011	N	331	--	4.41	8.96	7.5	7.86	-38.4	5580	4.61	3950	5910	3830	--	154000	--	73.2	--	865000	--	211000	--	138000
MS019	06/13/2011	N	430	--	4.47	7	7.3	7.5	83	6170	6.07	4450	6496	4140	--	164000	--	194	--	981000	--	245000	--	180000
MS020	08/03/2010	N	447	400	6	8.1	--	8.5	-27	4293	12.6	4100	5400	4350	--	179000	--	134	--	886000	--	243000	--	179000
MS020	10/27/2010	N	311	--	4.96	9.93	--	7.7	86.3	3974	3.94	2570	3590	2460	--	126000	--	168	--	547000	--	170000	--	112000
MS020	04/19/2011	N	293	--	4.07	10.42	7.7	8.25	-41.2	5117	7.35	3700	5380	3490	--	168000	--	58.4	--	797000	--	187000	--	133000
MS020	06/13/2011	N	402	--	3.7	7.7	7.8	7.8	134	5974	18.3	4350	6465	4010	--	178000	--	137	--	949000	--	234000	--	174000
MS021	10/26/2010	N	155	--	1.87	9.5	--	7.4	300.0	2800	2.4	1820	2450	1630	--	157000	--	108	--	348000	--	68800	--	70400
MS021	04/19/2011	N	140	--	2.38	15.42	7.2	8.03	-35.3	3560	0.12	2370	3520	2340	--	200000	--	64.8	--	454000	--	77700	--	75500
MS021	06/13/2011	N	165	--	2.11	12.1	7.4	7.5	137	3500	2.4	2480	3458	2120	--	186000	--	< 50	--	490000	--	78800	--	89400
MS023	08/03/2010	N	< 100	--	--	3.97	--	7.65	4.7	1330	20.61	--	--	--	--	--	--	--	--	--	--	--	--	--
MS023	04/19/2011	N	87.9	--	0.6	12.42	7.7	8.6	-38.0	730	3.32	352	502	308	--	67200	--	54	--	44800	--	20100	--	16900

Table 4-2
Water Quality Monitoring Station and Groundwater Quality Data

Sys Loc Code	Sample Date	Sample Type Code	Alkalinity, total, lab NA	Alkalinity, total, field NA	Chloride NA	Dissolved oxygen, field NA	pH, lab NA	pH, field NA	Redox (oxidation potential), field NA	Specific Conductance, field NA	Temperature, field NA	Hardness, total as CaCO3 NA	Solids, total dissolved NA	Sulfate NA	Calcium Dissolved	Calcium Total	Iron Dissolved	Iron Total	Magnesium Dissolved	Magnesium Total	Potassium Dissolved	Potassium Total	Sodium Dissolved	Sodium Total
		Units	mg/l	mg/l	mg/l	mg/l	pH units	pH units	mV	umhos/cm	deg C	mg/l	mg/l	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l
MS023	06/13/2011	N	114	--	0.72	10.4	8	7.8	87	1580	8	847	1249	790	--	133000	--	51.2	--	125000	--	41200	--	34500
SD-033	07/26/2010	N	336	--	4.33	7.47	--	7.82	--	2350	13.00	1300	1880	1110	--	99300	--	< 50	--	255000	--	57400	--	95300
SD-033	08/04/2010	N	348	275	4.46	9.72	--	7.12	-27.4	1722	14.07	1220	1790	1060	--	87200	--	60.4	--	244000	--	57300	--	100000
SD-033	08/25/2010	N	--	--	4.32	10.20	--	7.92	--	2434	14.56	--	--	1050	--	--	--	--	--	--	--	--	--	--
SD-033	09/09/2010	N	--	--	3.9	7.43	--	8.03	--	2174	10.82	--	--	949	--	--	--	--	--	--	--	--	--	--
SD-033	09/14/2010	N	365	--	3.9	8.18	--	7.88	--	2306	11.98	1200	1770	1040	--	81800	--	< 50	--	243000	--	58200	--	91300
SD-033	09/23/2010	N	--	--	4.22	6.1	--	7.7	--	2364	12.4	--	--	1110	--	--	--	--	--	--	--	--	--	--
SD-033	09/23/2010	FD	--	--	4.22	--	--	--	--	--	--	--	--	1110	--	--	--	--	--	--	--	--	--	--
SD-033	10/06/2010	N	--	--	4.37	10.13	--	7.61	--	2450	13.41	--	--	1140	--	--	--	--	--	--	--	--	--	--
SD-033	10/25/2010	N	362	--	4.54	10.32	--	5.35	10.3	2275	9.86	1280	1830	1110	--	87500	--	159	--	259000	--	56800	--	96300
SD-033	10/25/2010	FD	361	--	4.36	--	--	--	--	--	--	1290	1900	1110	--	87100	--	169	--	260000	--	57200	--	96200
SD-033	10/26/2010	N	363	--	4.9	6.46	--	7.83	--	2450	10.17	1350	1880	1140	--	98200	--	150	--	269000	--	53400	--	95000
SD-033	04/19/2011	N	230	--	2.6	10.73	8.1	8.61	-59.0	1473	4.14	770	1110	629	--	52700	--	54.1	--	155000	--	32800	--	57300
SD-033	04/19/2011	FD	229	--	2.57	--	8.1	--	--	--	--	744	1120	631	--	52200	--	51.6	--	149000	--	31300	--	54900
SD-033	06/02/2011	N	341	--	3.88	9.4	--	8.23	--	2241	6.47	1260	1780	961	--	85800	--	148	--	253000	--	49500	--	89200
SD-033	06/14/2011	N	357	--	4.24	11.32	7.95	8.2	305	2408	10.21	1350	1819	1040	--	96000	--	122	--	270000	--	50800	--	91700
SD-033	06/14/2011	FD	348	--	9.83	--	8.1	--	--	--	--	1320	1842	1060	--	90400	--	117	--	267000	--	49600	--	89900
Seep	11/08/2010	N	262	--	1.93	--	--	7.0	--	2600	7.6	1450	2440	1420	--	172000	--	122	--	248000	--	66200	--	103000
Seep	06/13/2011	N	267	--	1.77	4.5	7.3	6.99	119	2265	6.7	1170	1896	1130	--	156000	--	95.5	--	190000	--	53600	--	107000
Well A	02/13/2008	N	114	--	1.46	3.18	6.5	6.64	31.6	850	6.29	512	--	445	88800	87200	279	382	72400	70800	2980	3060	19200	18700
Well A	08/04/2010	N	85.3	< 100	1.31	0.87	--	5.10	-13.0	654	7.9	534	742	461	--	71600	< 50	< 50	--	86300	--	2390	--	16800
Well A	04/20/2011	N	86.9	--	1.23	1.7	--	6.7	-7.1	880	5.95	525	689	434	--	73000	< 50	< 50	--	83300	--	2780	--	18200
Well B	02/13/2008	N	114	--	1.85	3.87	6.7	6.65	209.0	1424	5.49	940	--	844	56800	56500	< 50	388	196000	194000	2690	2800	23800	23400
Well B	02/13/2008	FD	93.6	--	1.85	--	6.8	--	--	--	--	941	--	838	57500	56900	< 50	489	198000	194000	2710	2820	23900	23600
Well B	08/04/2010	N	118	< 100	1.84	1.93	--	4.53 **	-9.7	1266	7.34	1250	1620	1130	--	73200	< 50	< 50	--	259000	--	2880	--	23900
Well B	04/20/2011	N	118	--	1.84	2.0	6.8	6.9	-25.8	1780	5.88	1120	1520	1050	--	63100	< 50	208	--	234000	--	2730	--	22100

Footnotes

--	Not analyzed/not available.
j	Reported value is less than the stated laboratory quantitation limit and is considered an estimated value.
**	Unusable value, QA/QC criteria not met.
N	Sample Type: Normal
FD	Sample Type: Field Duplicate

Table 4-3
Pit Water Quality Monitoring Results

Chemical Name		Alkalinity, total, lab	Alkalinity, total, field	Chloride	Dissolved oxygen, field	pH, lab	pH, field	Redox (oxidation potential), field	Specific Conductance, field	Temperature, field	Hardness, total as CaCO3	Solids, total dissolved	Sulfate	Calcium	Iron	Magnesium	Potassium	Sodium
Total or Dissolved		NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Total	Total	Total	Total	Total
Units		mg/l	mg/l	mg/l	mg/l	pH units	pH units	mV	umhos/cm	deg C	mg/l	mg/l	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l
Sys Loc Code	Sample Date																	
MS002 - Spring Mine Lake	08/02/2010	**44.2**	< 100	< 2	**7.85**	--	**9.07**	**-21.5**	**103**	**23.09**	**42.9**	**78**	**13 j**	**8690**	**67.7**	**5160**	**2270**	**4680**
MS002 - Spring Mine Lake	10/27/2010	--	--	--	**8.57**	--	**7.12**	**87.2**	**120**	**8.46**	--	--	--	--	--	--	--	--
MS002 - Spring Mine Lake	04/19/2011	< 10	--	< 0.5	**6.8**	**7**	**8.87**	**2.2**	**38**	**0.57**	**8.83**	**61**	**1.79**	**2100**	**113**	**870**	**320**	< 2000
MS002 - Spring Mine Lake	06/13/2011	**37.2**	--	**0.6**	**6.39**	**8.1**	**7.9**	**119**	**116**	**18.8**	**44.7**	**89**	**9.85**	**9210**	**139**	**5280**	**2060**	**5050**
MS009 - Pit 5NW Shoreline	10/25/2010	**269**	--	**3.82**	**9.83**	--	**4.3**	**-15.2**	**2087**	**10.17**	**1150**	**1710**	**1070**	**83100**	< 50	**228000**	**52700**	**94000**
MS009 - Pit 5NW Shoreline	04/20/2011	**18.3**	--	< 0.5	**7.7**	**8.8**	**8.8**	**-33**	**109**	**2.62**	**32.4**	**39**	**21.1**	**5510**	< 50	**4520**	**2660**	**3450**
MS009 - Pit 5NW Shoreline	06/13/2011	**262**	--	**3.58**	**9.1**	**8.5**	**8.5**	**123.4**	**2023**	**18.24**	**1110**	**1661**	**933**	**83500**	< 50	**218000**	**47100**	**92600**
MS024 - Pit 5NE Shoreline	08/05/2010	**216**	**180**	**1.68**	**4.60**	--	**8.18**	--	**2149**	**23.38**	**1200**	**1700**	**1100**	**75800**	< 50	**245000**	**76500**	**79900**
MS024 - Pit 5NE Shoreline	10/25/2010	**229**	--	**1.76**	**6.24**	--	**5.29**	**-4.0**	**2281**	**10.99**	**1260**	**1950**	**1230**	**82200**	< 50	**257000**	**81700**	**84000**
MS024 - Pit 5NE Shoreline	04/20/2011	**110**	--	**0.62**	**11.15**	**8.5**	**8.32**	**-37.4**	**679**	**2.13**	**315**	**464**	**258**	**29200**	< 50	**58700**	**23500**	**23200**
MS024 - Pit 5NE Shoreline	06/13/2011	**202**	--	**1.52**	**5.7**	**8.6**	**8.4**	**100**	**1966**	**18.8**	**1030**	**1576**	**988**	**66600**	< 50	**210000**	**67300**	**73700**
MS025 - Pit 5NE Shoreline	08/05/2010	**203**	**180**	**1.51**	**6.0**	--	**8.34**	--	**2104**	**22.28**	**1170**	**1670**	**1090**	**75600**	< 50	**238000**	**75100**	**77000**
MS025 - Pit 5NE Shoreline	10/25/2010	**227**	--	**1.69**	**5.34**	--	**6.46**	**-9.3**	**2263**	**11.39**	**1250**	**1940**	**1210**	**83800**	< 50	**252000**	**78600**	**82600**
MS025 - Pit 5NE Shoreline	04/20/2011	**89.2**	--	**0.6**	**10.73**	**8.3**	**8.2**	**-36.9**	**640**	**4.10**	**290**	**428**	**248**	**22600**	**96.7**	**56600**	**19100**	**19900**
MS025 - Pit 5NE Shoreline	06/13/2011	**187**	--	**1.42**	**7**	**8.6**	**8.4**	**93**	**1860**	**19.5**	**987**	**1547**	**936**	**65500**	< 50	**200000**	**62000**	**66400**
MS027 - Pit 5NE Shoreline	10/25/2010	**270**	--	**1.81**	**5.95**	--	**8.4**	**-19.7**	**2231**	**10.77**	**1210**	**1830**	**1160**	**67600**	< 50	**253000**	**83600**	**84100**
MS027 - Pit 5NE Shoreline	04/20/2011	**35.5**	--	< 0.5	**6.69**	**8.3**	**8.2**	**-40.9**	**1140**	**7.23**	**85.4**	**117**	**64.9**	**8990**	< 50	**15300**	**8550**	**7300**
MS027 - Pit 5NE Shoreline	06/13/2011	**248**	--	**2.48**	**7.3**	**8.5**	**7.8**	**85**	**2245**	**17.8**	**1170**	**1838**	**1120**	**61500**	< 50	**247000**	**80000**	**90200**
Pit 5NE - Surface	08/04/2010	**259**	--	**1.78**	**6.02**	--	**8.30**	--	**2295**	**20.88**	**1160**	**1720**	**1160**	**66100**	< 50	**241000**	**82600**	**85200**
Pit 5NE - 6M	08/04/2010	**270**	--	**1.81**	**0.54**	--	**7.64**	--	**2333**	**11.84**	**1210**	**1790**	**1200**	**78800**	< 50	**247000**	**83200**	**87300**
Pit 5NE - 17M	08/04/2010	**284**	--	**2**	**0.41**	--	**7.52**	--	**2480**	**6.38**	**1320**	**1920**	**1300**	**97700**	< 50	**262000**	**69500**	**95400**
Pit 5NE - Bottom	08/04/2010	**301**	--	**2.17**	**0.04**	--	**6.99**	--	**2721**	**5.63**	**1350**	**2040**	**1410**	**97600**	**476**	**269000**	**69400**	**100000**
Pit 5NE - Surface	05/17/2011	**247**	--	**1.92**	**8.8**	--	**8.50**	--	**2197**	**11.10**	**1100**	**1770**	**1040**	**60000**	< 50	**232000**	**78800**	**84300**
Pit 5NE - 10M	05/17/2011	**255**	--	**2.02**	**0.4**	--	**8.00**	--	**2391**	**4.80**	**1210**	**1890**	**1110**	**73400**	< 50	**250000**	**74500**	**89100**
Pit 5NE - 20M	05/17/2011	**257**	--	**2.09**	**0**	--	**7.80**	--	**2464**	**4.80**	**1240**	**2020**	**1130**	**77300**	< 50	**255000**	**76300**	**89200**
Pit 5NW - Surface	08/02/2010	--	--	--	**7.07**	--	**8.59**	--	**2126**	**22.52**	--	--	--	--	--	--	--	--
Pit 5NW - 6M	08/02/2010	--	--	--	**7.47**	--	**8.46**	--	**2141**	**20.50**	--	--	--	--	--	--	--	--
Pit 5NW - 30M	08/02/2010	--	--	--	**0.06**	--	**7.06**	--	**3085**	**6.00**	--	--	--	--	--	--	--	--
Pit 5NW - Bottom	08/02/2010	--	--	--	**0.04**	--	**7.10**	--	**3717**	**5.80**	--	--	--	--	--	--	--	--
Pit 5NW - Surface	08/04/2010	**250**	--	**3.76**	--	--	--	--	--	--	**1060**	**1620**	**970**	**79200**	< 50	**210000**	**51100**	**90100**
Pit 5NW - 6M	08/04/2010	**255**	--	**3.79**	--	--	--	--	--	--	**1070**	**1580**	**1040**	**79200**	< 50	**212000**	**53000**	**91300**
Pit 5NW - 30M	08/04/2010	**461**	--	**10.8**	--	--	--	--	--	--	**1660**	**2500**	**1600**	**174000**	**1690**	**298000**	**57800**	**170000**
Pit 5NW - Bottom	08/04/2010	**480**	--	**10.7**	--	--	--	--	--	--	**1710**	**2520**	**1590**	**180000**	**1130**	**306000**	**58200**	**172000**
Pit 5NW - 5M	05/17/2011	**260**	--	**4.02**	**10.0**	--	**8.30**	--	**2116**	**9.40**	**1070**	**1700**	**979**	**81900**	< 50	**210000**	**47100**	**87900**
Pit 5NW - 20M	05/17/2011	**448**	--	**10.5**	**0.2**	--	**7.10**	--	**2977**	**6.40**	**1610**	**2490**	**1350**	**157000**	**99.5**	**296000**	**51900**	**160000**
Pit 5NW - 45M	05/17/2011	**476**	--	**11**	**0**	--	**7.00**	--	**3112**	**5.80**	**1640**	**2640**	**1410**	**161000**	**934**	**302000**	**51800**	**159000**

Table 4-4
USGS Field Leach Test Results

Chemical Name / Total or Dissolved / Units		Alkalinity, total NA mg/l	Chloride NA mg/l	Dissolved oxygen NA mg/l	pH NA pH units	Redox (oxidation potential) NA mV	Specific Conductance NA umhos/cm	Temperature NA deg C	Hardness, total as CaCO3 NA ug/l	Sulfate NA mg/l	Calcium Dissolved ug/l	Iron Dissolved ug/l	Magnesium Dissolved ug/l	Potassium Dissolved ug/l	Sodium Dissolved ug/l
Sys Loc Code	Sample Date														
FLT-1	11/08/2010	**11**	< 0.5	**94.0**	**8.03**	**180.2**	**145.7**	**20.55**	< 50	**39**	**17100**	< 50	**2460**	**620**	< 2000
FLT-2	11/08/2010	< 10	< 0.5	**96**	**4.44**	**286**	**154**	**20.51**	< 50	**45.6**	**15400**	< 50	**1770**	**1100**	< 2000
FLT-3	11/08/2010	**18.1**	< 0.5	**97**	**9.21**	**165.5**	**66.74**	**20.5**	**81**	**8.34**	**8590**	**81**	**1060**	**500**	< 2000
FLT-4	11/08/2010	< 10	< 0.5	**96.4**	**7.16**	**267.1**	**78.34**	**20.49**	< 50	**18.3**	**7140**	< 50	**720**	< 250	< 2000
FLT-5	11/08/2010	**12.2**	< 0.5	**95**	**9.45**	**165.4**	**76.25**	**20.39**	**117**	**13.3**	**7220**	**117**	**1680**	**900**	< 2000
FLT-6	11/08/2010	**18**	< 0.5	**91.2**	**9.52**	**160.5**	**40.64**	**20.57**	**51.9**	**1.08**	**5130**	**51.9**	**950**	**310**	< 2000

Table 4-5
Mass Balance Sulfate Values and Basis

Term in Water Balance		Assigned Sulfate Concentration (mg/L)	Basis for Concentration
Area 5NE			
Groundwater		23	Cotter et al., 1965
Runoff from Stockpiles/Haul Roads	Runoff	21	Average of FLT* values
	Shallow GW	2969(±880)	Average seep concentration - MS019, MS020, MS021, MS023, "Seep"
Runoff from Pit Walls		21	Average of FLT values
Runoff from Undisturbed Areas	Runoff	0	Overland flow from undisturbed areas is assumed to contribute no sulfate load
	Shallow GW	34	Cotter et al., 1965
Area 5NW			
Groundwater		23	Cotter et al., 1965
Runoff from Stockpiles/Haul Roads	Runoff	21	Average of FLT values
	Shallow GW	2969(±880)	Average seep concentration - MS019, MS020, MS021, MS023, "Seep"
Runoff from Pit Walls		21	Average of FLT values
Runoff from Undisturbed Areas	Runoff	0	Overland flow from undisturbed areas is assumed to contribute no sulfate load
	Shallow GW	34	Cotter et al., 1965
Inflow from 5NE		1165	Measured average of samples
SD033			
Runoff from Stockpiles/Haul Roads	Runoff	21	Average of FLT values
	Shallow GW	1793(±1221)	Average seep concentration - MS013B, MS014
Runoff from Undisturbed Areas	Runoff	0	Overland flow from undisturbed areas is assumed to contribute no sulfate load
	Shallow GW	34	Cotter et al., 1965
Inflow from 5NW		991	Measured average of surface samples

* FLT = USGS Field Leach Test

Table 4-6
Statistical Description of Seepage Sulfate Concentrations

Statistical Description of Seepage Sulfate Concentration		
	Reporting to Area 5NW and 5NE Pits	Reporting to Spring Mine Creek (SD033)
Mean (mg/L)	2969	1793
Standard Dev. (mg/L)	1457	1164
Minimum (mg/L)	308	85
Maximum (mg/L)	4570	2610
Count	13	6
95% Confidence Level	880	1221

Table 4-7
Proportional Stockpile Sulfate Load Allocation

	Divided by surface watersheds. . .	Surface Area	Surface Area	Volume	Mass waste rock*	Proportional Area	Proportional Volume	Sulfate Load (Low Scenario)	Sulfate Load (Mean Scenario)	Sulfate Load (High Scenario)
Runoff from Stockpiles/Haul Roads	**Area 5NW Pit**	ft^2	Acres	ft^3	kg			mt/yr	mt/yr	mt/yr
	5031E	248,000	5.7	16,304,121	1.13E+09	12%	10%		0.06	
	5027S	614,175	14.1	52,591,726	3.64E+09	29%	33%		0.16	
	5026S	297,975	6.8	29,029,103	2.01E+09	14%	18%		0.08	
	5022N	17,450	0.4	369,522	2.56E+07	1%	0%		0.00	
	Combined 5001-4003-5025-5024S	915,350	21.0	60,580,893	4.19E+09	44%	38%		0.24	
	Sum	*2,092,950.00*	*48.05*	*158,875,365.00*	*1.10E+10*				***0.54***	
	Remnant Spring Mine Creek									
	5031W	209,525	4.8	13,146,820	9.10E+08					
	Area 5NE Pit									
	5022S	254,050	5.8	6,042,116	4.18E+08	0%	5%		0.00	
	5020S	845,700	19.4	52,034,491	3.60E+09	1%	47%		0.01	
	5030	400,850	9.2	24,143,695	1.67E+09	0%	22%		0.00	
	5021S	109,624,063	2,516.6	1,530,375	1.06E+08	98%	1%		0.98	
	Combined 5001-4003-5025-5024E	491,025	11.3	27,399,866	1.90E+09	0%	25%		0.004	
	Sum	*111,615,687.50*	*2,562.34*	*111,150,542.25*	*7.70E+09*				***1.00***	
	SD-033									
	5004_5029_5028S	1,199,400	27.5	42,487,872	2.94E+09	37%	22%		0.13	
	5027N	273,950	6.3	18,470,292	1.28E+09	9%	9%		0.03	
	Combined 5001-4003-5025-5024W	774,850	17.8	64,879,594	4.49E+09	24%	33%		0.081	
	5026N	974,325	22.4	69,502,481	4.81E+09	30%	36%		0.10	
	Sum	*3,222,525.00*	*73.98*	*195,340,239.06*	*1.35E+10*				***0.34***	
	Outside									
	5004_5029_5028N	446,250	10.2	19,579,386	1.36E+09	17%	12%		0.05	
	Combined 5001-4003-5025-5024N	189,400	4.3	15,497,295	1.07E+09	7%	10%		0.013	
	5020N	534,425	12.3	35,950,719	2.49E+09	20%	22%		0.00	
	5021N	1,461,325	33.5	89,321,775	6.18E+09	56%	56%		0.01	
	Sum	*2,631,400.00*	*60.41*	*160,349,175.00*	*1.11E+10*				***0.08***	

	Divided by bedrock watersheds. . .	Surface Area	Surface Area	Volume	Mass waste rock*	Proportional Area	Proportional Volume	Sulfate Load (Low Scenario)	Sulfate Load (Mean Scenario)	Sulfate Load (High Scenario)
Shallow Groundwater from Stockpiles/Haul Roads	**Area 5NW Pit**	ft^2	Acres	ft^3	kg			mt/yr	mt/yr	mt/yr
	5031	457,425	10.5	29,447,191	2.04E+09	51%	45%	48	68	88
	5027S	385,400	8.8	31,634,140	2.19E+09	43%	49%	51	73	94
	5026S	46,375	1.1	3,789,825	2.62E+08	5%	6%	6	9	11
	Sum	*889,200.00*	*20.41*	*64,871,155.63*	*4.49E+09*			***105***	***149***	***193***
	Area 5NE Pit									
	5022	269,850	6.2	6,370,312	4.41E+08	6%	2%	4	6	8
	5020S	797,850	18.3	47,542,547	3.29E+09	17%	16%	33	47	61
	5030	400,850	9.2	24,143,695	1.67E+09	8%	8%	17	24	31
	5021S	2,349,700	53.9	170,368,700	1.18E+10	49%	57%	120	170	220
	Combined 5001-4003-5025-5024E	943,800	21.7	51,934,588	3.60E+09	20%	17%	36	52	67
	Sum	*4,762,050.00*	*109.32*	*300,359,841.69*	*2.08E+10*			***211***	***300***	***388***
	SD-033									
	5026N	1,225,800	28.1	94,733,263	6.56E+09	34%	41%	30	96	161
	5027N	503,250	11.6	39,445,488	2.73E+09	14%	17%	13	40	67
	5004_5029_5028S	1,177,275	27.0	41,754,206	2.89E+09	32%	18%	13	42	71
	Combined 5001-4003-5025-5024W	744,550	17.1	57,275,113	3.97E+09	20%	25%	18	58	97
	Sum	*3,650,875.00*	*83.81*	*233,208,068.75*	*1.61E+10*			***75***	***235***	***395***
	Outside									
	5004_5029_5028N	468,275	10.8	20,306,031	1.41E+09	20%	14%	7	20	34
	Combined 5001-4003-5025-5024N	680,750	15.6	59,036,731	4.09E+09	29%	40%	30	59	89
	5020N	582,475	13.4	40,441,850	2.80E+09	25%	27%	28	40	52
	5021N	642,575	14.8	28,574,687	1.98E+09	27%	19%	20	28	37
	Sum	*2,374,075.00*	*54.50*	*148,359,299.50*	*1.03E+10*			***85***	***149***	***212***

* Assumes a bulk density of 1.84 long tons/cubic yard (J. Tieberg, personal communication)
** Assumes 0.24 wt.% sulfide in waste rock (Barr, 2010).
*** Assumes sulfide oxidation rate of $1.1x10^9$ kg sulfate/kg sulfide/second (Barr, 2010).

Table 4-8
Sulfate Load Allocation by Area

		Sulfate Load, mt/yr			Sulfate Load, as % of load leaving SD033*		
		Low Scenario	Mean Scenario	High Scenario	Low Scenario	Mean Scenario	High Scenario
Area 5NE							
Stockpiles/Haul Roads							
	5020	33	47	61	4%	6%	8%
	5021	121	171	221	15%	21%	27%
	Combined 5001-4003-5025-5024	36	52	67	4%	6%	8%
	5022 above water	4	6	8	1%	1%	1%
	5030 above water	17	24	31	2%	3%	4%
In-Pit Load		178	90	1	22%	11%	0%
Pit Walls		2	2	2	0%	0%	0%
Deep Groundwater		2	2	2	0%	0%	0%
Undisturbed Areas		0	0	0	0%	0%	0%
Area 5NW							
Stockpiles/Haul Roads							
	Combined 5001-4003-5025-5024	0.2	0.2	0.2	0%	0%	0%
	5026	6	9	11	1%	1%	1%
	5027	51	73	94	6%	9%	12%
	5031	48	68	88	6%	8%	11%
Inflow from 5NE		394	394	394	--	--	--
In-Pit Load		106	62	18	13%	8%	2%
Pit Walls		1	1	1	0%	0%	0%
Deep Groundwater		2	2	2	0%	0%	0%
Undisturbed Areas		0	0	0	0%	0%	0%
SD033							
Stockpiles/Haul Roads							
	5026	31	96	161	4%	12%	20%
	5027	13	40	67	2%	5%	8%
	Combined 5004-5028-5029	14	42	71	2%	5%	9%
	Combined 5001-4003-5025-5024	18	58	97	2%	7%	12%
Inflow from 5NW		609	609	609	--	--	--
"In-Pit" Load		131	-29	-189	16%	-4%	-23%
Undisturbed Areas		1	1	1	0%	0%	0%
Load Reporting to North							
	5020	28	40	52	--	--	--
	5021	20	29	37	--	--	--
	Combined 5001-4003-5025-5024	30	59	89	--	--	--
	Combined 5004-5028-5029	7	21	34	--	--	--

** Totals may not add to 100%, due to rounding*

Table 4-9

Sulfate Load as a Percentage of SD033 Sulfate Load, Listed in Order of Importance for Each Scenario

	Sulfate Source	Percent of SD033 load
Low Scenario	5NE In-Pit Load	22
	SD033 "In-Pit" load	16
	Stockpile 5021	15
	5NW In-Pit Load	13
	Stockpile 5027	8
	Stockpile 5001-4003-5025-5024	6
	Sum	***80***
Mean Scenario	Stockpile 5021	21
	Stockpile 5027	14
	Stockpile 5026	13
	Stockpile 5001-4003-5025-5024	13
	5NE In-Pit Load	11
	Stockpile 5031	8
	Sum	***80***
High Scenario	Stockpile 5021	27
	Stockpile 5026	21
	Stockpile 5027	20
	Stockpile 5001-4003-5025-5024	20
	Sum	***88***

Table 4-10
Estimate of sulfide Depletion Time

Total P and Q waste rock			Estimated sulfide	Estimated sulfide	Sulfur**	Mass sulfate removed from Area 5 in 2010-2011		Sulfur	Years to deplete
yd3	ft3	kg*	wt. %	kg	moles	mt	kg	moles	yrs
1.38E+07	3.73E+08	2.58E+10	0.24%	6.19E+07	1.03E+09	970	9.70E+05	1.01E+07	1.0E+02
1.38E+07	3.73E+08	2.58E+10	1.00%	2.58E+08	4.30E+09	970	9.70E+05	1.01E+07	4.3E+02
1.38E+07	3.73E+08	2.58E+10	2.00%	5.16E+08	8.60E+09	970	9.70E+05	1.01E+07	8.5E+02

* Bulk density is 1.84 long tons per cubic yard (J. Tieberg, personal communication)
** Sulfide approximated as pyrite (FeS_2)

Table 5-1 Summary of water chemistry concentrations and parameter values.

Field and laboratory data for Bear Creek (control stream), Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1) for Summer (July 26, 2010), Fall (mean of Sept 14 , 2010 and Oct 26, 2010), and Spring (June 2, 2011).

Site	**Bear Creek (Control stream)**			**Upper Spring Mine Creek (SD033)**			**Lower Spring Mine Creek (PM12.1**		
Sampling date	**Summer '10**	**Fall '10**	**Spring '11**	**Summer '10**	**Fall '10**	**Spring '11**	**Summer '10**	**Fall '10**	**Spring '11**
General Parameters (mg/L unless noted)									
Total Alkalinity	39.3	43.75	35.7	336	364	341	197	173.5	120
Biochemical Oxygen Demand (5-day)	2	1.75	1.5	1.2	1.35	1.2	1.5	1.35	1.5
Dissolved Organic Carbon	35.4	16.7	17	4	4.75	4.9	13.7	11.35	16.2
Total Organic Carbon	35.3	20.6	17.4	3.9	4.75	5	14.4	15.35	16
Chemical Oxygen Demand	92.7	58.1	56.9	5	13.5	19.2	37.7	28.15	33.4
Chloride	1.26	0.745	0.25	4.33	4.4	3.88	1.14	2.46	1.17
Dissolved oxygen	3.8	5.13	5.49	7.47	7.32	9.4	5.34	7.545	7.16
Total Hardness, as CaCO3	51.4	54.35	39.9	1300	1275	1260	396	454	330
Nitrate + Nitrite	0.05	0.05	0.05	0.19	0.205	0.33	0.05	0.05	0.05
Total Nitrogen (kjeldahl)	2.21	2.35	0.25	1.02	1.485	0.76	1.35	1.115	1.14
Total Nitrogen (N2)	2.21	2.45	0.25	1.21	1.675	1.09	1.45	1.195	1.14
pH	6.59	6.61	6.96	7.82	7.855	8.23	7.6	7.495	7.71
Total Phosphorus	0.056	0.036	0.021	0.025	0.011	0.02	0.044	0.02	0.022
Total Dissolved Solids	94	81.5	77	1880	1825	1780	531	602	490
Total Suspended Solids	2.5	20.15	1.6	3.6	3	4.8	7.6	0.85	2.8
Specific Conductance µmhos@ 25°C	90	95.55	55	2350	2378	2241	846	943	685
Sulfate	0.5	1.18	0.5	1110	1090	961	258	337	235
Temperature (°C)	20.82	10.71	12.77	13	11.075	6.47	20.07	11.025	12.76
Turbidity (NTU)	5.1	3.2	0	0	0	0	0.1	0	0

Site	Bear Creek (Control stream)			Upper Spring Mine Creek (SD033)			Lower Spring Mine Creek (PM12.1		
Sampling date	**Summer '10**	**Fall '10**	**Spring '11**	**Summer '10**	**Fall '10**	**Spring '11**	**Summer '10**	**Fall '10**	**Spring '11**
Metals (µg/L unless noted)									
Antimony			0.25			0.25			0.25
Barium	35.6	35.7	22.7	3.2	4.0	3.1	23.9	20.75	18.5
Beryllium	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.1
Boron	25	25	25	169	157	158	25	25	50.4
Cadmium	0.10	0.02	0.10	0.10	0.01	0.10	0.10	0.01	0.1
Calcium (mg/L)	15.20	17.15	12.80	99.30	90.00	85.80	39.00	41.9	33
Chromium	0.50	2.09	0.50	0.50	0.50	0.50	0.50	0.5	0.5
Cobalt	0.53	0.68	0.10	0.37	0.47	0.31	0.29	0.1	0.1
Copper	0.82	1.12	0.35	1.61	2.00	1.62	0.77	0.81	0.35
Iron	6490	2940	1110	25	88	148	446	151.5	320
Lead	0.25	0.36	0.25	0.25	0.03	0.25	0.25	0.0275	0.25
Magnesium (mg/L)	3.26	2.80	1.93	255.00	256.00	253.00	72.40	84.8	60.2
Manganese	218.0	284.0	140.0	326.0	1273.0	344.0	399.0	96.55	161
Molybdenum	0.41	0.15	0.10	3.32	4.20	3.63	0.38	0.375	0.46
Nickel	2.12	1.86	0.67	3.63	4.21	2.46	1.51	1.36	0.88
Potassium	0.55	1.14	0.92	57.40	55.80	49.50	15.40	18.15	12.7
Selenium	0.50	0.20	0.06	0.50	0.79	0.52	0.50	0.338	0.0605
Silver	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.1
Sodium (mg/L)	1.0	1.0	1.0	95.3	93.2	89.2	30.6	35.1	23
Thallium	0.26	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.1
Tin	0.25	0.25		0.25	0.25		0.25	0.25	
Zinc	3.00	4.70	3.00	3.00	3.00	3.00	3.00	3	3

Table 5-2 Habitat characteristics and macroinvertebrate data summary for stream sampling sites

Parameter	Bear Creek (reference)		Lower Spring Mine Creek (PM12.1)		Upper Spring Mine Creek (SD033)	
Date Sampled	9/16/2010	6/2/2011	9/16/2010	6/2/2011	9/16/2010	6/2/2011
Watershed	Embarrass River	Embarrass River	Embarrass River	Embarrass River	Embarrass River	Embarrass River
UTM coordinate (NAD 83, Zone 15) Upstream End of Reach	5285620, 560384	5285620, 560384	5280431, 570956	5280431, 570956	5275398, 569845	5275398, 569845
UTM coordinate (NAD 83, Zone 15) Downstream End of Reach	5285518, 560364	5285518, 560364	5280321, 570995	5280321, 570995	5275536, 569817	5275536, 569817
Stream width at cross-section (ft)	13.0	9.5	8.0	6.0	8.2	4.5
Maximum depth at cross-section (ft)	1.8	1.8	0.8	1.1	0.7	0.8
Discharge (cfs)	7.06	8.62	2.55	4.82	1.00	1.15
Water temperature (°C)	10.2	15.7	10.1	16.5	13.6	8.3
pH	6.9	6.4	7.7	7.8	8.2	8.2
Specific Conductivity (µmhos)	105	62	1062	664	2340	2006
Dissolved oxygen (ppm)	6.4	6.8	8.9	9.5	11.3	11.7
Habitat types (in-stream cover)	undercut bank/overhanging vegetation	undercut bank/overhanging vegetation	undercut banks	undercut banks	riffles	woody debris
	woody debris	woody debris	emergent vegetation	submerged vegetation	woody debris	riffles
	emergent vegetation	submerged vegetation	woody debris	woody debris	sediment	sediment
	sediment	sediment				
Substrate	muck	muck	sand	sand	cobble	boulder
	detritus	detritus	detritus	detritus	gravel	gravel
					sand	sand
					detritus	detritus
Riparian zone vegetation	herbaceous/shrub	herbaceous/shrub	herbaceous/shrub	herbaceous/shrub	forest/shrub	forest/shrub
Qualitative Habitat Evaluation Index (QHEI)[3]	---	44	---	44	---	73

Parameter	Bear Creek (reference)		Lower Spring Mine Creek (PM12.1)		Upper Spring Mine Creek (SD033)	
Date Sampled	9/16/2010	6/2/2011	9/16/2010	6/2/2011	9/16/2010	6/2/2011
Shannon-Wiener Diversity Index (H')	2.91	2.42	2.31	2.43	2.23	2.83
Evenness	0.75	0.64	0.61	0.66	0.66	0.82
Hilsenhoff Biotic Index (HBI)[2]	6.36	5.94	5.33	5.10	5.82	5.60
	Fairly Poor	Fair	Good	Good	Fair	Fair
Richness (Family)	32	34	33	26	20	19
Richness (Genera)	46	43	42	35	25	29
# of Insect Genera	38	33	37	32	22	26
% Insects of total individuals present at site	63%	61%	68%	77%	96%	98%
# Ephemeroptera, Plecoptera and Trichoptera (EPT) Genera	14	9	19	15	7	9
# Ephemeroptera, Plecoptera and Trichoptera (EPTO) Genera	19	12	22	20	7	9
% EPT of total individuals present at site	24%	37%	44%	46%	22%	11%
% EPTO of total individuals present at site	28%	38%	45%	46%	22%	11%
% Diptera (true flies) of total individuals present at site	30%	23%	20%	26%	70%	86%
% Chironomids (bloodworms) of Diptera	53%	31%	15%	15%	6%	43%
% Simulidae of total individuals present at site	11%	15%	16%	20%	64%	47%

[1]The UTM coordinates are given for the furthest downstream point of the sample reach.

[2]See Table 6 for a summary of HBI values and descriptors.

[3]Based on MPCA Stream Habitat Assessment

Table 5-3 Results of Analysis of Variance (F-values and p-values).

Showing variables that were significantly different ($p < 0.0015$) among the sites, Upper Spring Mine Creek (SD033), Lower Spring Mine Creek (PM 12.1) and Bear Creek (control stream)

Parameter	F-value	p-value	Tukey's HSD test [1]		
			Upper Spring Mine	Lower Spring Mine	Bear Creek
Alkalinity	194.14	0.0001	A	B	C
Hardness, total as $CaCO_3$	1017.3	<0.0001	A	B	C
pH	185.96	0.0001	A	B	C
Total Dissolved Solids	1304.3	<0.0001	A	B	C
Specific Conductance	489.3	<0.0001	A	B	C
Sulfate	3149.2	<0.0001	A	B	C
Barium	209.6	<0.0001	C	B	A
Boron	54.9	0.0012	A	B	B
Calcium	513.8	<0.0001	A	B	C
Magnesium	1062.6	<0.0001	A	B	C
Molybdenum	127.6	0.0002	A	B	B
Potassium	562.6	<0.0001	A	B	C
Sodium	900.17	<0.0001	A	B	C

[1] For the Tukey's HSD test, letters earlier in the alphabet indicate higher values for the respective parameter, and sites with the same uppercase letter were not significantly different. (E.g. for Boron concentration, Lower Spring Mine Creek (PM 12.1) was not significantly different from Bear Creek (control stream); however, both Lower Spring Mine Creek (PM 12.1) and Bear Creek were significantly different from Upper Spring Mine Creek (SD033)).

Table 5-4 Comparison of average water chemistry concentrations and parameter values with applicable Minnesota Water Quality (WQ) Standards.

Bear Creek, Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM12.1)

Site	Bear Creek (control stream)	Upper Spring Mine Creek (SD033)	Lower Spring Mine Creek (PM 12.1)	WQ Criterion
General Parameters (mg/L, unless noted)				
Chloride	0.75	4.20	1.59	230
Dissolved oxygen	4.81	8.06	6.68	5.0
Total Hardness, as CaCO3	48.55	1278.33	393.33	305
pH	6.72	7.97	7.60	6.5-8.5
Total Dissolved Solids	84.17	1828.33	541.00	700
Specific Conductance µmhos@ 25°C	80.18	2323.00	824.67	1000
Metals (µg/L, unless noted)				
Arsenic	1.01	0.99	0.42	53
Boron	25.00	161.17	33.47	500
Cadmium [1]	0.07	0.07	0.07	0.32-3.4
Chromium [1]	1.03	0.50	0.50	55.4-644
Cobalt	0.44	0.38	0.16	5
Copper [1]	0.76	1.74	0.64	3.6-23
Lead [1]	0.29	0.18	0.18	0.41-19
Nickel [1]	1.55	3.43	1.25	40.4-509
Selenium	0.25	0.60	0.30	5
Silver	0.10	0.10	0.10	1
Thallium	0.15	0.10	0.10	0.56
Zinc [1]	3.57	3.00	3.00	27.1-343

[1] For the metals, cadmium, chromium, copper, lead, nickel and zinc, the criteria (listed as a range) are dependent upon hardness. Values marked in red were higher than the WQ criterion.

Table 5-5 Water Quality Classification Index[1].

Bear Creek (control stream), Upper Spring Mine Creek (SD033) and Lower Spring Mine Creek (PM 12.1)

Site	Bear Creek (Control Stream)		Upper Spring Mine Creek (SD033)		Lower Spring Mine Creek (PM 12.1)	
Parameter	**Index Value**	**Classification**	**Index Value**	**Classification**	**Index Value**	**Classification**
Biochemical Oxygen Demand (5-day)	1.16	Excellent-Acceptable	0.83	Excellent	0.96	Excellent
Chemical Oxygen Demand	6.92	Slightly Polluted-Polluted	1.26	Excellent-Acceptable	3.31	Acceptable-Slightly Polluted
Chlorides	0.02	Excellent	0.14	Excellent	0.05	Excellent
Dissolved oxygen	4.8	Slightly Polluted-Polluted	1.04	Excellent	2.4	Acceptable-Slightly Polluted
pH, standard units	0.56	Excellent	0.94	Excellent	0.36	Excellent
Solids, total suspended	<1	Excellent	<1	Excellent	<1	Excellent
Iron	9.49	Heavily Polluted	0.91	Excellent	2.03	Acceptable-Slightly Polluted
Manganese	2.34	Acceptable-Slightly Polluted	4.95	Slightly Polluted-Polluted	2.37	Acceptable-Slightly Polluted

[1] Water Quality Classification Index based on Prati et al. (1971)

Table 5-6 Whole Effluent Toxicity (WET) test results.

Outfall SD033 and downstream receiving waters.

Test #	Site/Dilution Water	Sampling Date	WET Report Date	Survival		Reproduction		
				100% Effluent(1)	75% Effluent	Number of young per adult C. dubia	IC25 (%)	NOEC (%)
Test #1	SD033/Bear Creek	7/26/2010	8/12/2010	100%	100%	20.2 / 30.3	72.5%	50.0%
Test #2	SD033/Synthetic Lab Water	10/26/2010	11/8/2010	100%	100%	17.0 / 18.3	>100	100%
	SD033/Embarrass River (PM12)	10/26/2010	11/8/2010	100%	100%	17.0 / 16.7	>100	100%
	Lower Spring Mine Creek (PM12.1)	10/26/2010	11/8/2010	100%	100%	20.3	---	---
Test #3	SD033/Synthetic Lab Water	6/3/2011	6/16/2011	100%	100%	8.0 / 19.2	50%	<12.5
	SD033/Embarrass River (PM12)	6/3/2011	6/16/2011	100%	100%	8.0 / 19.1	83%	75%
	Lower Spring Mine Creek (PM12.1)	6/3/2011	6/16/2011	100%	100%	13.7	---	---

(1) 100% effluent = 100 percent Bear Creek, Laboratory or Embarrass River water.

Table 5-7 Whole Effluent Toxicity (WET) testing results and corresponding chemical analysis data

(Data related to SD033 and SD026, background water (Bear Creek), downstream waters and receiving waters (Embarrass River and Partridge River))

Site	Sampling Date	Report Date	Young Production per Adult *C. dubia*	Sp Con (us/cm)	TDS (mg/L)	Cl (mg/L)	Alk (mg/L)	SO_4 (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	Hardness (mg/L)	DOC or TOC (mg/L)	TP (mg/L)	TN (mg/L)	As (µg/L)	Ba (µg/L)	B (µg/L)	Co (µg/L)	Cu (ug/L)	Fe (µg/L)	Mn (µg/L)	Mo (ug/L)	Ni (ug/L)	K (mg/L)	Se (µg/L)	Zn (ug/L)
Outfall SD033	7/26/2010	8/12/2010	20.2	2350	1,880	4.33	336	1,110	99.3	255	95.3	1,300	4	0.025	1.21	**0.50**	3.2	169	0.37	1.61	**25**	326	3.32	3.63	57.4	**0.500**	**3.00**
Bear Creek	7/26/2010	8/12/2010	30.3	90	94	1.26	39.3	0.5	15.2	3.26	1	51.4	35.4	0.056	2.21	1.96	35.6	25	0.53	0.82	6,490	218	0.41	2.12	0.55	0.5	3.00
Outfall SD033	10/26/2010	11/8/2010	17.0	2420	1,880	4.9	363	1,140	98.2	269	95	1,350	4.9	0.013	2.05	1.47	4.61	155	0.58	2.14	150	1700	3.72	5.06	53.4	0.452	**3.00**
Bear Creek	10/26/2010	11/11/2010	22.2	97	56	0.92	39.9	1.35	15.4	2.65	1	49.4	8.3	0.056	1.12	0.5	43.8	25	1.12	1.85	3,270	453	0.1	2.63	1.53	0.102	6.39
Embarrass River-PM12	10/26/2010	11/8/2010	16.7	135	90	4.96	50.3	1.65	13.8	5.4	4.07	56.7	19.4	0.037	1.76	**5.00**	18.1	**25**	0.50	0.58	2150	184	0.25	1.12	1.1	0.085	**3.00**
Lower Spring Mine Creek-PM 12.1	10/26/2010	11/8/2010	20.3	876	551	2.76	159	311	39.6	80.1	32.4	429	9.6	0.024	1.19	**0.50**	20.4	**25**	**0.10**	0.86	172	118	0.39	1.43	17.8	0.096	**3.00**
Outfall SD033	6/2/2011	6/16/2011	8.0	2210	1780	3.88	341	961	85.8	253	89.2	1260	4.9	0.02	1.09	0.93	3.09	158	0.31	1.62	148	344	3.63	2.46	49.5	0.515	**3.00**
Bear Creek	6/2/2011	6/16/2011	22.6	82	77	0.25	35.7	0.5	12.8	1.93	1	39.9	17	0.021	0.25	0.25	22.7	25	0.1	0.35	1110	140	0.1	0.67	0.92	0.0605	3.00
Embarrass River-PM12	6/2/2011	6/16/2011	19.1	71	79	2.33	27	**0.5**	8.36	3.25	2.88	34.2	32.5	0.022	1.56	0.53	10.9	**25**	0.35	1	1420	71.2	**0.10**	1.36	0.3	0.0605	**3.00**
Lower Spring Mine Creek-PM12.1	6/2/2011	6/16/2011	13.7	684	490	1.17	120	235	33	60.2	23	330	16	0.022	1.14	**0.25**	18.5	50.4	**0.10**	**0.35**	320	161	0.46	0.88	12.7	0.0605	**3.00**
Outfall SD026	7/26/2010	8/12/2010	18.2	1231	747	11.4	548	170	81.5	109	46.9	652	5.0	0.042	0.91	1.80	38.9	260	0.89	2.02	1,980	1,370	36.20	2.50	8.9	**0.500**	9.8
Bear Creek	7/26/2010	8/12/2010	30.3	90	94	1.26	39	0.5	15.2	3.26	1	51.4	35	0.056	2.21	1.96	35.6	25	0.53	0.82	6,490	218	0.41	2.12	0.55	0.5	3.0
Outfall SD026	10/26/2010	11/8/2010	18.6	1125	637	12.8	474	155	79	102	42.1	617	5.4	0.014	0.61	**0.50**	17.6	239	**0.10**	0.91	185	121	24.00	2.46	8.6	0.037	**3.0**
Partridge River	10/26/2010	11/8/2010	22.1	336	185	10.0	70	74.4	36.4	16.2	9.96	158	15	0.013	1.04	**0.50**	12.9	169	0.25	3.15	388	170	1.60	3.64	2.3	0.762	6.4
Second Creek-PM 17	10/26/2010	11/8/2010	20.7	1116	715	17.2	322	303	77.5	111	24.3	651	11	0.02	0.94	1.74	22.9	87.4	**0.10**	0.74	375	148	6.62	3.00	7.3	0.095	**3.0**
Outfall SD026	6/2/2011	6/16/2011	11.4	1059	646	9.43	429	150	77.6	96.4	34.9	591	5	0.016	0.68	0.25	16.4	214	0.1	0.35	325	173	20.6	1.58	6.57	0.061	3
Partridge River	6/2/2011	6/16/2011	18.0	144	134	2.92	28.9	23.8	14.3	6.35	4.14	61.8	29	0.024	1.59	**0.25**	8.9	55.7	0.29	3.96	858	106	0.79	2.55	1.2	0.607	**3.0**
Second Creek-PM 17	6/2/2011	6/16/2011	13.3	1459	1210	5.92	274	613	51.9	188	29.3	904	13	0.022	1.19	0.73	16.7	107	0.32	**0.35**	524	420	5.02	1.82	10.0	0.0605	**3.0**

Chemical abbreviations in the table defined below:

Bold= below detectioni limit, value set to 1/2 detection limit

Sp Con=	Specific conductance
TDS	Total dissolved solids
Cl	Chloride
Alk	Alkalinity
SO_4	Sulfate
Ca	Calcium
Mg	Magnesium
Na	Sodium
Hardness	Hardness
DOC or TOC	Dissolved or Total Organic Carbon
TP	Total Phosphorus
TN	Total Nitrogen
As	Arsenic
Ba	Barium
B	Boron
Co	Cobalt
Cu	Copper
Fe	Iron
Mn	Manganese
Mo	Molybdenum
Ni	Nickel
K	Potassium
Se	Selenium
Zn	Zinc

Table 5-8 Comparison of mining outfalls to background surface waters.

Average concentrations of constituents monitored which are lower in mining outfalls (SD033 and SD026 combined) and parameters that are higher in mining outfalls compared to background surface waters.

(Averages of these parameters are also provided for background waters (Bear Creek, Partridge River, and Embarrass River--combined) and waters consisting of mixtures of mining and background waters (defined as Mining Influenced Water and includes Trimble Creek and Second Creek))

	Parameters Lower Due to Properties of Mine Pit Waters							Parameters Elevated Due to Mining					
Site	Barium (µg/L)	Cobalt (µg/L)	Copper (ug/L)	Iron (µg/L)	DOC or TOC (mg/L)	TP (mg/L)	Total N (mg/L)	Nickel (ug/L)	Magnesium/ Calcium	Alkalinity (mg/L)	Sulfate (mg/L)	Potassium (mg/L)	Young Production
Permitted Outfalls	14.0	0.39	1.4	469	5	0.022	1.1	2.9	2.0	415	614	31	16
Background Waters	21.8	0.45	1.7	2241	22	0.033	1.4	2.0	0.3	42	15	1	23
Mining Influenced Waters	19.6	0.16	0.6	348	12	0.022	1.1	1.8	2.2	219	366	12	18

Table 5-9 Evaluation of the effect of parameter concentrations elevated by mining operations on C. dubia young production in WET tests.

(Young production predicted using the model equation provided in note 1 and other constituent concentrations provided in note 2.)

Condition	Magnesium/ Calcium	Alkalinity (mg/L)	Sulfate (mg/L)	Potassium (mg/L)	Predicted Number of Young Production
Mining Levels	2.0	415.2	614.3	30.7	15.5
	1.7	352.9	572.9	27.6	15.5
	1.4	294.1	477.4	23.0	15.6
Mining Influenced	1.2	245.1	397.8	19.2	15.7
	1.0	204.2	331.5	16.0	15.7
Background	0.8	170.2	276.3	13.3	15.8
	0.7	141.8	230.2	11.1	15.8
	0.3	42	366	12	15.3

Note 1:
Predictive Model #4; Young Production=31*1/(1+EXP(-(-2.02+0.0435*Ba-1.90*Co-0.225*Cu +0.769*Ni +0.000246*Fe+0.0564*DOC +19.5*TP-0.485*TN +0.0503*Mg/Ca -0.00101*Alk-0.00136*Sulfate +0.0354*Potassium)))

Note 2:
Concentration of other parameters used in the model includes: Barium (µg/L) = 14, Cobalt (µg/L) = 0.39, Copper (µg/L) = 01.4, Iron (µg/L) = 469, TOC or DOC (mg/L) = 4.9, TP (mg/L) = 0.022, Total N (mg/L) = 1.09, Nickel (µg/L) = 2.94.

Table 5-10 Total macroinvertebrates sampled in stream sites related to SD033

Taxa				HBI Value	Bear Creek (reference)		Lower Spring Mine Creek (SD033)		Upper Spring Mine Creek (PM12.1)	
Class	Order	Family	*Genus species*	(10-0)	2010	2011	2010	2011	2010	2011
Insecta	Coleoptera	Curculionidae	undetermined	5						
		Dystiscidae	*Agabus* adults	5					8	46
			Hydroporus adults	5					10	
			Dytiscus larvae			1				
			Nebrioporus					41		
		Elmidae	*Dubiraphia* larvae	6			48	21		
			Dubiraphia adults					1		
			Macronychus		16					
			Macronychus adults	5				2		
			Optioservus	4	8	2	80	9	100	4
			Stenelmis larvae	5	16		40	21		
			Stenelmis adult	5				7		
			undetermined	4						
		Gyrinidae	*Gyrinus* adults		48		40			
		Hydrophilidae	*Tropisternus* adults							2
	Diptera		undetermined Diperta larva						16	32
			undetermined Diptera pupae				8			
		Chironomidae	undetermined	5						
			Chironomus	10						
			Cladopelma							
			Cryptochironomus	8						
			Dicrotendipes							4
			Endochironomus	10	8					
			Labrundinia	7						
			Microtendipes	6	64		144			
			Paratendipes							4
			Polypedilum	6	32	6	8	12		
			Stenochironomus		136	4	8			
			Xenochironomus							
		Chironominae	*Pseudochironomus*							
			Microsectra			10				144
			Paratanyytarsus							
			Rheotanytarsus	6	60					
			Tanytarsus	6		20	24	33	20	4
		Diamesinae	*Diamesa*	5					8	112
		Orthocladiinae	*Undetermined*							
			Acricotopus	7						4
			Brillia					1		
			Chaetocladius							32
			Cricotopus	7						0
			Cricotopus (C.) bicinctus group							8
			Eukiefferiella	4					24	156
			Heterotrissocladius	4						
			Orthocladius	6		4	32		8	804
			Parametriocnemus	5					20	60
			Psectrocladius							
			Pseudorthocladius	0						
			Rheocricotopus	6		4				
			Symposiocladius							
			Thienemanniella	6		2				
			Tvetenia	5						
			Xylotopus	5	32					
		Prodiamesinae	*Prodiamesa*	8					8	
		Tanypodinae	*Ablabesmyia*	6		16				
			Larsia	6						
			Nilotanypus	6			16		8	
			Paramerina	6						
			Thienemannimyia group	6	4			10		
			Conchapelopia	6	64	4	24	16		
			Procladius	9	52	4				
			Zavrelimyia			4				
		Ceratopogonidae	*Bezzia/Palpomyia*	6	64					
			Ceratopogon	6	16					
			Culicoides							
			Probezzia	6			8		4	
			undetermined			6				41
		Dixidae	*Dixa*	1						
			Dixella			4				
		Empididae	undetermined Empidid larvae	6						
		Simuliidae	*Simulium*	6	308	162	1,424	396	972	1,068
			Simulium pupae						628	624
		Tabanidae	*undetermined Tabanid*	5	8					
		Tipulidae	*Antocha*	3					16	
			Dicronota	3					8	
			Limnophila	3			16			
			Lipsothrix							
			Tipula	6		2			2	
			undetermined Tipulidae				2	28		
		Ptychopteridae	*Ptycoptera*			1				
	Ephemeroptera	Ameletidae	*Ameletus*			4				
		Arthropleidae	*Arphroplea*			4				
		Baetidae	*Baetis brunneicolor*	4	12	264	1,976	506		
			Baetis flavistriga	4			32			
			Baetis intercalaris	6						
			Baetis tricaudatus	6						
			undetermined *Baetis*			4		1		4
			Acentrella	4		68				
			Labiobaetis	na	12					
			Acerpenna macdunnoughi	5	4					
			Callibaetis	7						
		Caenidae	*Caenis*	7			16	2		
		Ephemerellidae	*Attenella*	3			16			
		Heptageniidae	*Stenacron*	7	8		16	2		
			Maccaffertium		2		96	16		
		Leptophlebiidae	*Leptophlebia*		6		536			
		Siphlonuridae	*Siphlonurus*	4		2				
		Metretopodidae	*undetermined Genus*		16					
	Hemiptera	Corixidae	*Sigara*							1
	Odonata	Aeshnidae	*Aeshna*	5	10	8	56	3		
			Anax	8						
			Boyeria		12		14	1		
		Calopterygidae	*Calopteryx*	5	54		66	1		
		Coenagrionidae	undetermined Immatures							
		Gomphidae	*Gomphus*	6		1				
			immature Gomphus nymph		4					
		Cordulegasteridae	*Cordulegaster*	3				3		
		Corduliidae	*Somatochlora*		32	10		1		
		Libellulidae	undetermined (immature)							
	Megaloptera	Sialidae	*Sialis*	4	13					
	Lepidoptera	Pyralidae	*Acentria*	5			8			
			Paraponyx	5	8	1				
	Plecoptera	Perlidae	*Paragnetina*	1						
			Perlesta	5		22				
			immature Perlidae							
		Isoperliidae	*Isoperla*	2			168			

Taxa				HBI Value	Bear Creek (reference)		Lower Spring Mine Creek (SD033)		Upper Spring Mine Creek (PM12.1)	
Class	Order	Family	*Genus species*	(10-0)	2010	2011	2010	2011	2010	2011
		Nemouridae	*Amphinemora*							124
			Nemoura	1					4	123
		Taeniopterugidae	undetermined earlyi nstar nymph				16	8	240	
	Trichoptera	Arctopsychidae	*Parapsyche*	0					8	
		Goeridae	*Goera*	3			240	59		
		Helicopsychidae	*Helicopsyche*	3						
		Hydropsychidae	*Hydropsyche slossonae*	4			192	17	56	108
			Hydropsyche alhydra	4						
			Hydropsyche betteni	6	128	1	16	1	124	12
			Hydropsyche betteni pupae							
			undetermined *Hydropsyche*	4					36	
			Cheumatopsyche	5	144	4	8	29	20	16
		Hydroptilidae	*Hydroptila*	6						4
			Undet. Pupae						8	
		Lepidostomatidae	*Lepidostoma*	1		4		84		
		Leptoceridae	*Ceraclea*							
			Oecetis	8			8			
			Triaenodes	6				8		
			undetermined pupae					4		
		Limnephilidae	*Anabolia*	5		17		82		2
			Hydatophylax	2	8		24			
			Limnephilus	3	4		82	7		1
			Platycentropus					10		
			Pycnopsyche	4				8		
			very immature larva							
			undetermined pupae							
		Molannidae	*Molanna*	6			32	28		
		Philopotamidae	*Chimarra*	4						
		Phryganeidae	*Banksiola*							
			Ptilostomis	5	14		84		2	
			very immature larva							
		Polycentropodidae	*Nyctiophylax*	5			8			
			Polycentropus	6	208	13	80	9	40	2
		Psychomiidae	*Lype*	2	112		136			
		undetermined pupae	undetermined pupae			1		7		
Crustacea	Amphipoda	Talitridae	*Hyalella*	8	356	218	16	2		
		Gammaridae	*Gammarus*	6			2			
	Decapoda	Astacidae	*Orconectes*	6	2					
Malacostraca	Isopoda	undetermined	*undetermined*							
Entoprocta	Urnatellida	Urnatellidae	*Urnatella gracilis*		16					
Annelida	Oligochaeta		undetermined	8	588	160	48		28	32
	Arhynchnobdellida	Erpobdellidae	*Erpobdella punctata*		2	4				
	Rhynchnobdellida	Glossiphoniidae	*Helobdella stagnalis*	6						
			undetermined Leech			1				
Gastropoda	Basommatophora	Ancylidae	*Ferrisia*	7	32	4				
		Lymnaeidae	*Pseudosuccinea*	6						
			Fossaria	6						
			Stagnicola			1				
		Planorbidae	*Gyraulus*							
		Actinommidae	*Helisoma*	6		2	4			
		Physidae	*Physa*	7	22	3	2,570	218	48	26
	undetermined slug	undetermined slug	undetermined slug							
Bivalvia/Pelecypoda	Veneroida	Pisidiidae(clams)	*Musculium*	6					12	
			Pisidium	6		32		217		1
			Sphaerium	6	6					
			very immature Sphaeriidae	6	16		160		8	
Hydrozoa	Hydroida	Clavidae	*Cordylophora*			4				
Nematoda (phylum)	undetermined	undetermined	undetermined							
Total					**2,787**	**1,113**	**8,648**	**1,932**	**2,494**	**3,605**

Table 5-11 Classes, orders, families and abundance of macroinvertebrates.

Taxa	Bear Creek (reference)		Lower Spring Mine Creek (SD033)		Upper Spring Mine Creek (PM12.1)	
	2010	2011	2010	2011	2010	2011
Class	6	6	5	4	4	4
Order	14	14	11	9	7	9
Family	32	34	33	26	20	19
Genera	46	43	42	35	25	29
Total Organisms	2,787	1,113	8,648	1,932	2,494	3,605

Table 5-12 Percentage of macroinvertebrate classes collected at each site.

(**bold font** in cells represent dominant classes)

Class	Bear Creek (reference)		Lower Spring Mine Creek (SD033)		Upper Spring Mine Creek (PM12.1)	
	2010	2011	2010	2011	2010	2011
Insecta	**62.7%**	**61.5%**	**67.6%**	**77.4%**	**96.2%**	**98.4%**
Crustacea	**12.8%**	**19.6%**	0.2%	0.1%	0.0%	0.0%
Malacostraca	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Entoprocta (Phylum)	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Annelida	**21.2%**	**14.8%**	0.6%	0.0%	1.1%	0.9%
Gastropoda	1.9%	0.9%	**29.8%**	**11.3%**	1.9%	0.7%
Bivalvia	0.8%	2.9%	1.9%	**11.2%**	0.8%	0.0%
Hydrozoa	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
Nematoda	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-13 Percentage of macroinvertebrate orders collected at each site.

(**bold font** in cells represent dominant orders)

Order	Bear Creek (reference)		Lower Spring Mine Creek (SD033)		Upper Spring Mine Creek (PM12.1)	
	2010	2011	2010	2011	2010	2011
Coleoptera	3.2%	0.3%	2.4%	5.3%	4.7%	1.4%
Diptera	**30.4%**	**22.7%**	**19.8%**	**25.7%**	**69.8%**	**85.9%**
Ephemeroptera	2.2%	**31.1%**	**31.1%**	**27.3%**	0.0%	0.1%
Hemiptera	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Odonata	4.0%	1.7%	1.6%	0.5%	0.0%	0.0%
Megaloptera	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
Lepidoptera	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%
Plecoptera	0.0%	2.0%	2.1%	0.4%	**9.8%**	**6.9%**
Trichoptera	**22.2%**	3.6%	**10.5%**	**18.3%**	**11.8%**	**4.0%**
Amphipoda	**12.8%**	**19.6%**	0.2%	0.1%	0.0%	0.0%
Decapoda	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Urnatellida	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%
Oligochaeta	**21.1%**	**14.4%**	0.6%	0.0%	1.1%	0.9%
Arhynchnobdellida	0.1%	0.4%	0.0%	0.0%	0.0%	0.0%
Rhynchnobdellida	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Basommatophora	1.9%	0.9%	**29.8%**	**11.3%**	1.9%	0.7%
Veneroida	0.8%	2.9%	1.9%	**11.2%**	0.8%	0.0%
Isopoda	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Hydroida	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%
Nematoda-unknown	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-14 Hilsenhoff Biotic Index (HBI) values for streams.

HBI Value	**Water Quality**	**Degree of Organic Pollution**
0.00-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very Good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly Poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.00	Very Poor	Severe organic pollution

Table 5-15 Hilsenhoff Biotic Index (HBI) calcuations for each stream sampling site.

Taxa					Bear Creek (reference) 2010			Bear Creek (reference) 2011			Lower Spring Mine Creek (SD033) 2010			Lower Spring Mine Creek (SD033) 2011			Upper Spring Mine Creek (PM12.1) 2010			Upper Spring Mine Creek (PM12.1) 2011		
Class	Order	Family	*Genus species*	Tolerance Value (10-0)	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum
Insecta	Coleoptera	Curculionidae	undetermined	5																		
		Dysticae	*Agabus* adults	5													8	8	40	46	46	230
			Hydroporus adults	5													10	10	50			
			Dytiscus larvae	na				1														
			Nebrioporus	na										41								
		Elmidae	*Dubiraphia* larvae	6							48	48	288	21	21	126						
			Dubiraphia adults	6										1	1	6						
			Macronychus	5	16	16	80															
			Macronychus adults	5										2	2	10						
			Optioservus	4	8	8	32	2	2	8	80	80	320	9	9	36	100	100	400	4	4	16
			Stenelmis larvae	5	16	16	80				40	40	200	21	21	105						
			Stenelmis adult	5										7	7	35						
			undetermined	4																		
		Gyrinidae	*Gyrinus* adults	na	48						40											
		Hydrophilidae	*Tropisternus* adults	na																2		
	Diptera		undetermined Diperta larva	na													16			32		
			undetermined Diptera pupae	na							8											
		Chironomidae	undetermined	5																		
			Chironomus	10																		
			Cladopelma	9																		
			Cryptochironomus	8																		
			Dicrotendipes	na																4		
			Endochironomus	10	8	8	80															
			Labrundinia	7																		
			Microtendipes	6	64	64	384				144	144	864									
			Paratendipes	8																4	4	32
			Polypedilum	6	32	32	192	6	6	36	8	8	48	12	12	72						
			Stenochironomus	5	136	136	680	4	4	20	8	8	40									
			Xenochironomus	na																		
		Chironominae	*Pseudochironomus*	5																		
			Microsectra	na				10												144		
			Paratanytarsus	6																		
		(Tanytarsini)	*Rheotanytarsus*	6	60	60	360															
		(Tanytarsini)	*Tanytarsus*	6				20	20	120	24	24	144	33	33	198	20	20	120	4	4	24
		Diamesinae	*Diamesa*	5													8	8	40	112	112	560
		Orthocladiinae	undetermined	na																		
			Acricotopus	na																4		
			Brillia	5										1	1	5						
			Chaetocladius	na																32		
			Cricotopus (Cricotopus)	7																0		
			Cricotopus (C.) bicinctus	na																8		
			Eukiefferiella	4													24	24	96	156	156	624
			Heterotrissocladius	4																		
			Orthocladius	6				4	4	24	32	32	192				8	8	48	804	804	4,824
			Parametriocnemus	5													20	20	100	60	60	300
			Psectrocladius	8																		
			Pseudorthocladius	0																		
			Rheocricotopus	6				4	4	24												
			Symposiocladius	na																		
			Thienemanniella	6				2	2	12												
			Tvetenia	5																		
			Xylotopus	5	32	32	160															
		Prodiamesinae	*Prodiamesa*	8													8	8	64			
		Tanypodinae	*Ablabesmyia*	na				16														
			Conchapelopia	6	64	64	384	4	4	24	24	24	144	16	16	96						
			Larsia	6																		
			Nilotanypus	6							16	16	96				8	8	48			
			Paramerina	na																		
			Procladius	9	52	52	468	4	4	36												

Taxa					Bear Creek (reference) 2010			Bear Creek (reference) 2011			Lower Spring Mine Creek (SD033) 2010			Lower Spring Mine Creek (SD033) 2011			Upper Spring Mine Creek (PM12.1) 2010			Upper Spring Mine Creek (PM12.1) 2011		
Class	Order	Family	*Genus species*	Tolerance Value (10-0)	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum
			Thienemannimya Group	6	4	4	24	0						10	10	60						
			Zavrelimyia	8				4	4	32												
		Ceratopogonidae	*Bezzia/Palpomyia*	6	64	64	384													0		
			Ceratopogon	6	16	16	96															
			Probezzia	6							8	8	48				4	4	24			
			undetermined	na				6												41		
		Dixidae	*Dixa*	1																		
			Dixella	na				4														
		Empididae	*undetermined Empidid* larvae	6																		
		Simuliidae	*Simulium*	6	308	308	1,848	162	162	972	1,424	1,424	8,544	396	396	2,376	972	972	5,832	1,068	1,068	6,408
			Simulium pupae	6													628	628	3,768	624	624	3,744
		Tabanidae	*undetermined Tabanid*	5	8	8	40															
		Tipulidae	*Antocha*	3													16	16	48			
			Dicronota	3													8	8	24			
			Limnophila	3							16	16	48									
			Lipsothrix	na																		
			Tipula	6				2	2	12							2	2	12			
			undetermined Tipulidae	na							2			28								
		Ptychopteridae	*Ptycoptera*	na				1														
	Ephemeroptera	Ameletidae	*Ameletus*	na				4														
		Arthropleidae	*Arphroplea*	na				4														
		Baetidae	*Baetis brunneicolor*	4	12	12	48	264	264	1,056	1,976	1,976	7,904	506	506	2,024						
			Baetis flavistriga	4							32	32	128									
			Baetis intercalaris	6																		
			Baetis tricaudatus	6																		
			undetermined *Baetis*	na				4						1						4		
			Acentrella	4				68	68	272												
			Labiobaetis	na	12																	
			Acerpenna macdunnoughi	5	4	4	20															
			Callibaetis	7																		
		Caenidae	*Caenis*	7							16	16	112	2	2	14						
		Ephemerellidae	*Attenella*	3							16	16	48									
		Heptageniidae	*Stenacron*	7	8	8	56				16	16	112	2	2	14						
			Maccaffertium	na	2						96			16								
		Leptophlebiidae	*Leptophlebia*	4	6	6	24				536	536	2,144									
		Siphlonuridae	*Siphlonurus*	4				2	2	8												
		Metretopodidae	undetermined genus	na	16																	
	Hemiptera	Corixidae	*Sigara*	na	0															1		
	Odonata	Aeshnidae	*Aeshna*	5	10	10	50	8	8	40	56	56	280	3	3	15						
			Anax	8																		
			Boyeria	na	12						14			1								
		Calopterygidae	*Calopteryx*	5	54	54	270				66	66	330	1	1	5						
		Coenagrionidae	undetermined immatures	na																		
		Gomphidae	*Gomphus*	6				1	1	6												
			immature Gomphus nymph	6	4	4	24															
		Cordulegasteridae	*Cordulegaster*	3										3	3	9						
		Corduliidae	*Somatochlora*	1	32	32	32	10	10	10				1	1	1						
		Libellulidae	undetermined (immature)	na																		
	Megaloptera	Sialidae	*Sialis*	4	13	13	52															
	Lepidoptera	Pyralidae	*Acentria*	5							8	8	40									
			Paraponyx	5	8	8	40	1	1	5												
	Plecoptera	Perlidae	*Paragnetina*	1																		
			Perlesta	5				22	22	110												
			immature Perlidae	na																		
		Isoperliidae	*Isoperla*	2							168	168	336									
		Nemouridae	*Amphinemora*	na																124		
			Nemoura	1													4	4	4	123	123	123
		Taeniopterugidae	undetermined early instar nymph	na							16			8			240					
	Trichoptera	Arctopsychidae	*Parapsyche*	0													8					
		Goeridae	*Goera*	3							240	240	720	59	59	177						

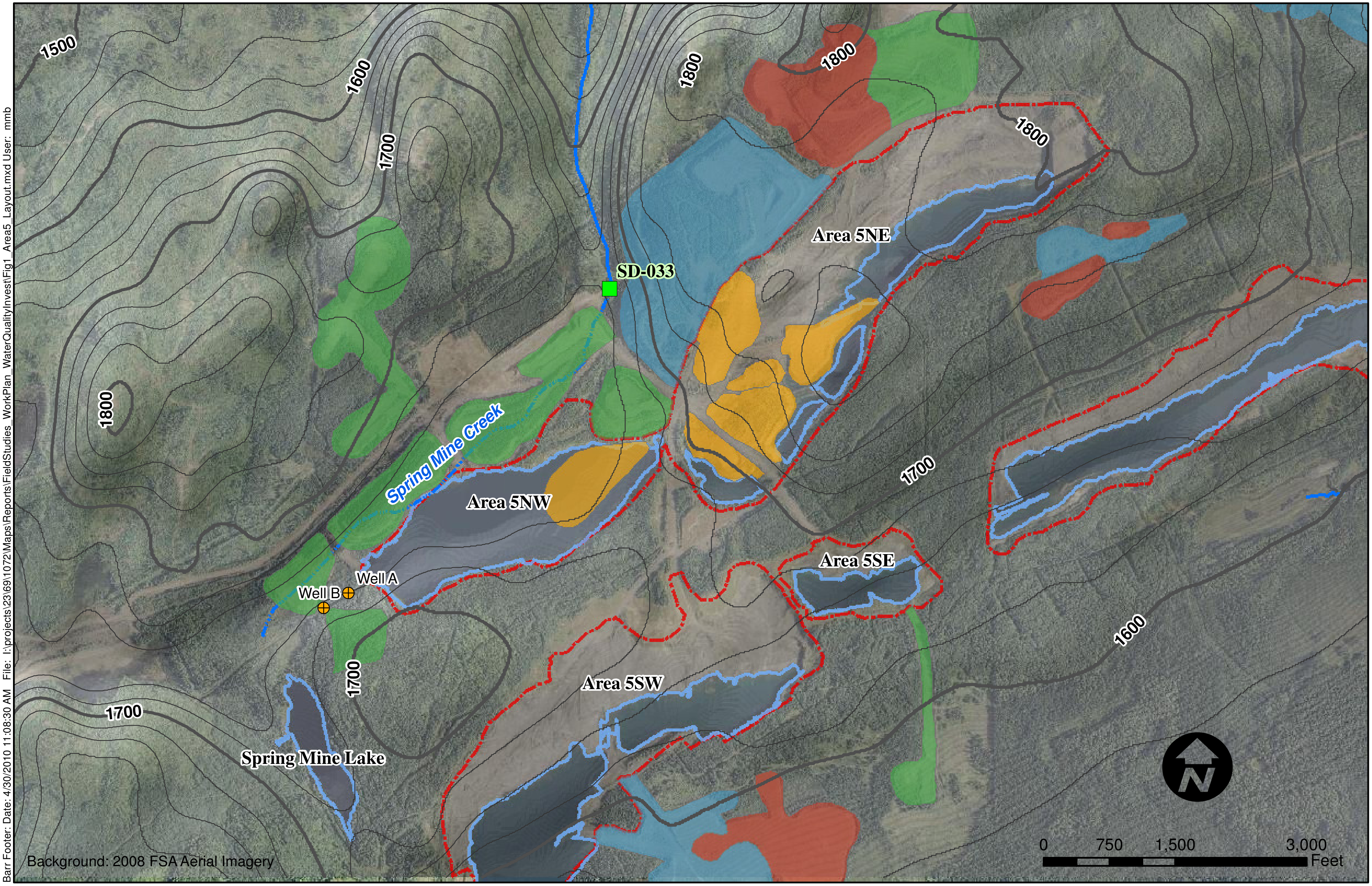
Taxa					Bear Creek (reference) 2010			Bear Creek (reference) 2011			Lower Spring Mine Creek (SD033) 2010			Lower Spring Mine Creek (SD033) 2011			Upper Spring Mine Creek (PM12.1) 2010			Upper Spring Mine Creek (PM12.1) 2011		
Class	Order	Family	*Genus species*	Tolerance Value (10-0)	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum	Total	Total with tolerance values	HBI Sum
		Helicopsychidae	*Helicopsyche*	3																		
		Hydropsychidae	*Hydropsyche slossonae*	4							192	192	768	17	17	68	56	56	224	108	108	432
			Hydropsyche alhydra	4																		
			Hydropsyche betteni	6	128	128	768	1	1	6	16	16	96	1	1	6	124	124	744	12	12	72
			Hydropsyche betteni pupae	6																		
			undetermined *Hydropsyche*	na													36					
			Cheumatopsyche	5	144	144	720	4	4	20	8	8	40	29	29	145	20	20	100	16	16	80
		Hydroptilidae	*Hydroptila*	6																4	4	24
			undetermined pupae	na													8					
		Lepidostomatidae	*Lepidostoma*	1				4	4	4				84	84	84						
		Leptoceridae	*Ceraclea*	na																		
			Oecetis	8							8	8	64									
			Triaenodes	6										8	8	48						
			undetermined pupae	na										4								
		Limnephilidae	*Anabolia*	5				17	17	85				82	82	410				2	2	10
			Hydatophylax	2	8	8	16				24	24	48									
			Limnephilus	3	4	4	12				82	82	246	7	7	21				1	1	3
			Platycentropus	na										10								
			Pycnopsyche	4										8	8	32						
			very immature larva	na																		
			undetermined pupae	na																		
		Molannidae	*Molanna*	6							32	32	192	28	28	168						
		Philopotamidae	*Chimarra*	4																		
		Phryganeidae	*Banksiola*	na																		
		Phryganeidae	*Ptilostomis*	5	14	14	70				84	84	420				2	2	10			
			very immature larva	na																		
		Polycentropodidae	*Nyctiophylax*	5							8	8	40									
			Polycentropus	6	208	208	1,248	13	13	78	80	80	480	9	9	54	40	40	240	2	2	12
		Psychomiidae	*Lype*	2	112	112	224				136	136	272									
		undetermined pupae	*undetermined pupae*	na				1						7								
Crustacea	Amphipoda	Talitridae	*Hyalella*	8	356	356	2,848	218	218	1,744	16	16	128	2	2	16						
		Gammaridae	*Gammarus*	6							2	2	12									
	Decapoda	Astacidae	*Orconectes*	6	2	2	12															
Malacostraca	Isopoda	undetermined	undetermined	na																		
Entoprocta	Urnatellida	Urnatellidae	*Urnatella gracilis*	na	16																	
Annelida	Oligochaeta		undetermined	8	588	588	4,704	160	160	1,280	48	48	384				28	28	224	32	32	256
	Arhynchnobdellida	Erpobdellidae	*Erpobdella punctata*	na	2			4														
	Rhynchnobdellida	Glossiphoniidae	*Helobdella stagnalis*	6																		
			undetermined Leech	na				1														
Gastropoda	Basommatophora	Ancylidae	*Ferrisia*	7	32	32	224	4	4	28												
		Lymnaeidae	*Pseudosuccinea*	6																		
			Fossaria	6																		
			Stagnicola	na				1														
		Planorbidae	*Gyraulus*	na																		
		Actinommidae	*Helisoma*	6				2	2	12	4	4	24									
		Physidae	*Physa*	7	22	22	154	3	3	21	2,570	2,570	17,990	218	218	1,526	48	48	336	26	26	182
	undetermined slug	undetermined slug	undetermined slug	na																		
Bivalvia/Pelecypoda	Veneroida	Pisidiidae(clams)	*Musculium*	6													12	12	72			
			Pisidium	6				32	32	192				217	217	1,302				1	1	6
			Sphaerium	6	6	6	36															
			very immature Sphaeriidae	na	16						160						8					
Hydrozoa	Hydroida	Clavidae	*Cordylophora*	na				4														
Nematoda (phylum)	undetermined	undetermined	undetermined	na																		
			TOTAL		**2,787**	2,663	16,944	**1,113**	1,052	6,297	**8,648**	8,312	44,334	**1,932**	1,816	9,264	**2,494**	2,178	12,668	**3,605**	3,209	17,962
			HBI Value				6.36			5.99			5.33			5.10			5.82			5.60
			Water Quality Rating (see Table 5-14)				Fairly Poor			Fair			Good			Good			Fair			Fair

Table 5-16 Total abundances (total # sampled by species), total length (TL) ranges, trophic guild and tolerance of all fish species sampled in Bear Creek (control stream) and Lower Spring Mine Creek (PM12.1) on July 26, 2010.

Species: Common name, Scientific name	**Bear Creek (Control Stream)**		**Lower Spring Mine Creek (PM 12.1)**		**Trophic guild**	**Tolerance**
	Total #	**TL (mm)**	**Total #**	**TL (mm)**		
Burbot *Lota lota*			6	135-240	Piscivore	Moderate
Central mudminnow *Umbra limi*	3	35-76	2	55-65	Insectivore	Tolerant
Common shiner *Luxilus cornutus*			1	25	Insectivore	Moderate
Creek chub *Semotilus atromaculatus*	-		5	25-33	Generalist	Tolerant
Golden shiner *Notemigonus crysoleucas*	1	25			Omnivore	Tolerant
Johnny darter *Etheostoma nigrum*	7	25-74	2	55-60	Insectivore	Moderate
Northern pike *Esox Lucius*	1	145			Piscivore	Moderate
Pearl dace *Margariscus margarita*			1	35	Insectivore	Moderate
White sucker *Catostomus commersonii*	8	40-210	3	29-35	Omnivore	Tolerant
Yellow perch *Perca flavescens*			1	85	Insectivore	Moderate

mm = millimeters

Figures



Taconite Pits
Mixed Stockpile
In-pit Rock Stockpile
Rock Stockpile
Overburden Stockpile
Approximate Pit Lake Surface
Top of Bedrock (Pre-Mining; interval = 25 ft)
Stream or River
Buried Stream or River Channel
Monitoring Well

Data Sources:
Taconite Pits, Pit Lake Surfaces, and
Top of Bedrock: Minnesota Geologcial Survey, M-163
Stockpiles and Spring Mine Creek:
Department of Natural Resources
Monitoring Well: Barr Engineering

Figure 1-1

AREA 5 SITE LAYOUT
PolyMet Mining, Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

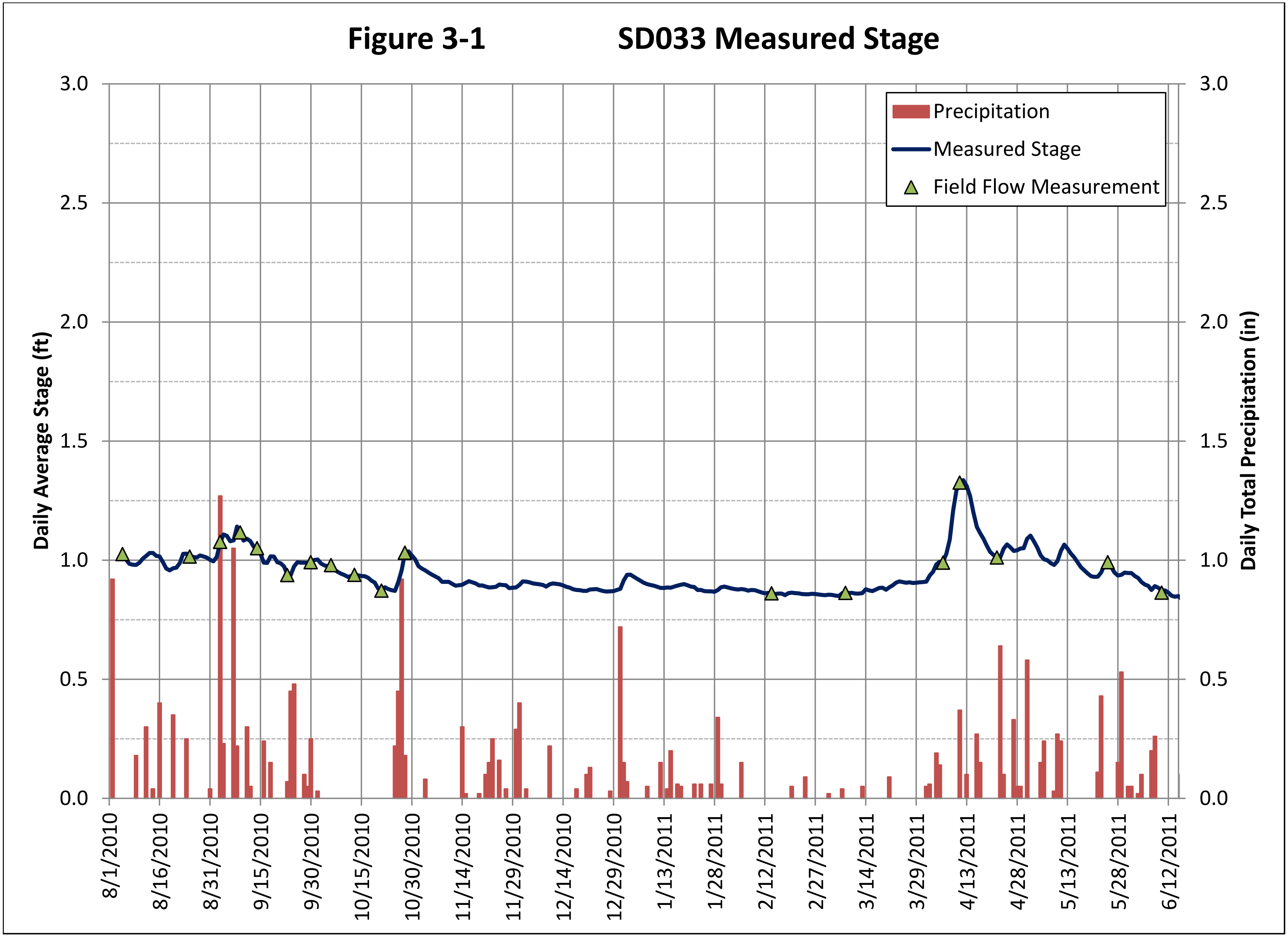
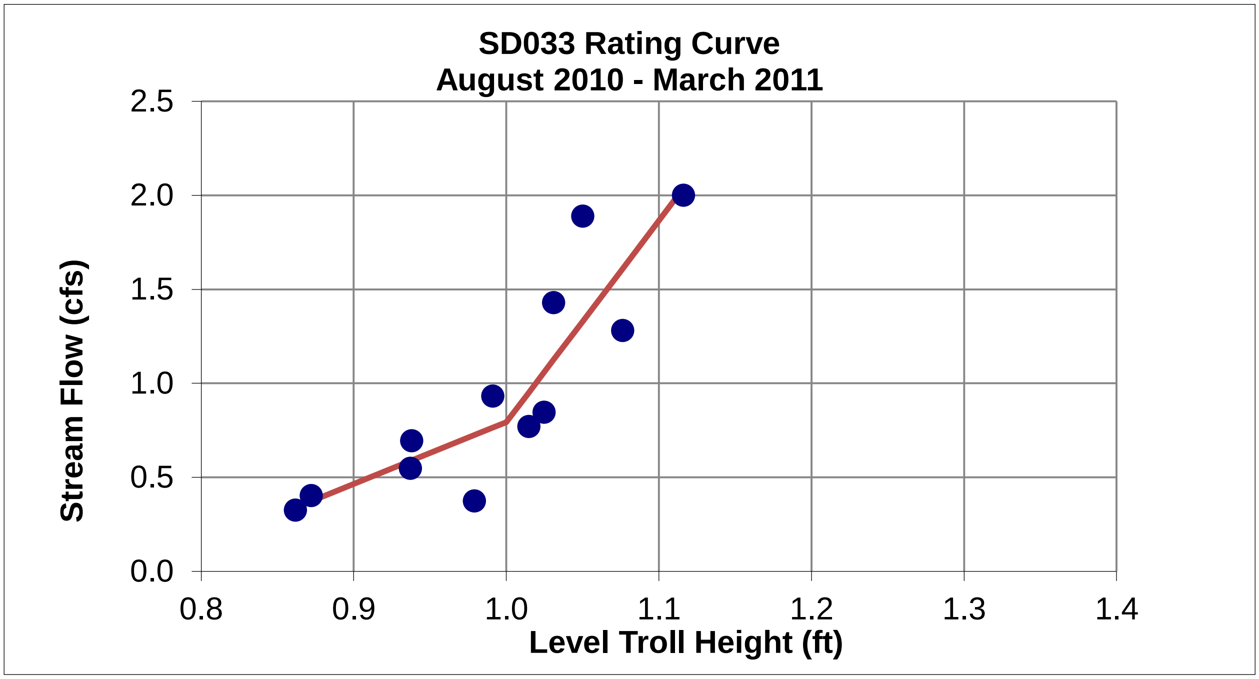
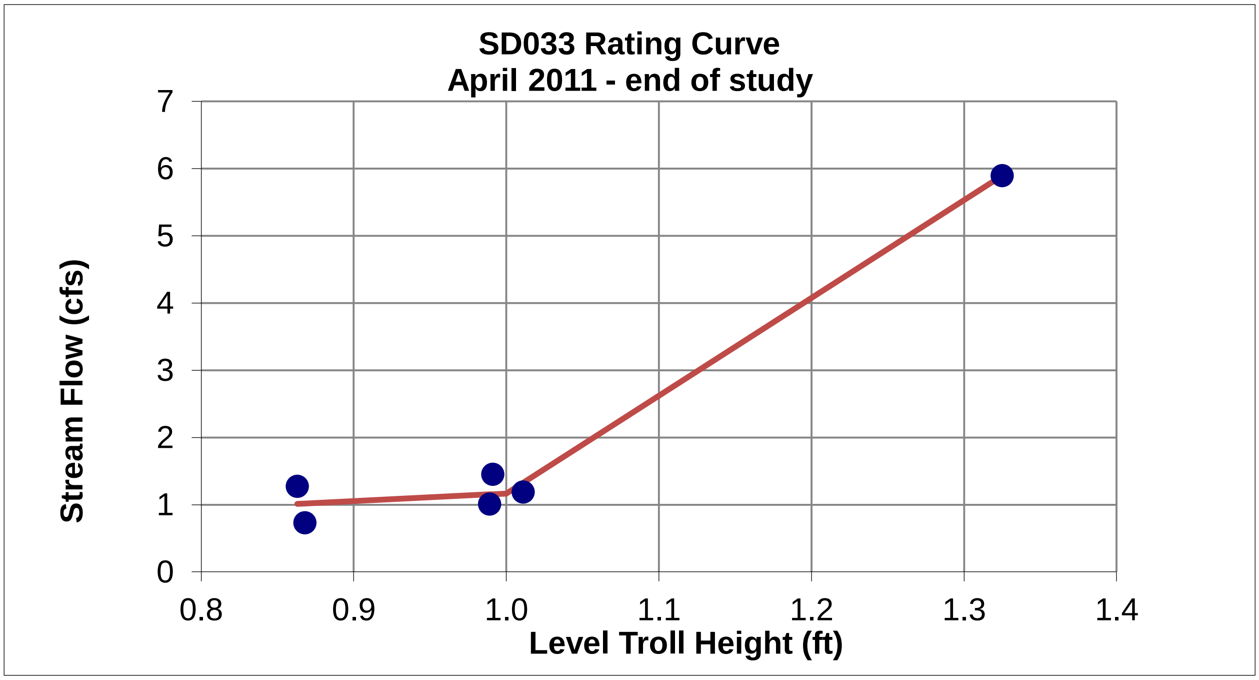


Figure 3-1
SD033 Measured Stage
Daily Average Stage (ft)
Daily Total Precipitation (in)
Precipitation
Measured Stage
Field Flow Measurement
0.0
0.5
1.0
1.5
2.0
2.5
3.0
8/1/2010
8/16/2010
8/31/2010
9/15/2010
9/30/2010
10/15/2010
10/30/2010
11/14/2010
11/29/2010
12/14/2010
12/29/2010
1/13/2011
1/28/2011
2/12/2011
2/27/2011
3/14/2011
3/29/2011
4/13/2011
4/28/2011
5/13/2011
5/28/2011
6/12/2011

Figure 3-2 Rating Curves for SD033





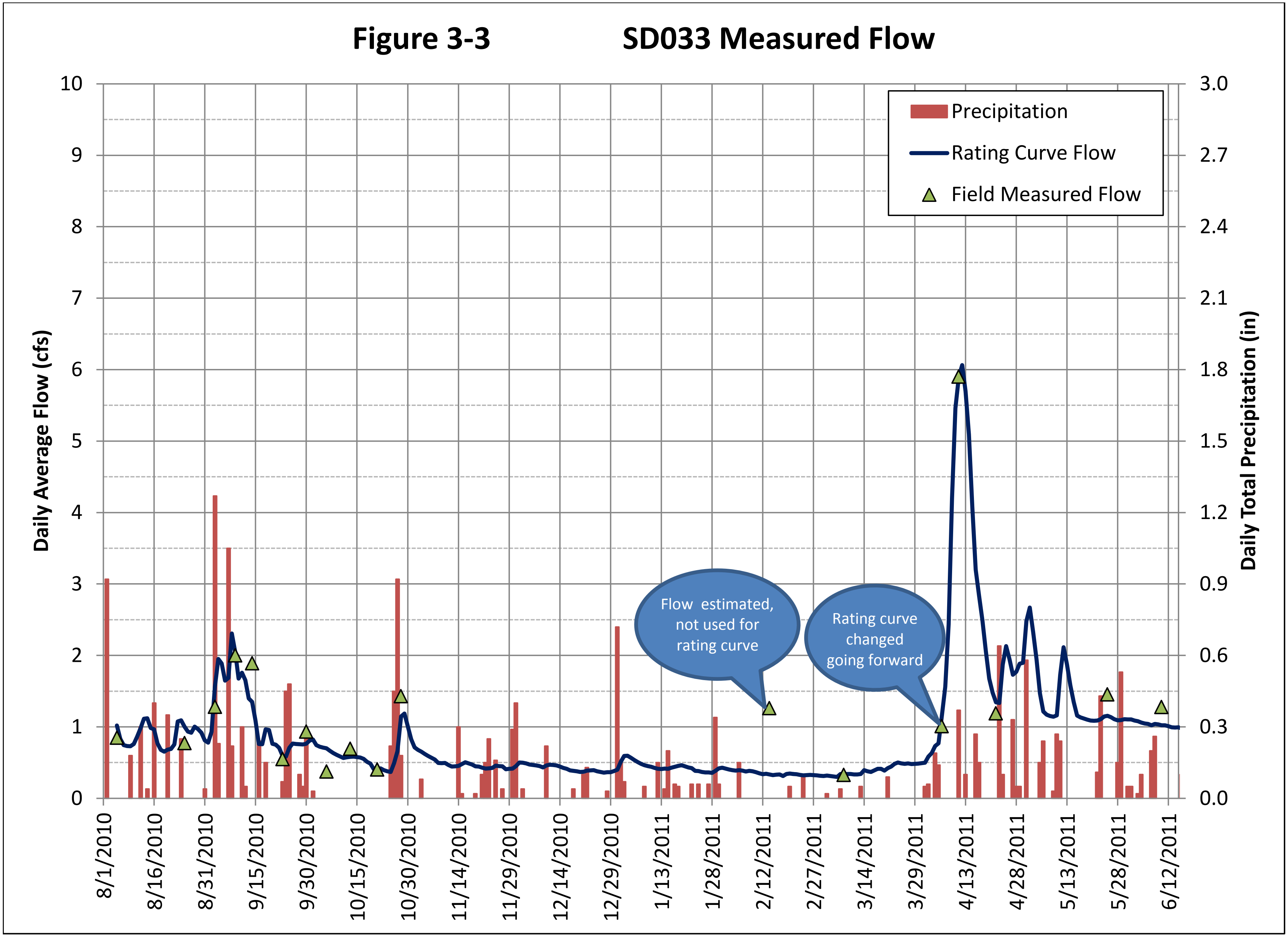


Figure 3-3
SD033 Measured Flow
Daily Average Flow (cfs)
Daily Total Precipitation (in)
Precipitation
Rating Curve Flow
Field Measured Flow
Flow estimated, not used for rating curve
Rating curve changed going forward
0
1
2
3
4
5
6
7
8
9
10
0.0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3.0
8/1/2010
8/16/2010
8/31/2010
9/15/2010
9/30/2010
10/15/2010
10/30/2010
11/14/2010
11/29/2010
12/14/2010
12/29/2010
1/13/2011
1/28/2011
2/12/2011
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5/13/2011
5/28/2011
6/12/2011

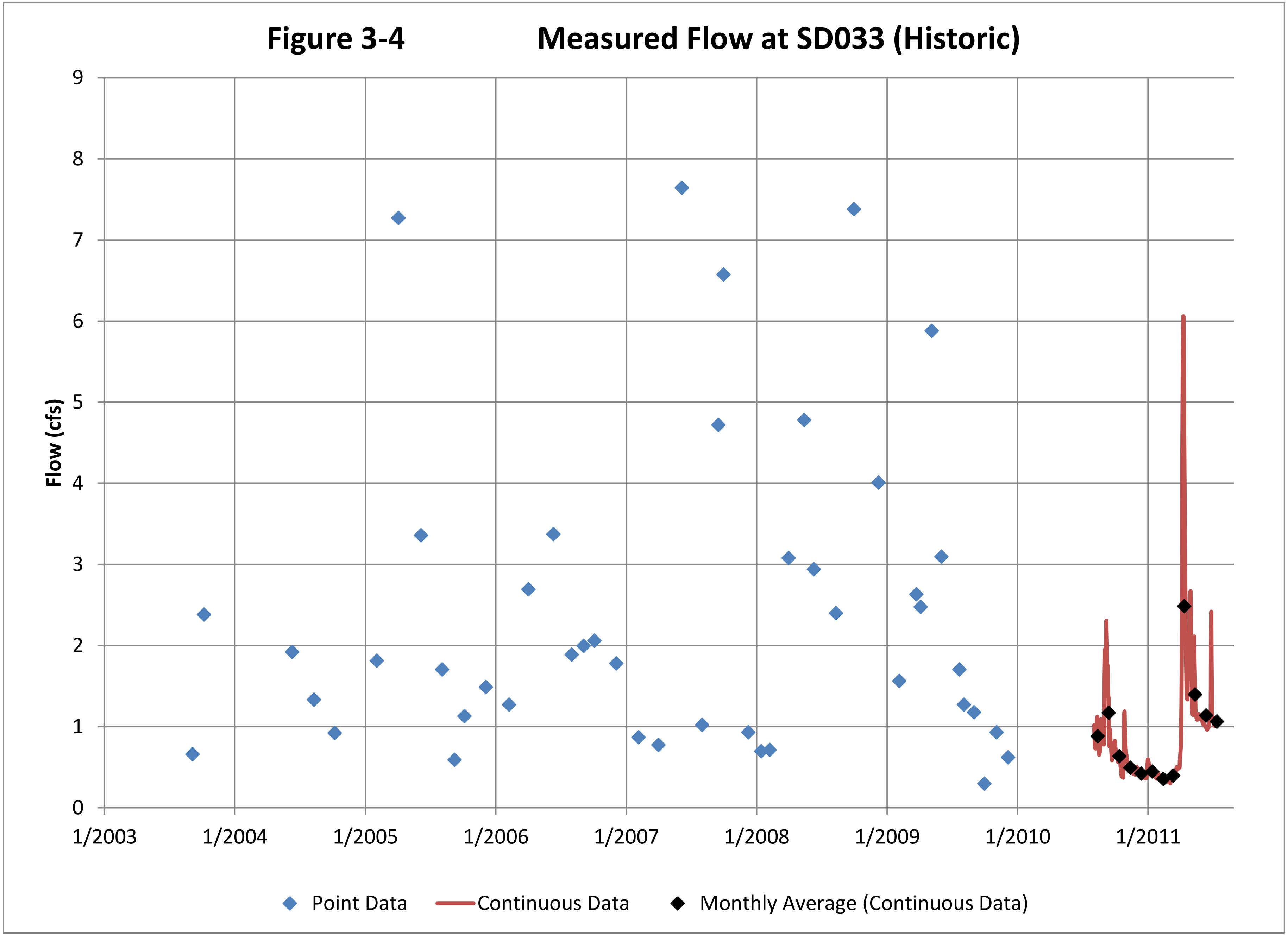
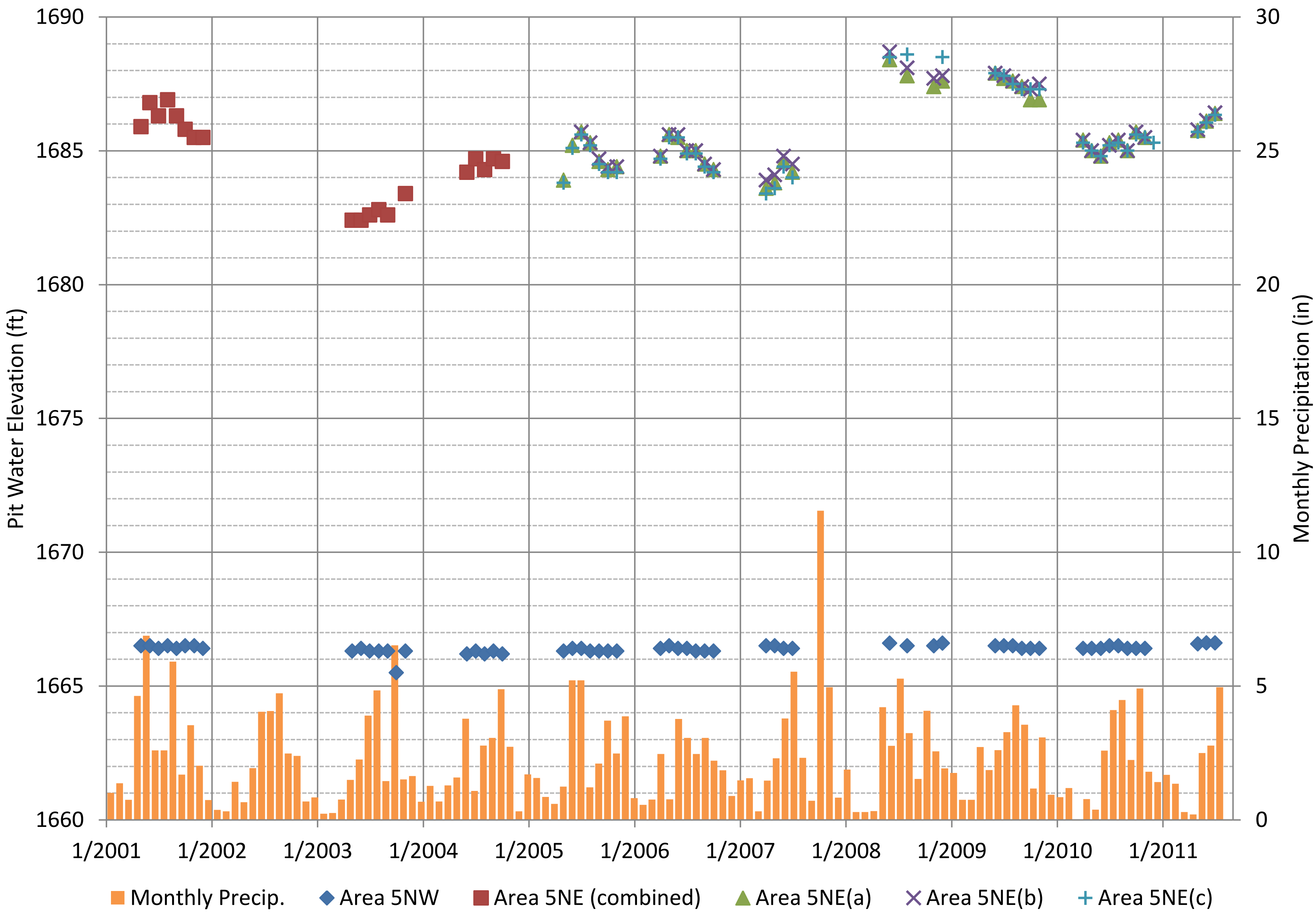
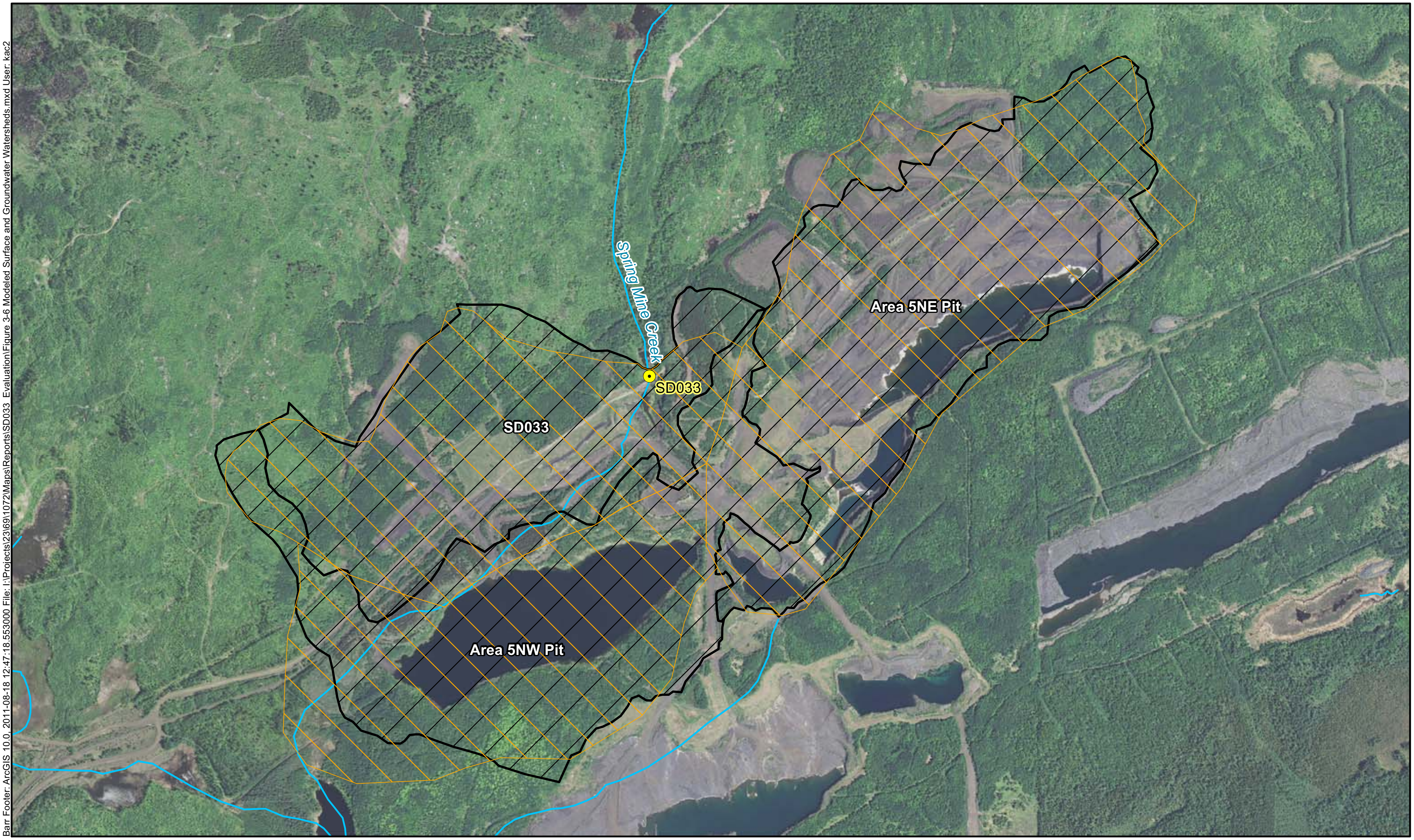


Figure 3-4
Measured Flow at SD033 (Historic)
Flow (cfs)
9
8
7
6
5
4
3
2
1
0
1/2003
1/2004
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
Point Data
Continuous Data
Monthly Average (Continuous Data)

Figure 3-5 Measured Pit Water Elevations

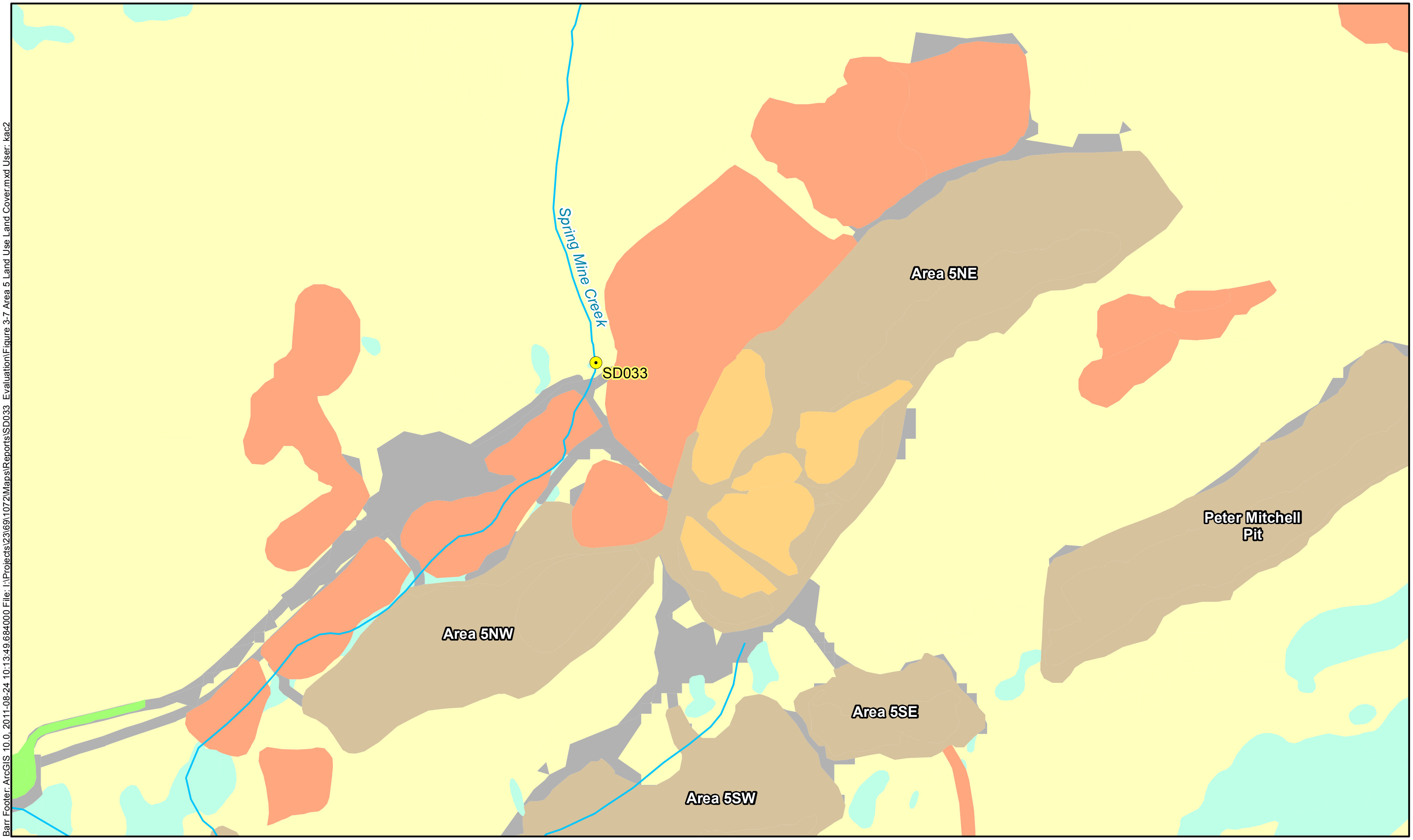




Water Quality Monitoring Location
Groundwatersheds
Area 5 Watersheds

1,500 750 0 1,500
Feet

Figure 3-6
MODELED SURFACE AND GROUNDWATER WATERSHEDS
Cliffs Natural Resources/ PolyMet Mining
St. Louis County, Minnesota



Water Quality Monitoring Location

Land Use / Land Cover

Haul Roads, Barren

In-pit Stockpile

Out-of-pit Stockpile

Pit Bare Rock (incl. water)

Tailings Basin

Undisturbed Non-Wetland

Wetland

1,300 650 0 1,300

Feet

Figure 3-7
AREA 5 LAND USE / LAND COVER
Cliffs Natural Resources/ PolyMet Mining
St. Louis County, Minnesota

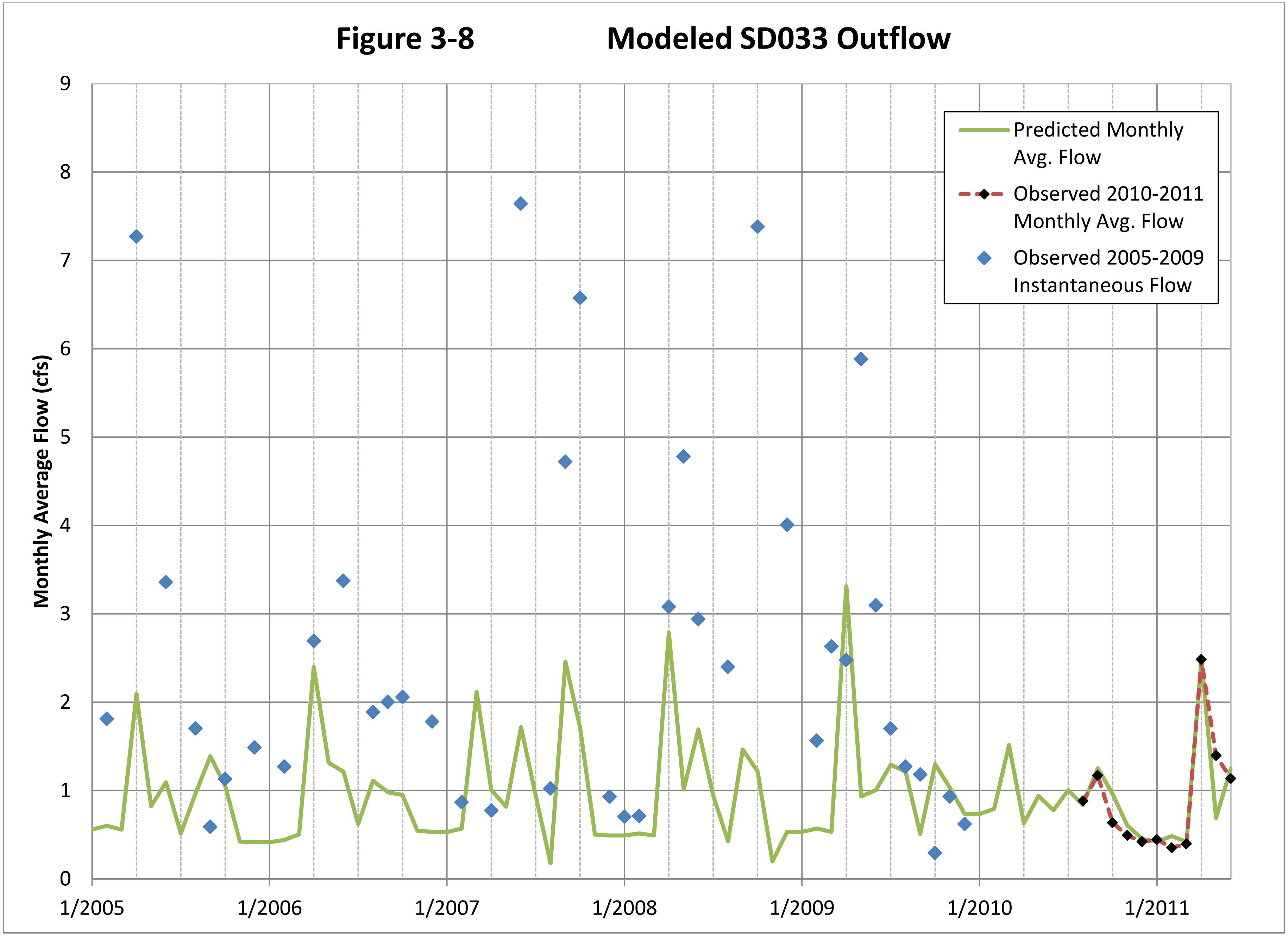
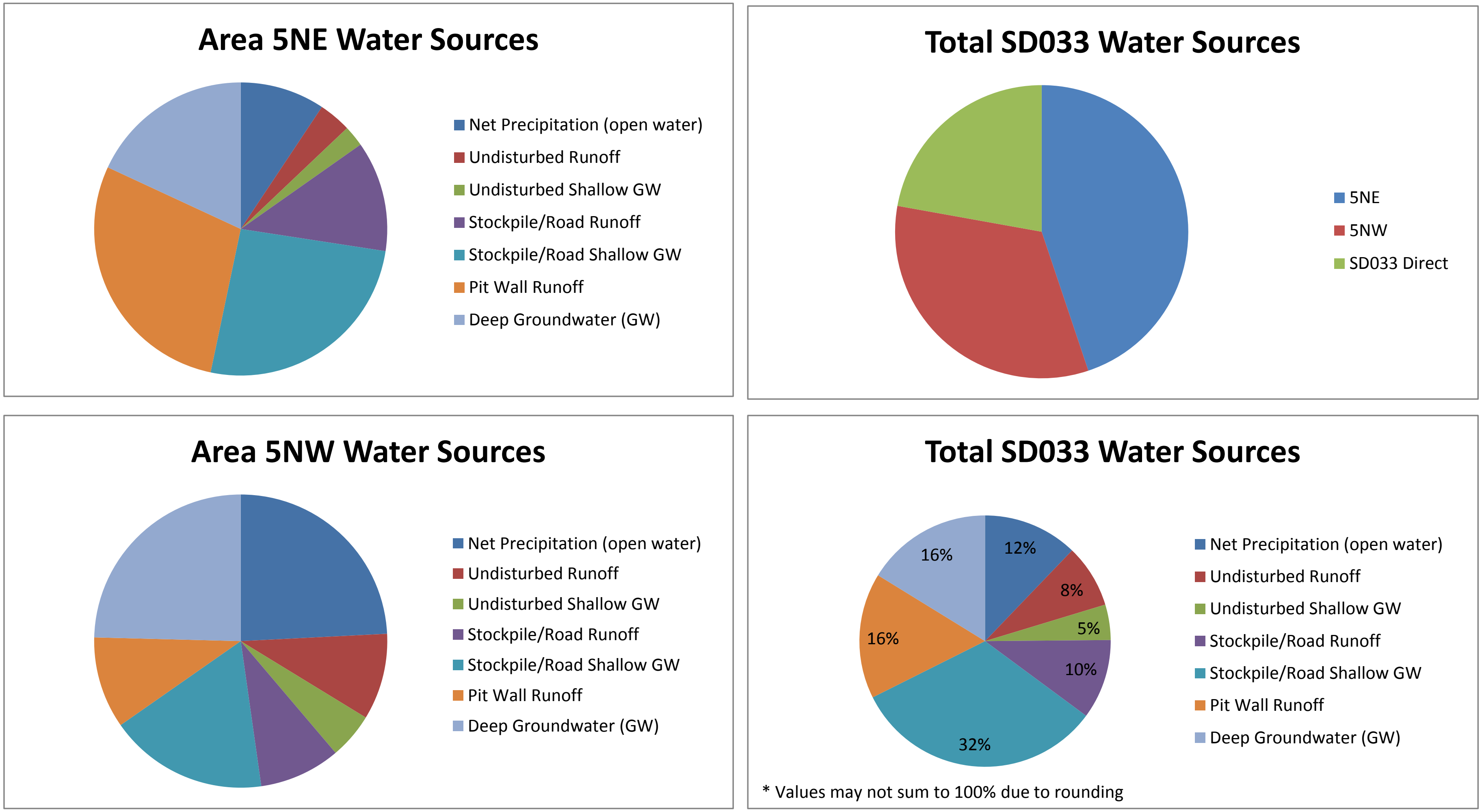


Figure 3-8
Modeled SD033 Outflow
Monthly Average Flow (cfs)
0
1
2
3
4
5
6
7
8
9
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
Predicted Monthly Avg. Flow
Observed 2010-2011 Monthly Avg. Flow
Observed 2005-2009 Instantaneous Flow

Figure 3-9 Area 5 (SD033) Water Balance Results



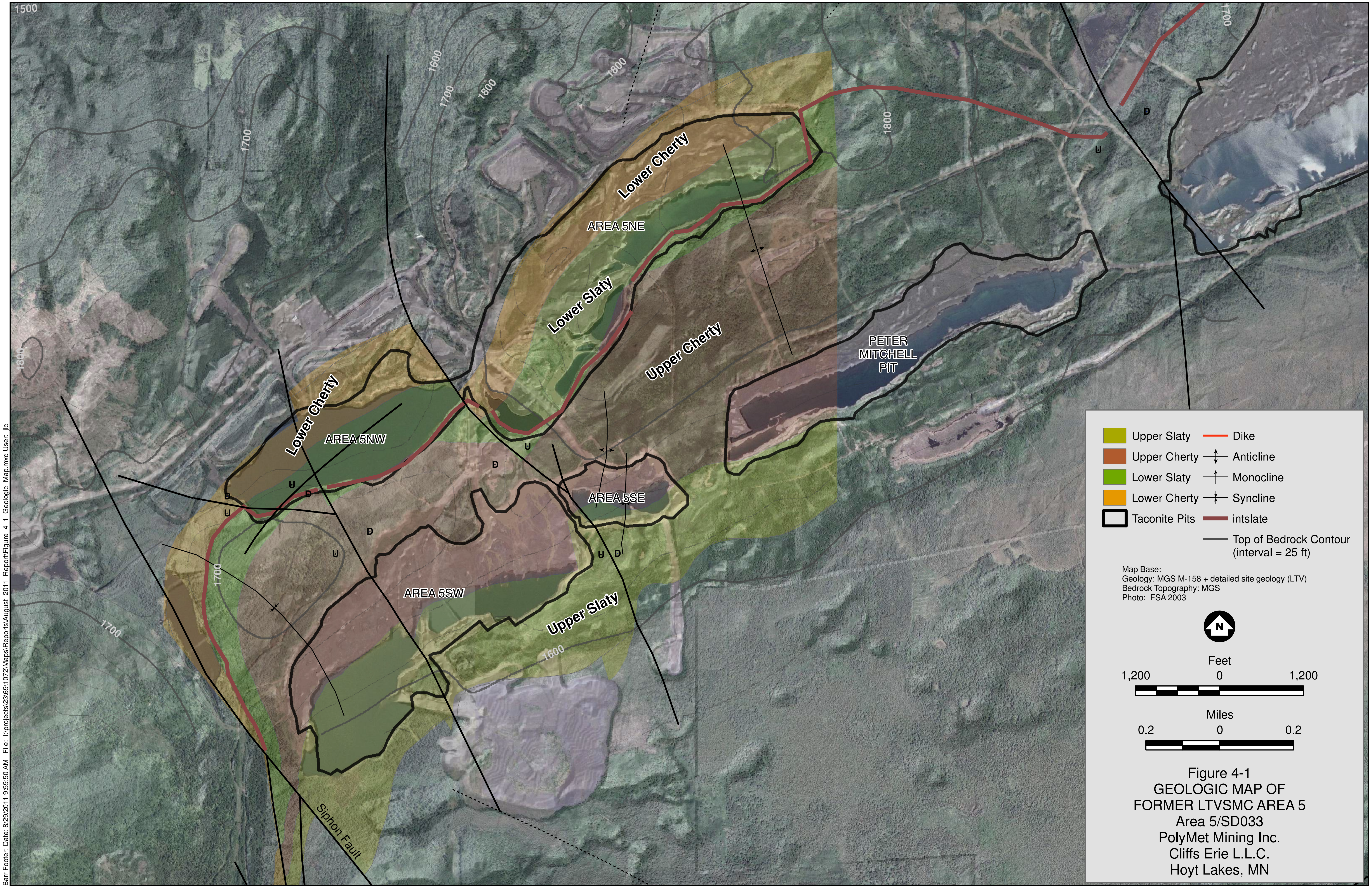


Figure 4-1
GEOLOGIC MAP OF
FORMER LTVSMC AREA 5
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

Barr Footer: Date: 8/29/2011 9:59:50 AM File: I:\projects\23\69\1072\Maps\Reports\August_2011_Report\Figure_4_1_Geologic_Map.mxd User: jlc

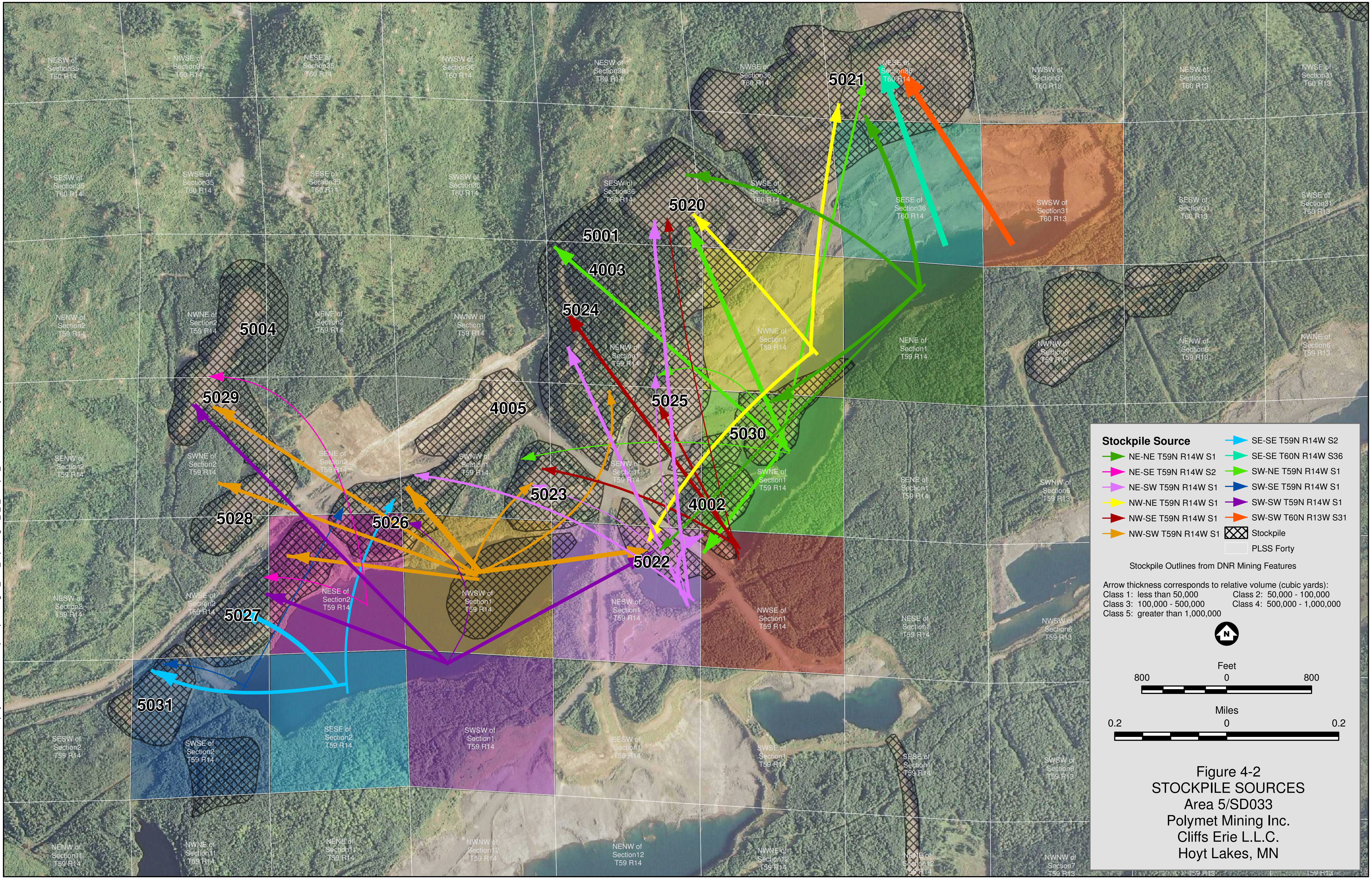


Figure 4-2
STOCKPILE SOURCES
Area 5/SD033
Polymet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

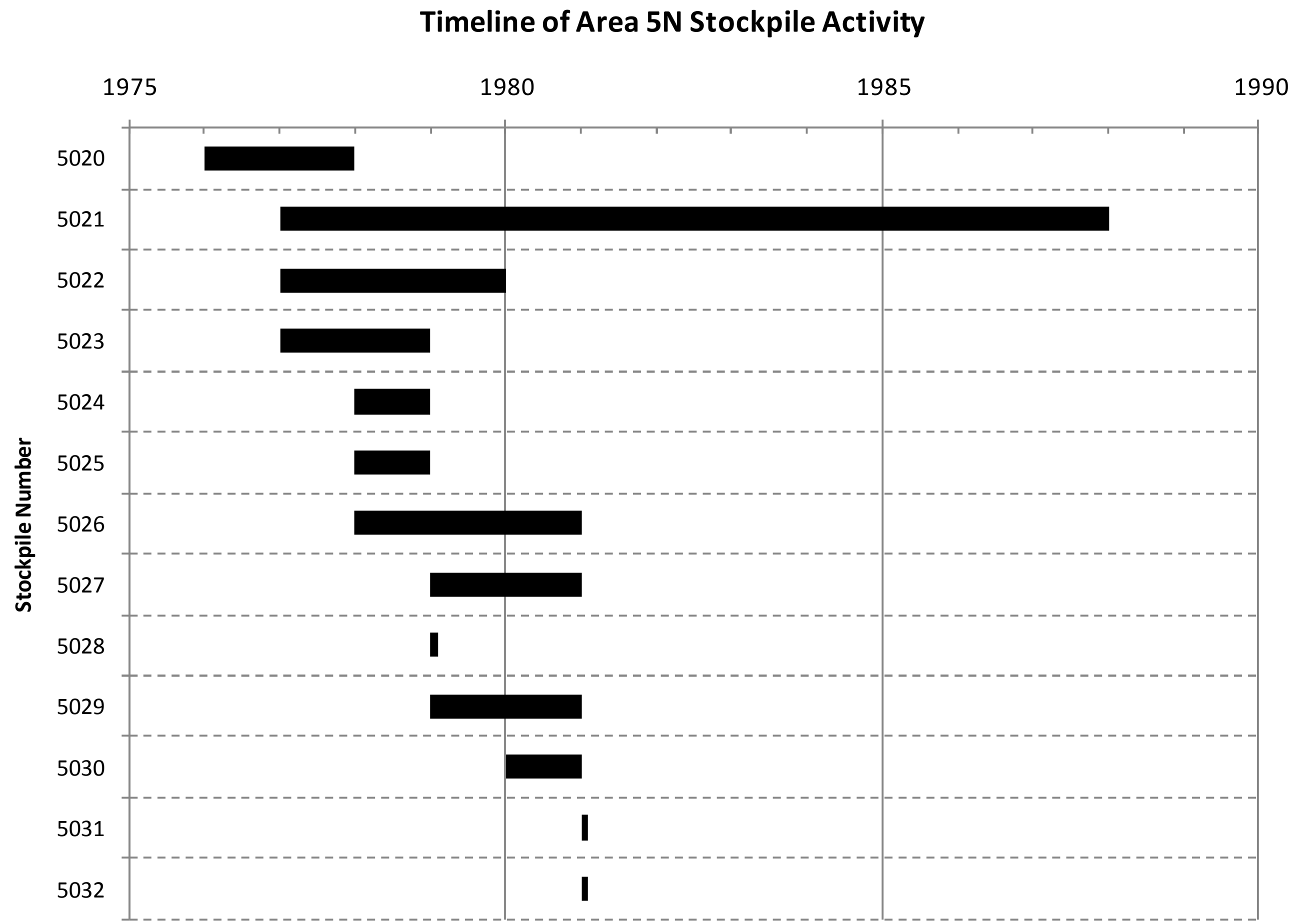


Figure 4-3 Timeline of stockpile use for stockpiles associated with the Area 5N mine pits.

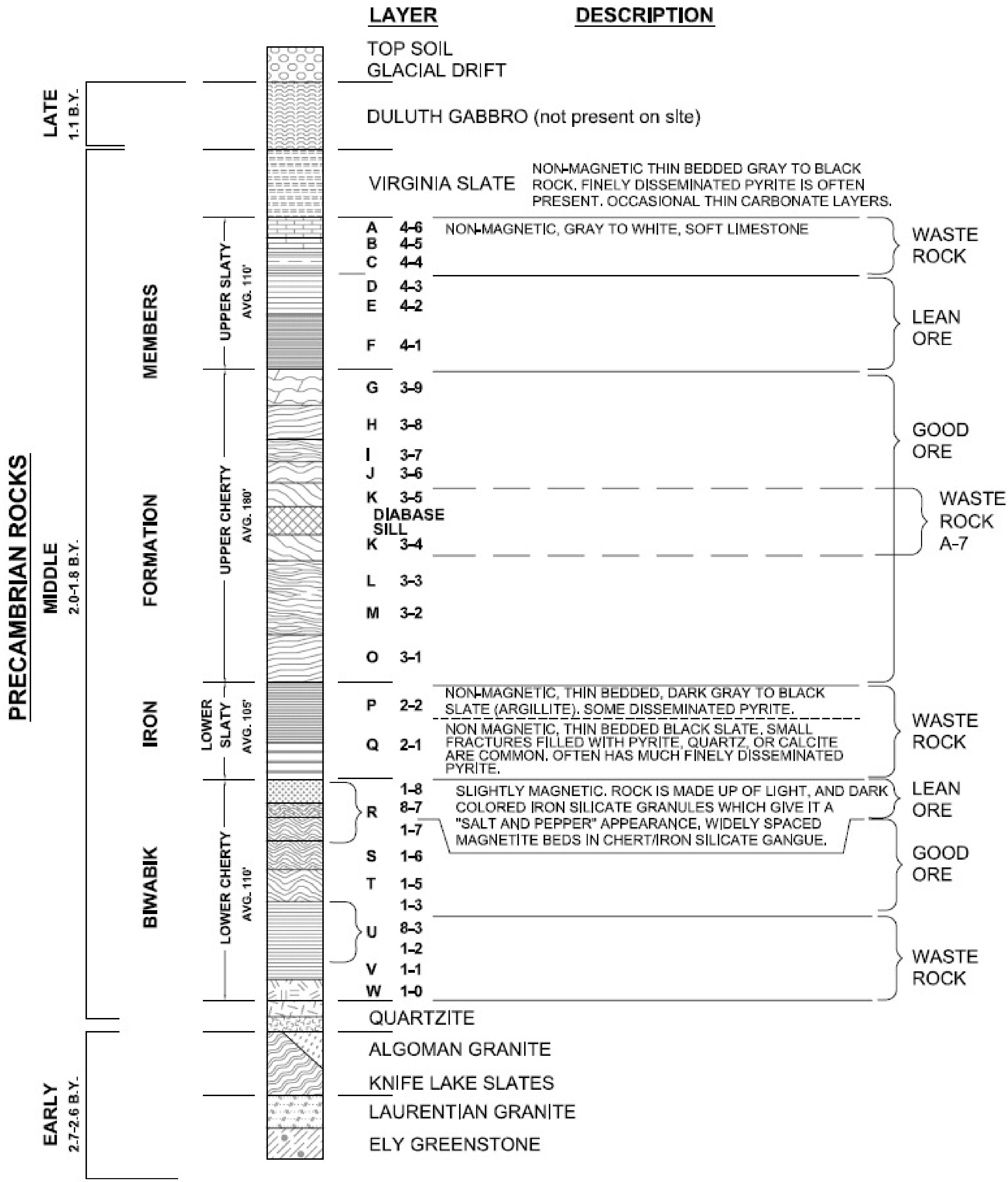


Figure 4-4 Generalized Aurora Area Stratigraphic Column. Source: Erie Mining Co.

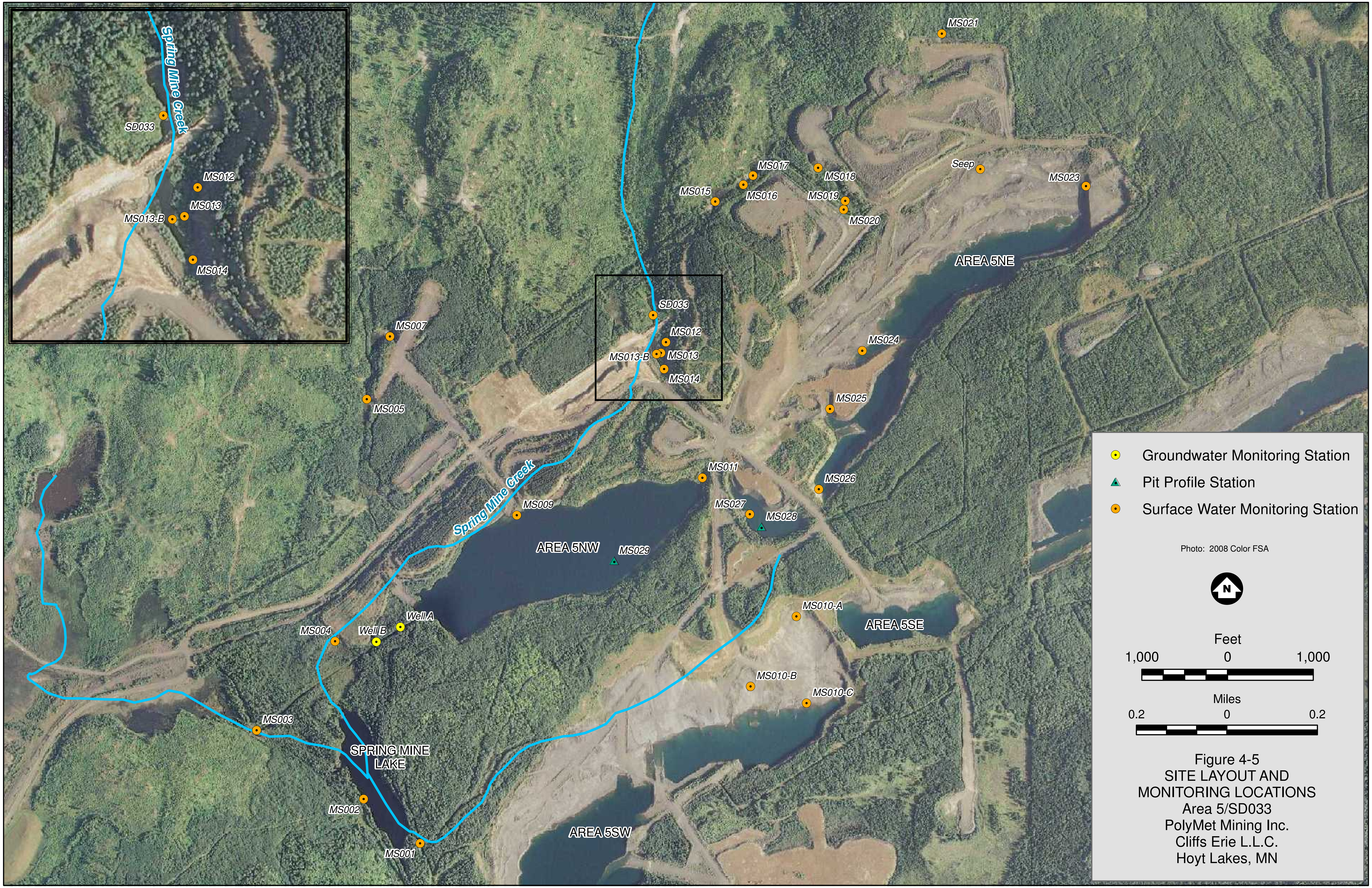


Figure 4-5
SITE LAYOUT AND
MONITORING LOCATIONS
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

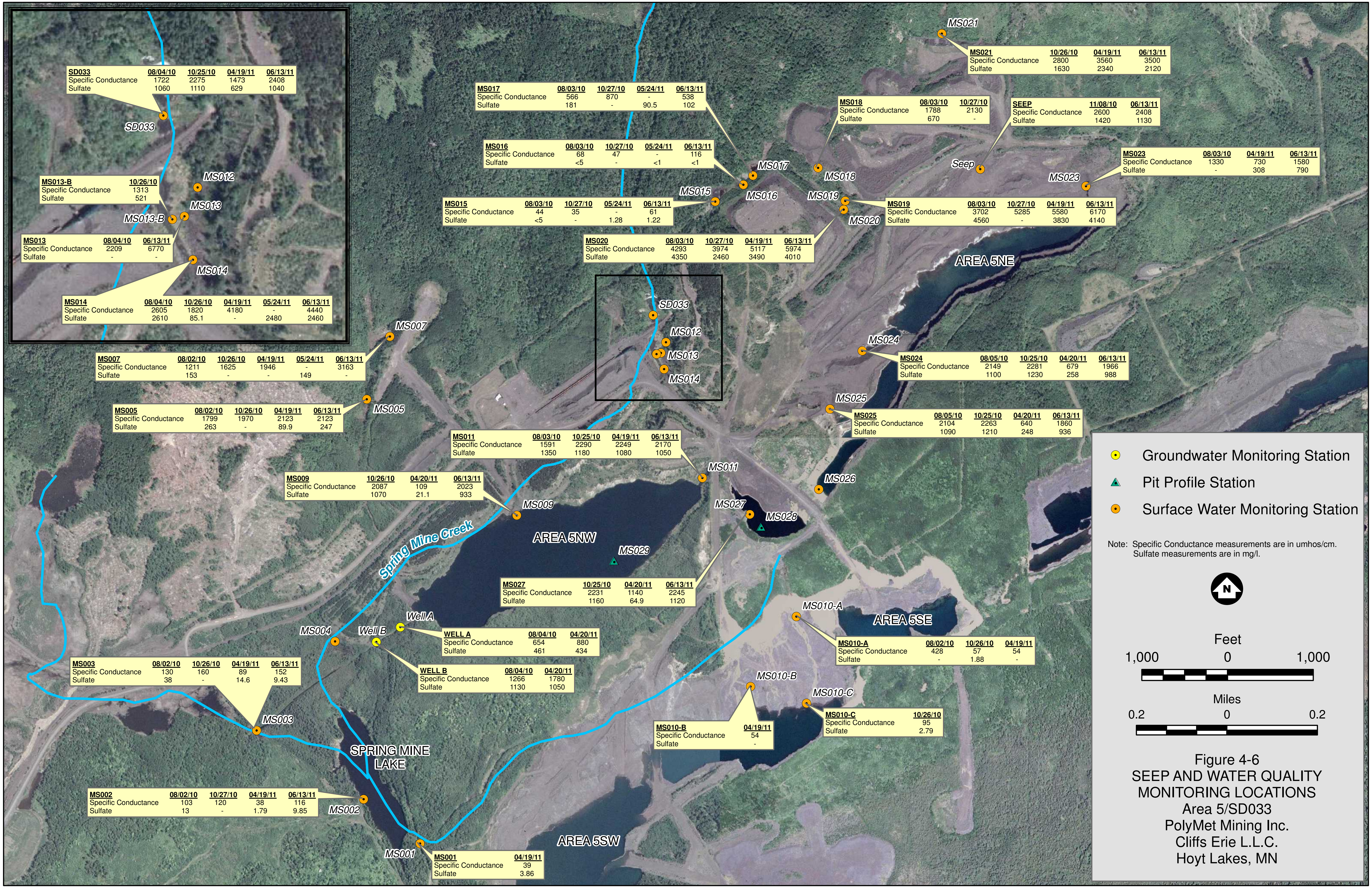


Figure 4-6
SEEP AND WATER QUALITY MONITORING LOCATIONS
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

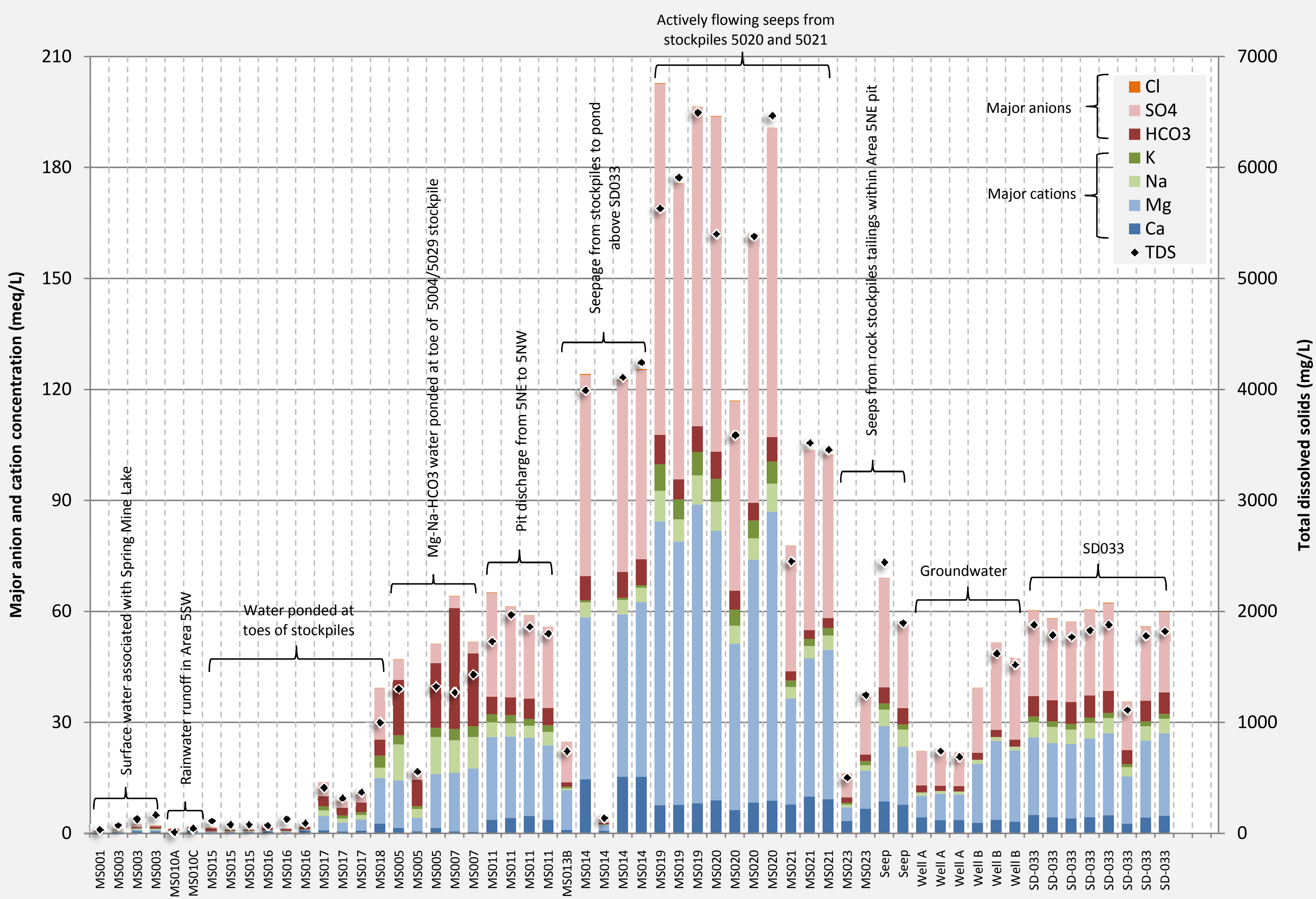


Figure 4-7 Hydrochemistry of Sampled Seeps, Groundwater, and SD033

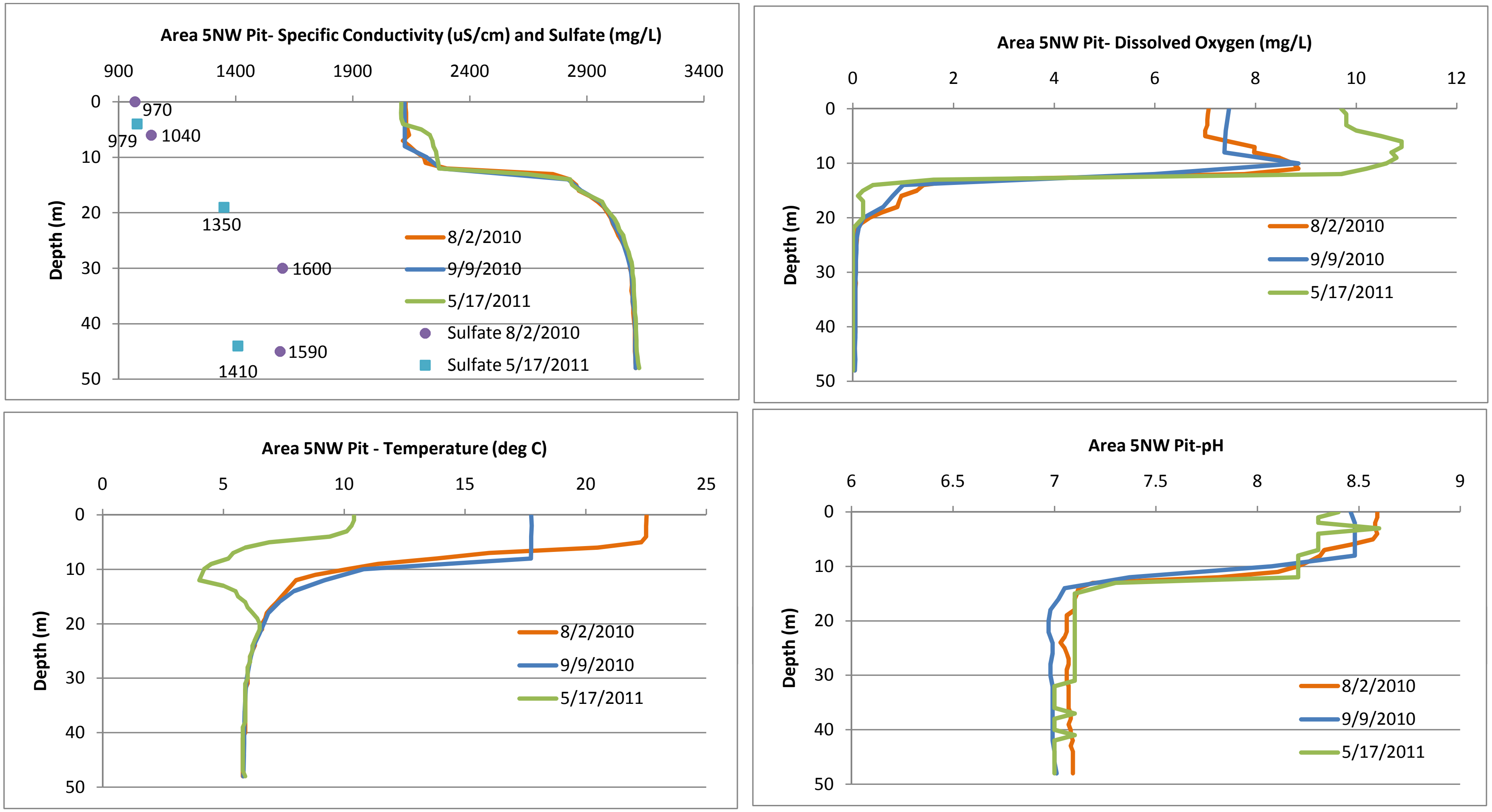


Figure 4-8 Water quality profile data for Area 5NW Pit

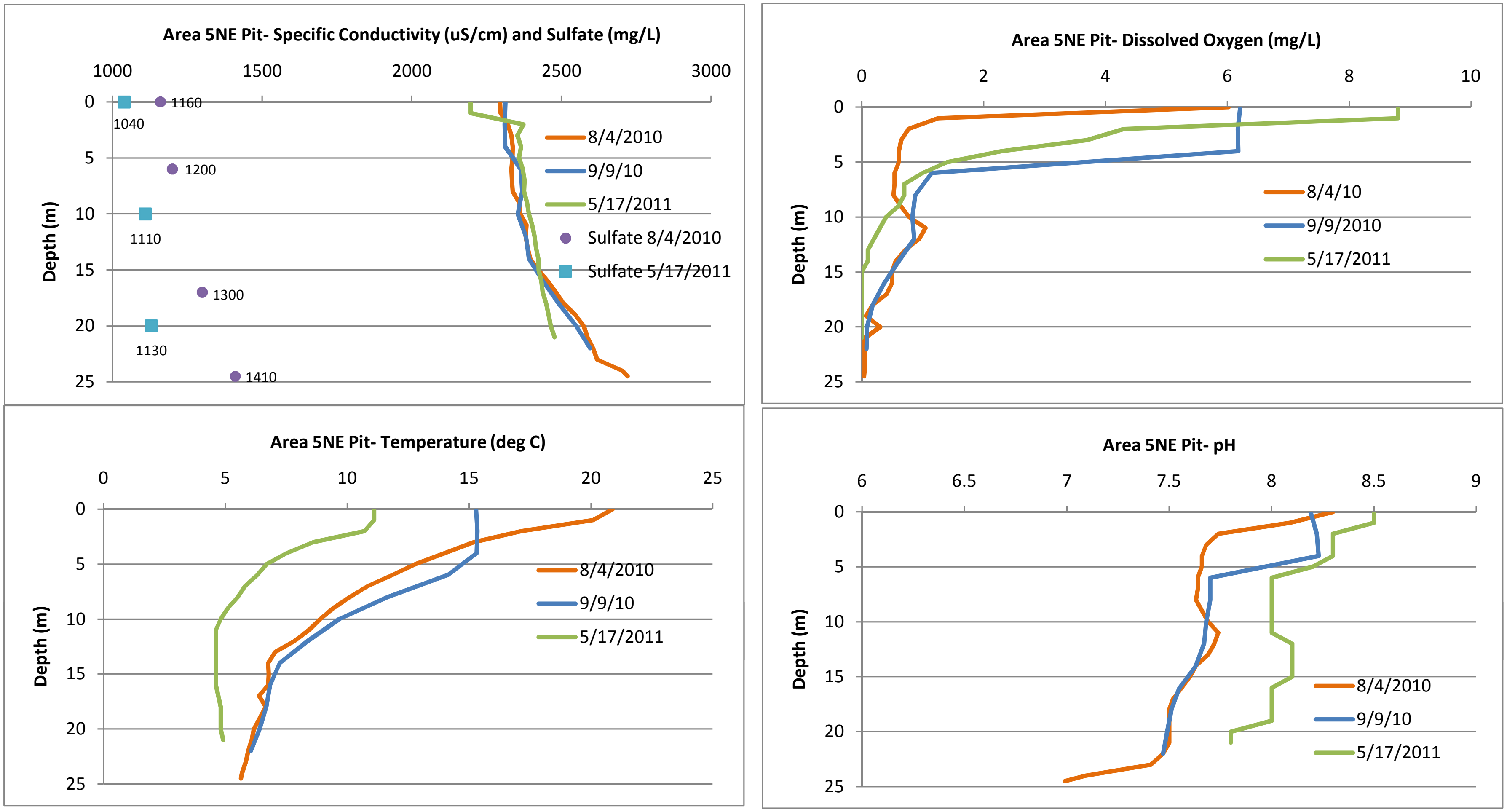


Figure 4-9 Water quality profile data for Area 5NE Pit

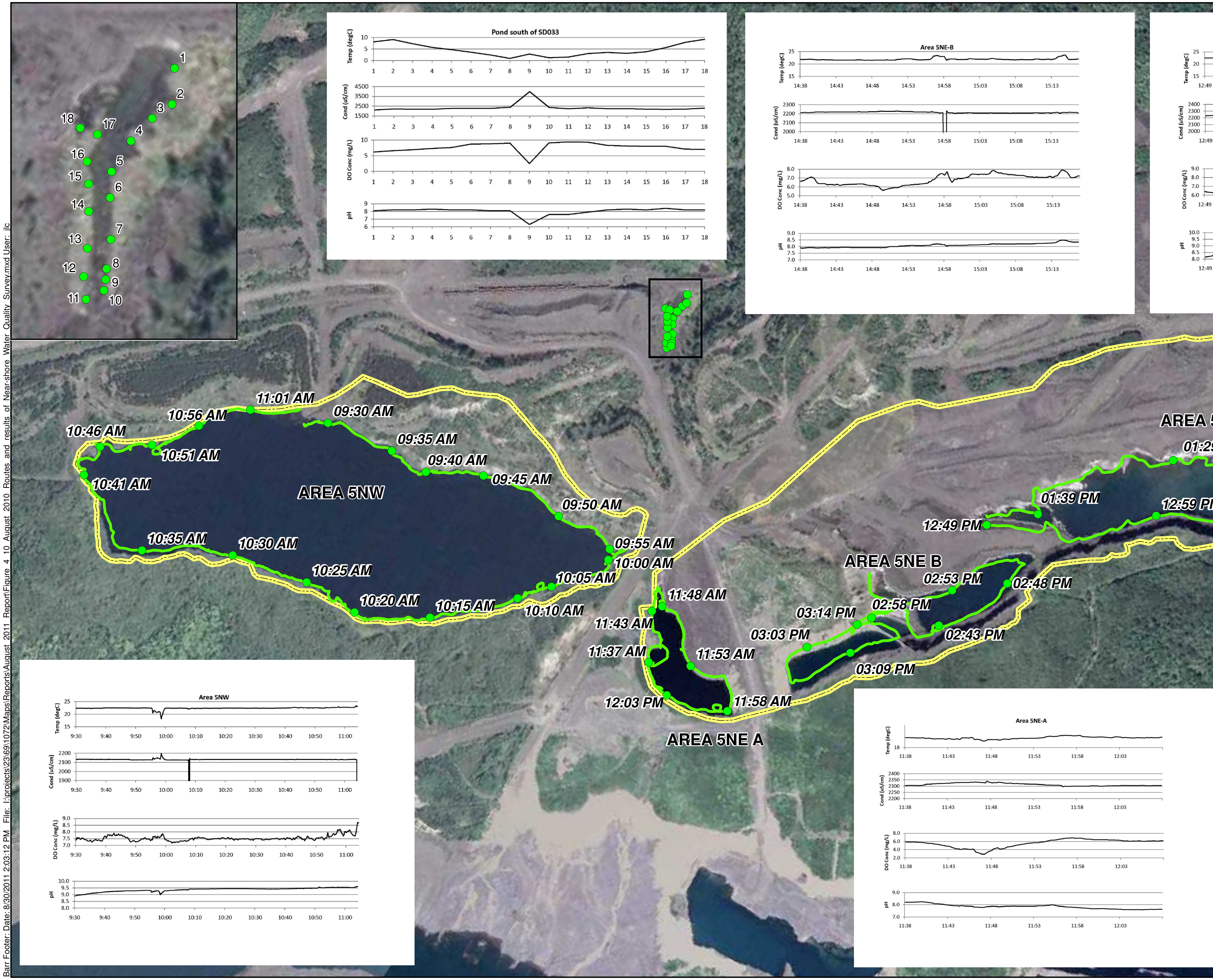


Figure 4-10
ROUTES AND RESULTS OF NEAR-SHORE WATER QUALITY SURVEY - AUGUST 2010
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

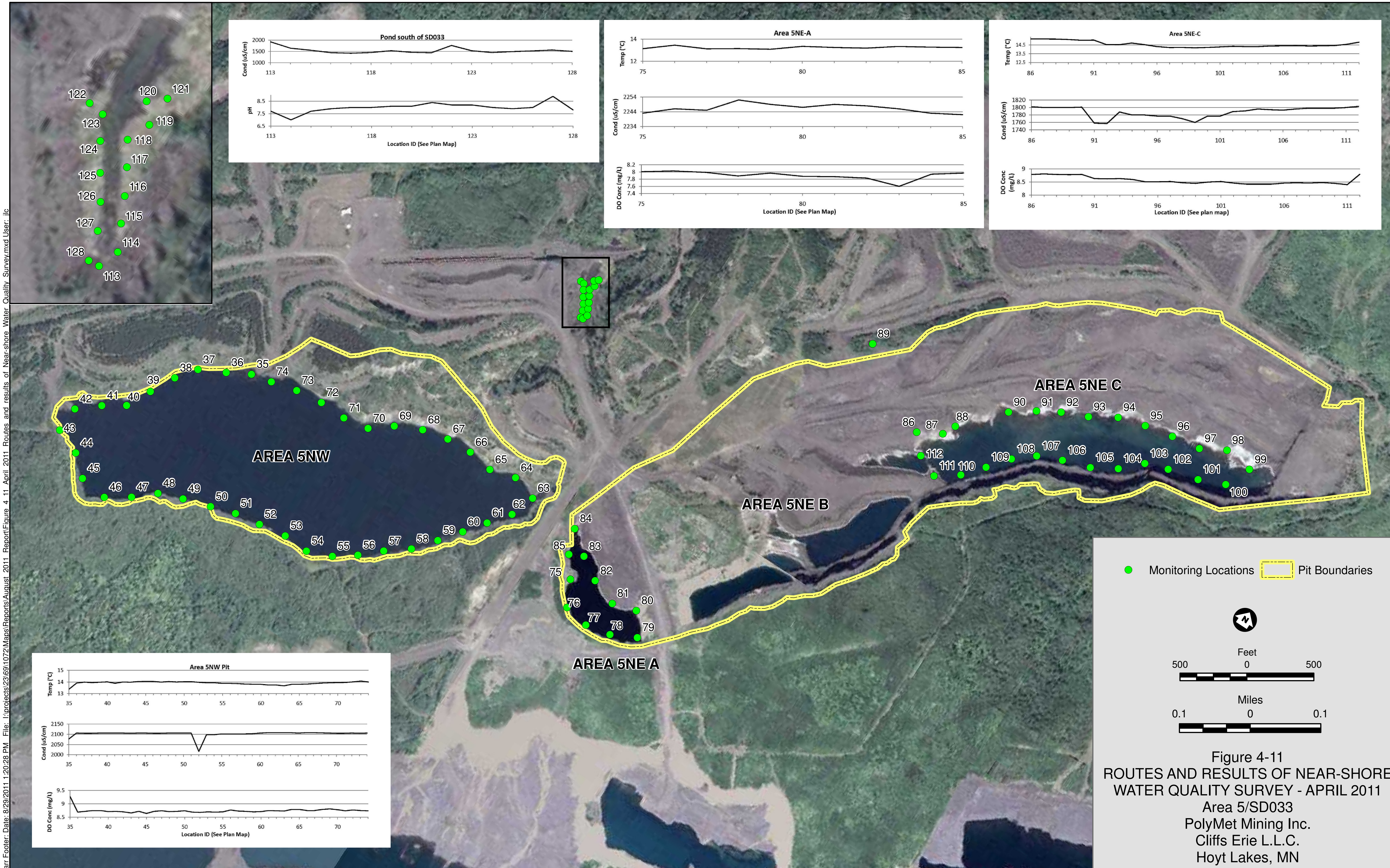


Figure 4-11
ROUTES AND RESULTS OF NEAR-SHORE WATER QUALITY SURVEY - APRIL 2011
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

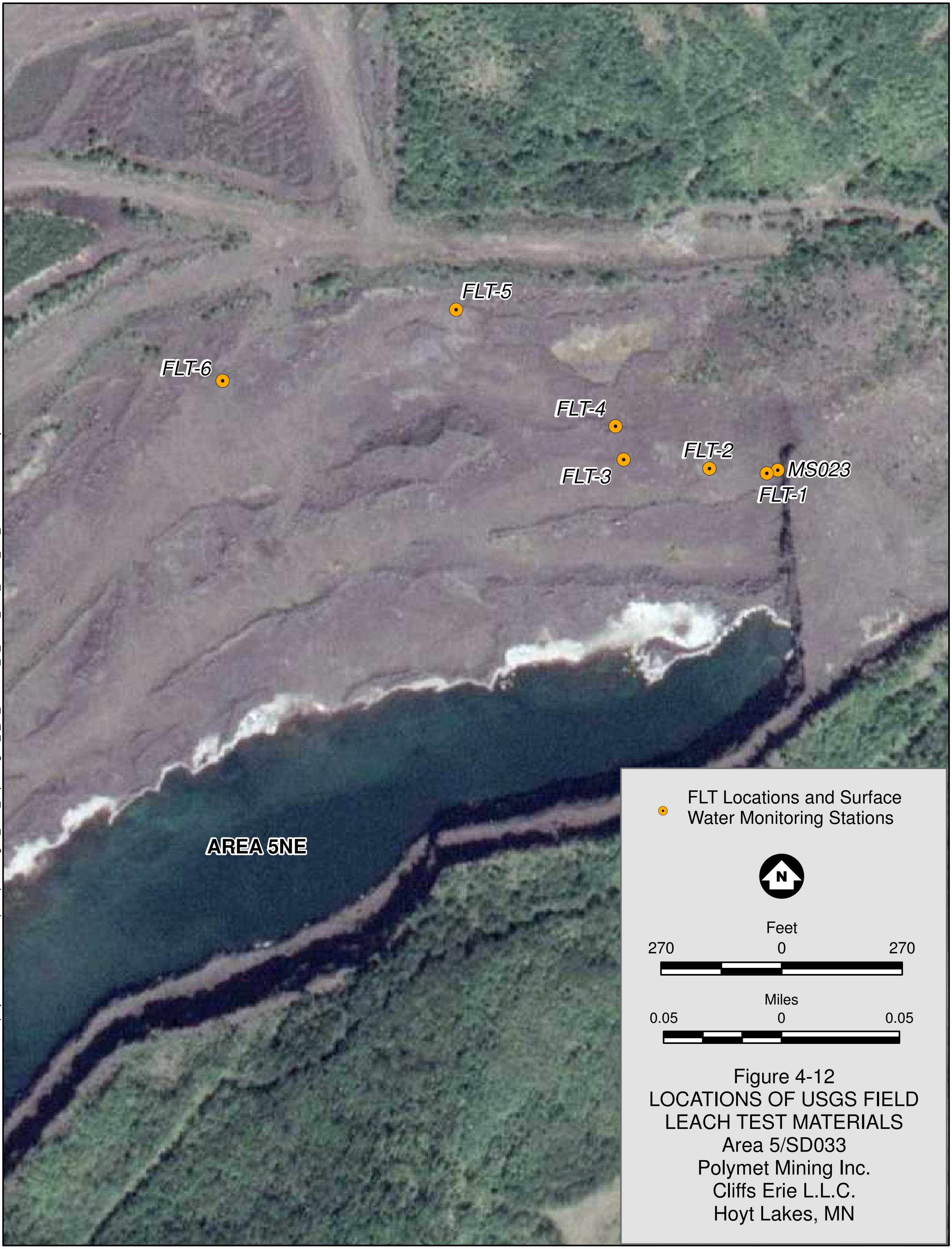


Figure 4-12
LOCATIONS OF USGS FIELD LEACH TEST MATERIALS
Area 5/SD033
Polymet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

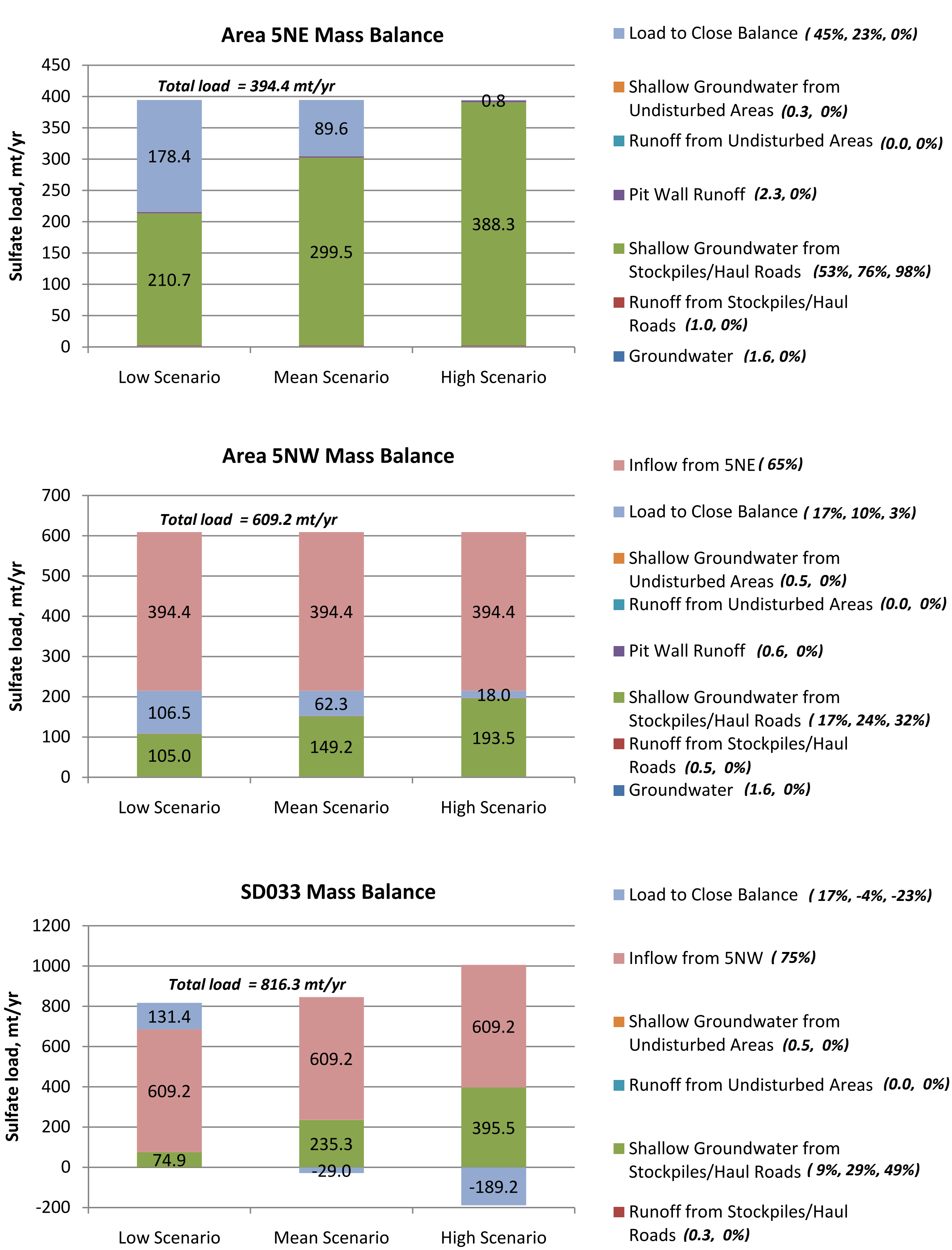


Figure 4-13 Sulfate load allocations from various sources to Pit 5NE, Pit 5NW, and SD033. Italicized values following the balance terms in the legend are load in mt/yr (unless specifically called out on chart), and percentage of load to each pit/SD033.

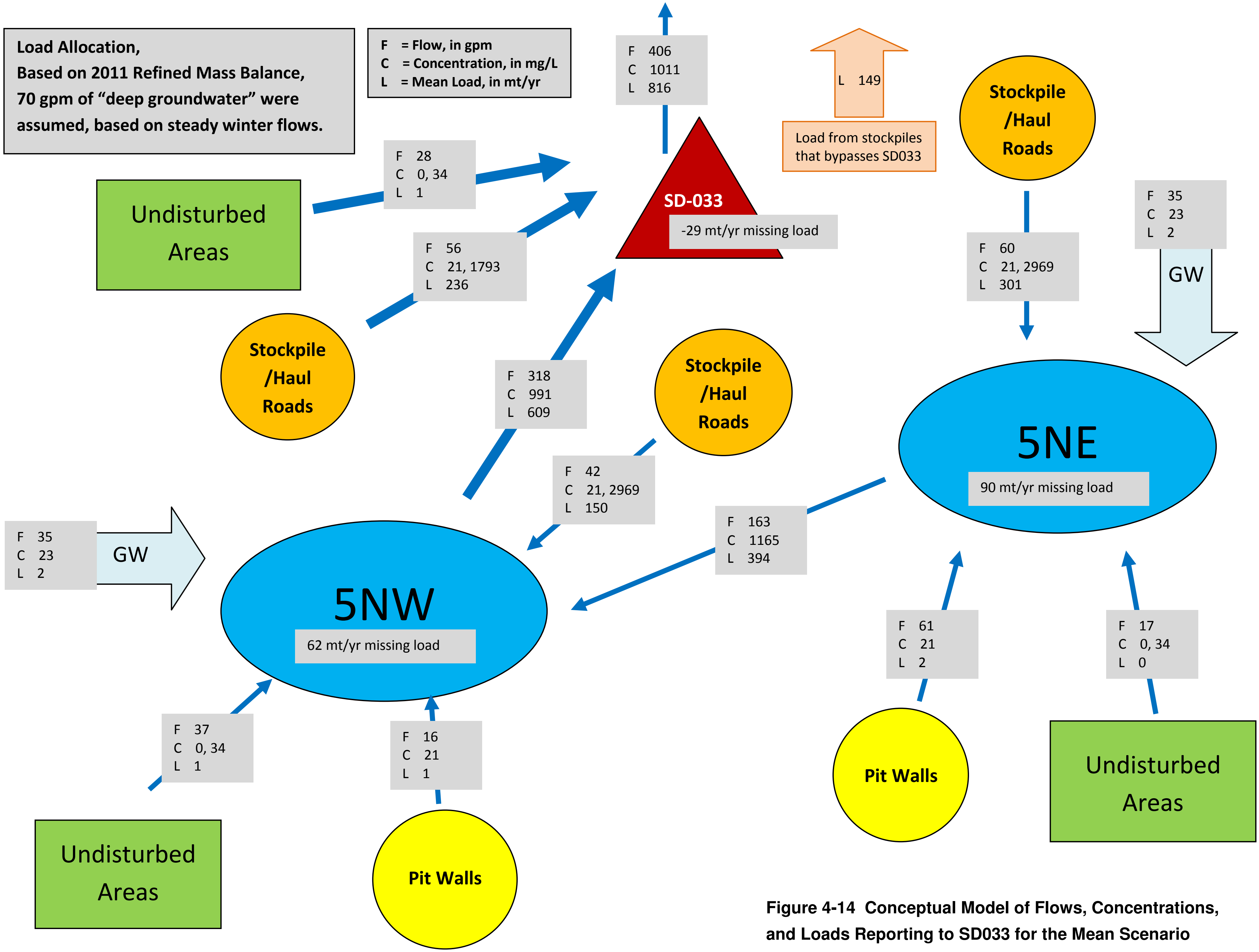


Figure 4-14 Conceptual Model of Flows, Concentrations, and Loads Reporting to SD033 for the Mean Scenario

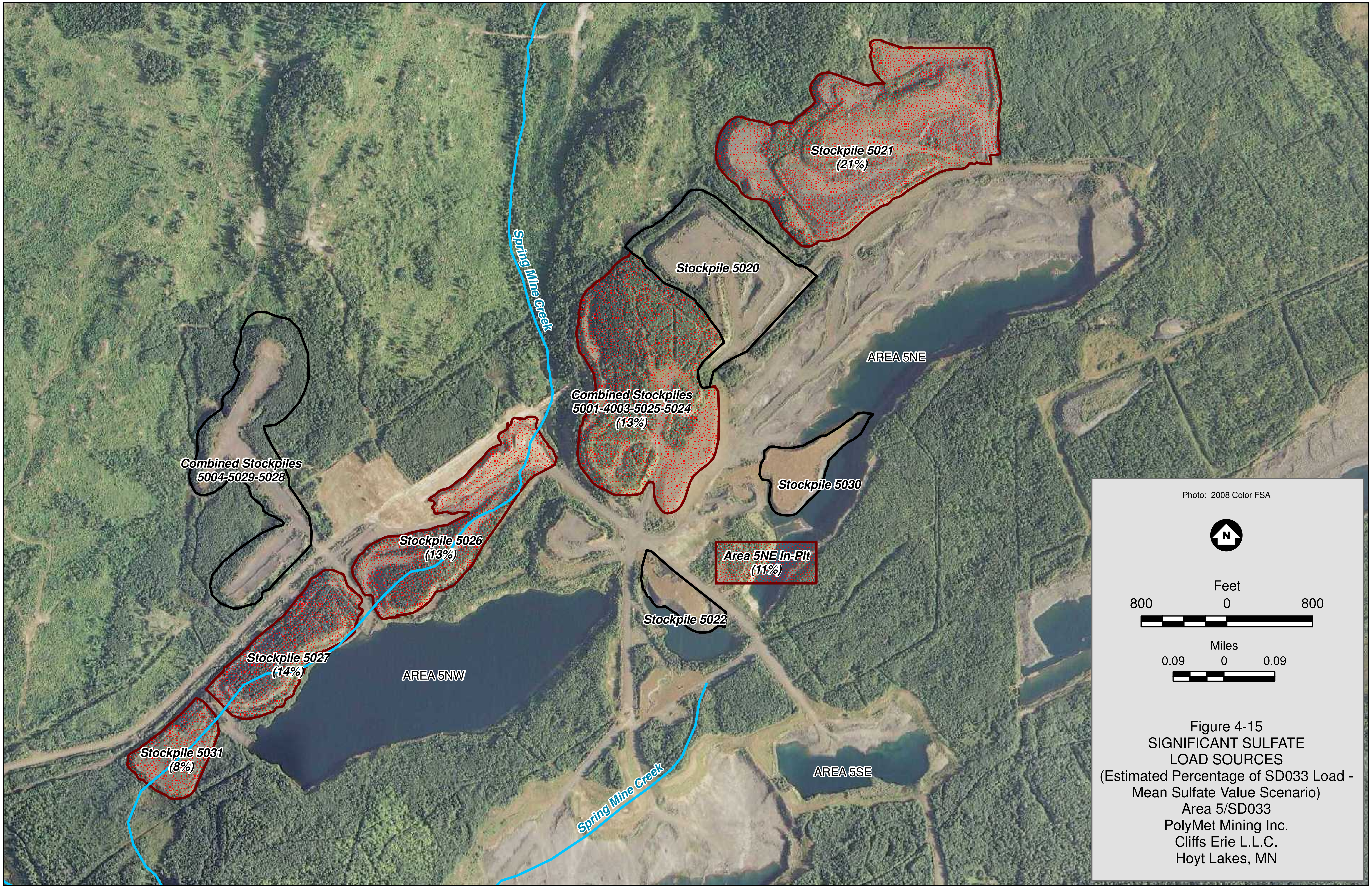
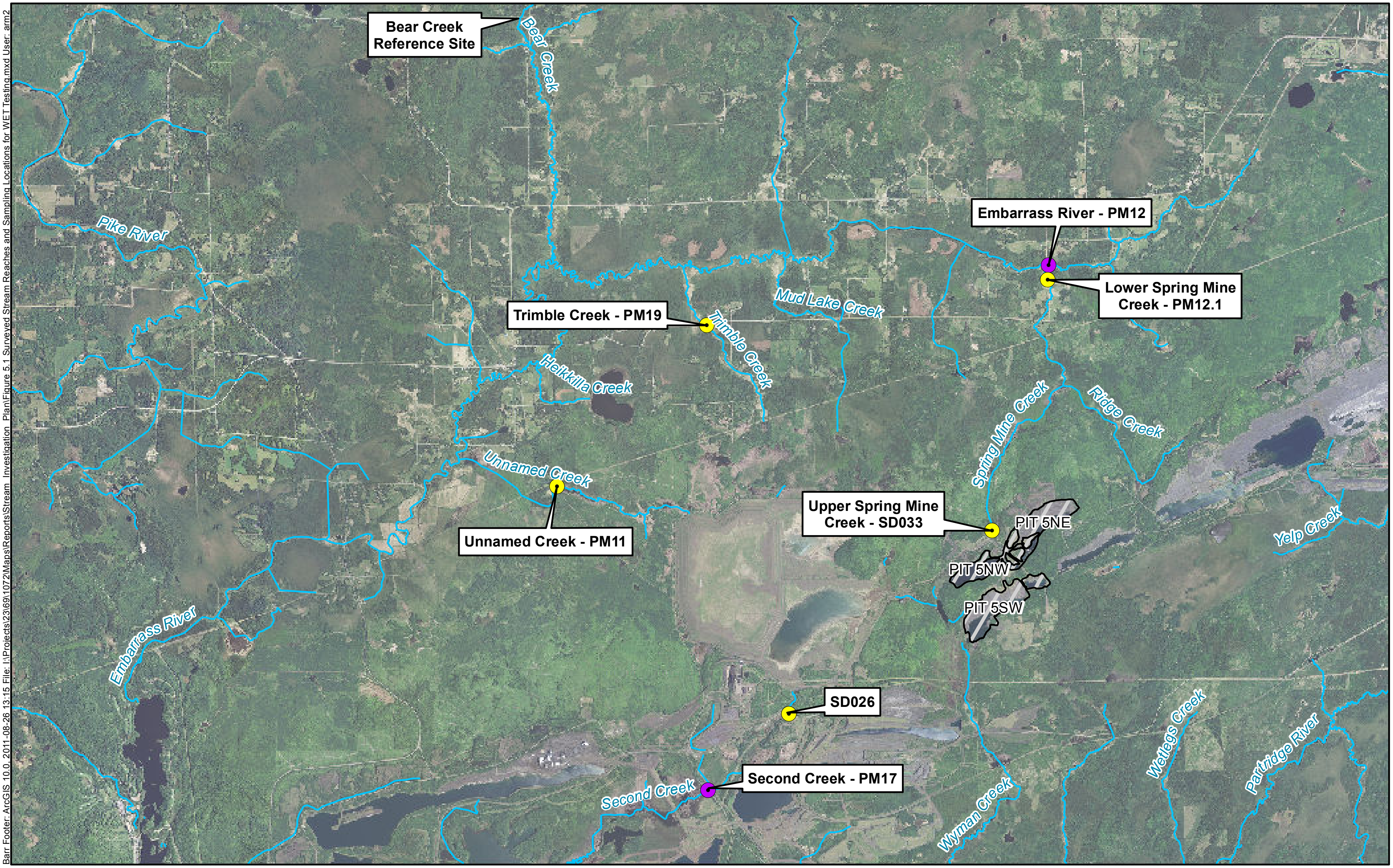


Figure 4-15
SIGNIFICANT SULFATE
LOAD SOURCES
(Estimated Percentage of SD033 Load -
Mean Sulfate Value Scenario)
Area 5/SD033
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN



Water Sample Collection Points

- Sampling Locations
- WET Tests Only
- Rivers & Streams
- Area 5 Pits

0 1 2

Miles

Figure 5.1
SURVEYED STREAM REACHES
AND SAMPLING LOCATIONS FOR
WHOLE EFFLUENT TOXICITY TESTING
St. Louis County, MN

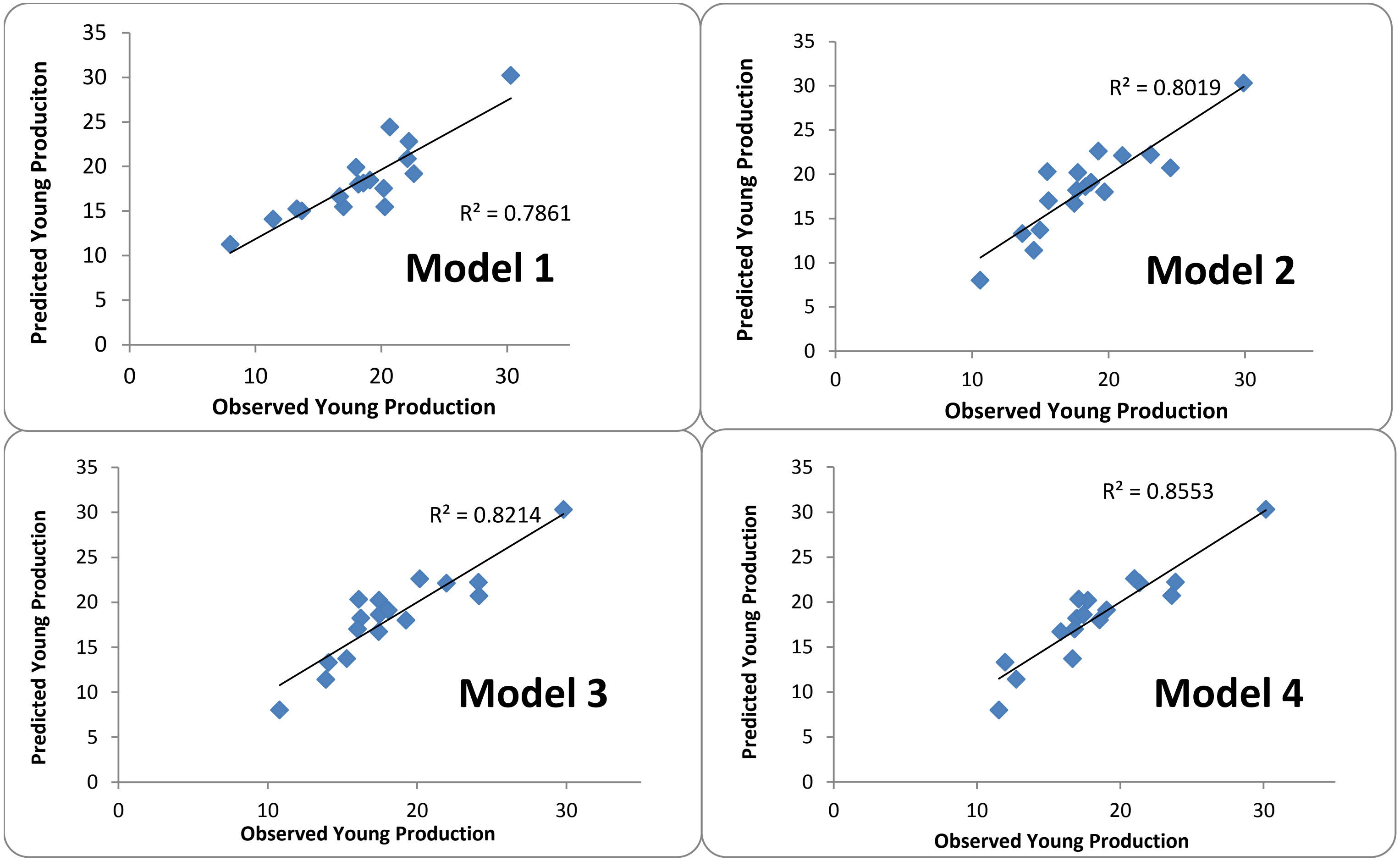


Figure 5-2. Evaluation of the predictive capacity of the multi-parameter logistic model for observed C. dubia young production compared to predicted production (goodness-of-fit assessment)

Model 1 young production =31*1/(1+EXP(-(-2.12+0.0212*Ba-2.22*Co-0.17*Cu+0.75*Ni+0.000247*Fe+0.051*DOC+41.9*TP-0.46*TN)))

Model 2 young production=31*1/(1+EXP(-(-1.96+0.019*Ba-2.11*Co-0.226*Cu+0.761*Ni+0.000130*Fe+0.0468*DOC+46.4*TP -0.366*TN-0.127*Ca/Mg)))

Model 3 young production=31*1/(1+EXP(-(-1.51*Ba-2.02*Co-0.210*Cu+0.752*DOC+0.000199*Fe+0.0336*DOC+36.75*TP-0.395*TN-0.0771*Mg/Ca-0.000969*Alkalinity)))

Model 4 young production=31*1/(1+EXP(-(-2.02+0.0435*Ba-1.90*Co-0.225*Cu+0.769*Ni+0.000246*Fe+0.0564*DOC+19.5*TP-0.485*TN+0.0503*Mg/Ca-0.00101*Alk-0.00136*Sulfate+0.0354*Potassium)))

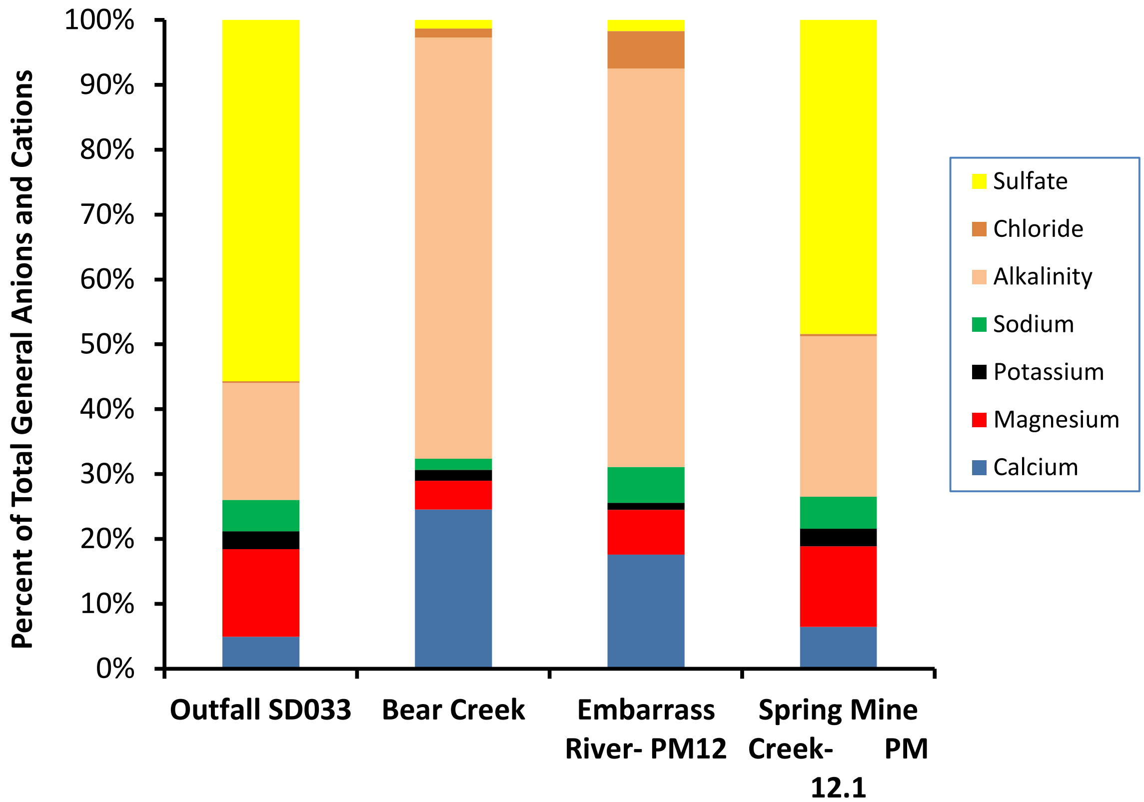


Figure 5-3. Comparison of the relative proportions of major cations and anions in mining outfall waters (SD033, SD026) and background receiving waters

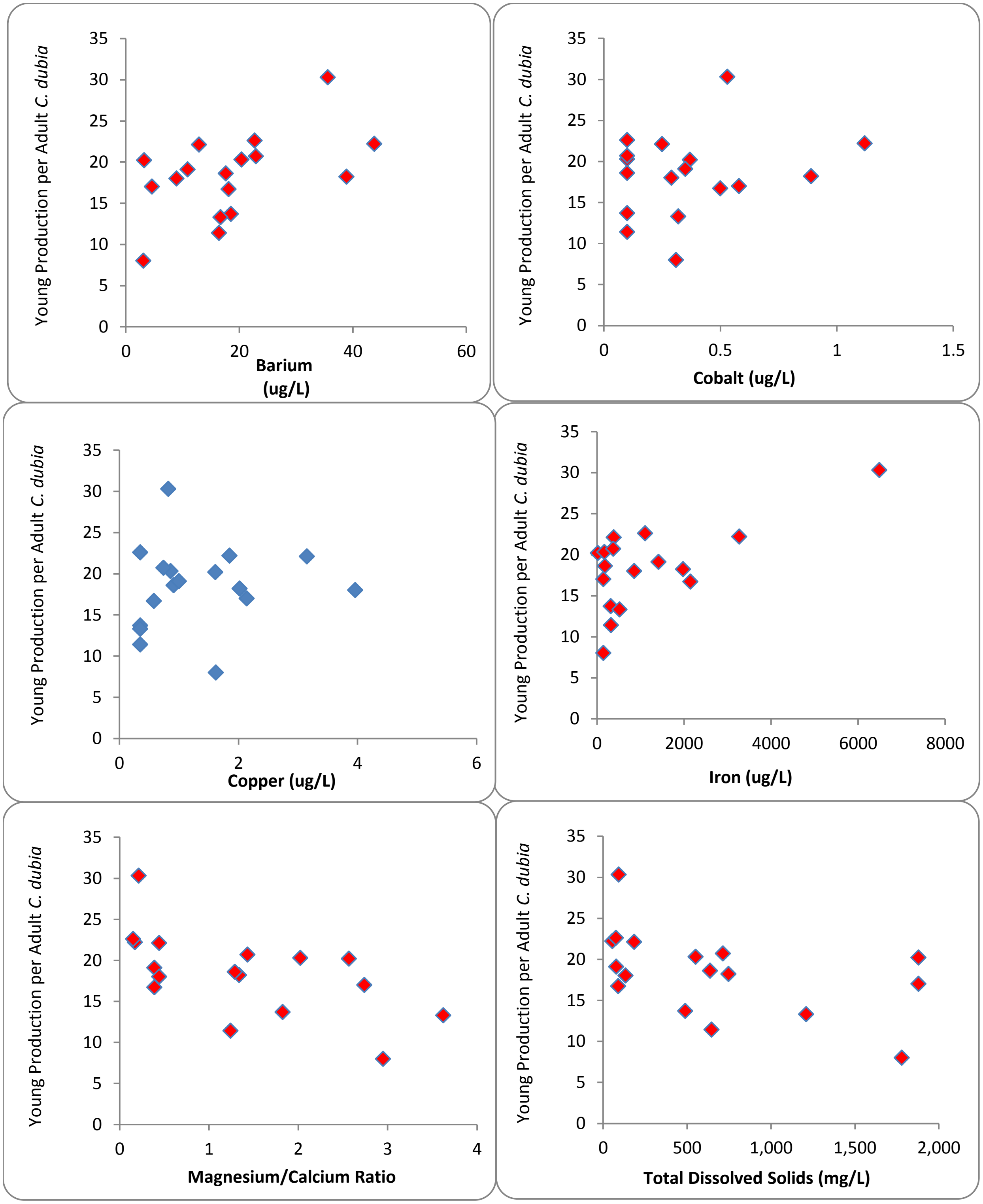


Figure 5-4. Relationship between chemical concentrations in mining outfalls (SD033 and SD026) and background and receiving waters with WET test results (young production per adult C. dubia) (parameters = barium, cobalt, copper, iron, magnesium/calcium ratio, total dissolved solids)

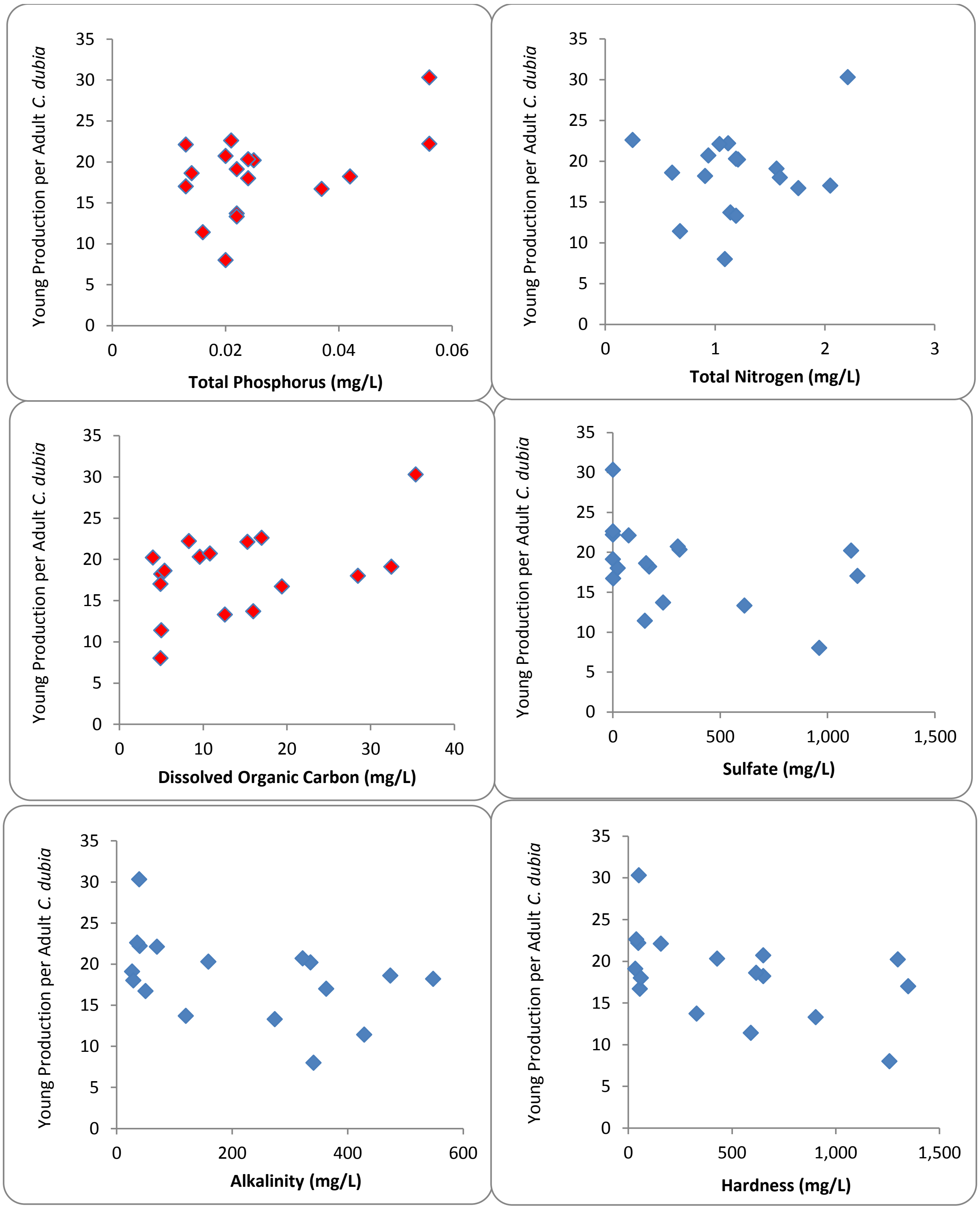
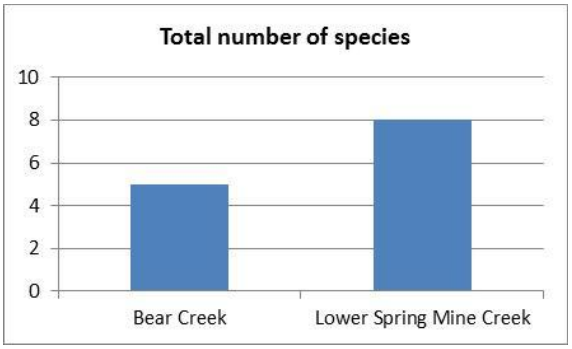
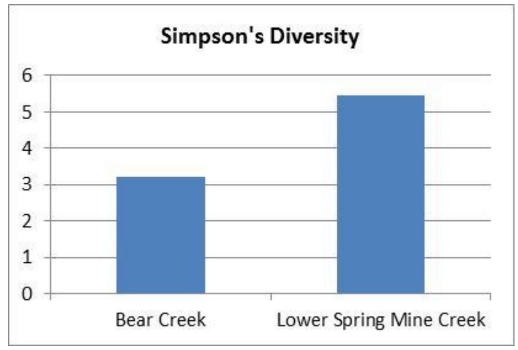


Figure 5-5. Relationship between chemical concentrations in mining outfalls (SD033 and SD026) and background and receiving waters with WET test results (young production per adult C. dubia) (parameters = total phosphorus, total nitrogen, dissolved organic carbon, sulfate, alkalinity, hardness)

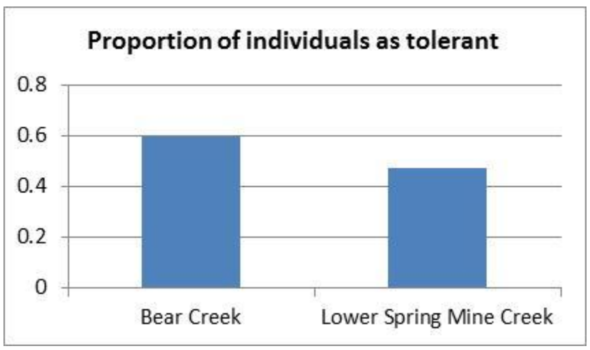
a)



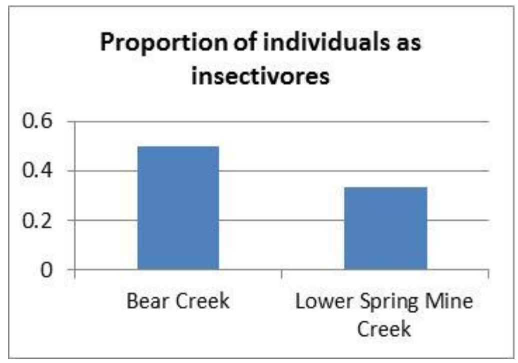
b)



c)



d)



e)

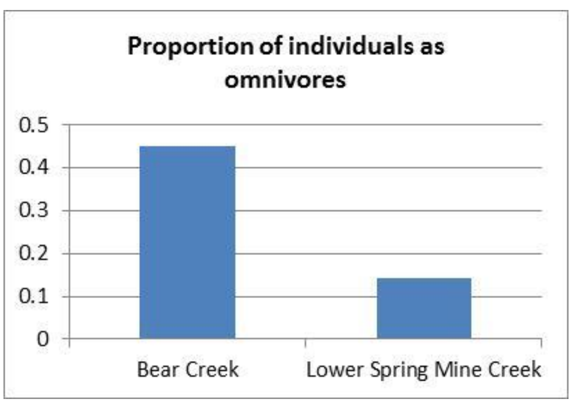


Figure 5-6 Summary of fish survey results for Bear Creek (control stream) and Lower Spring Mine Creek (PM 12.1)

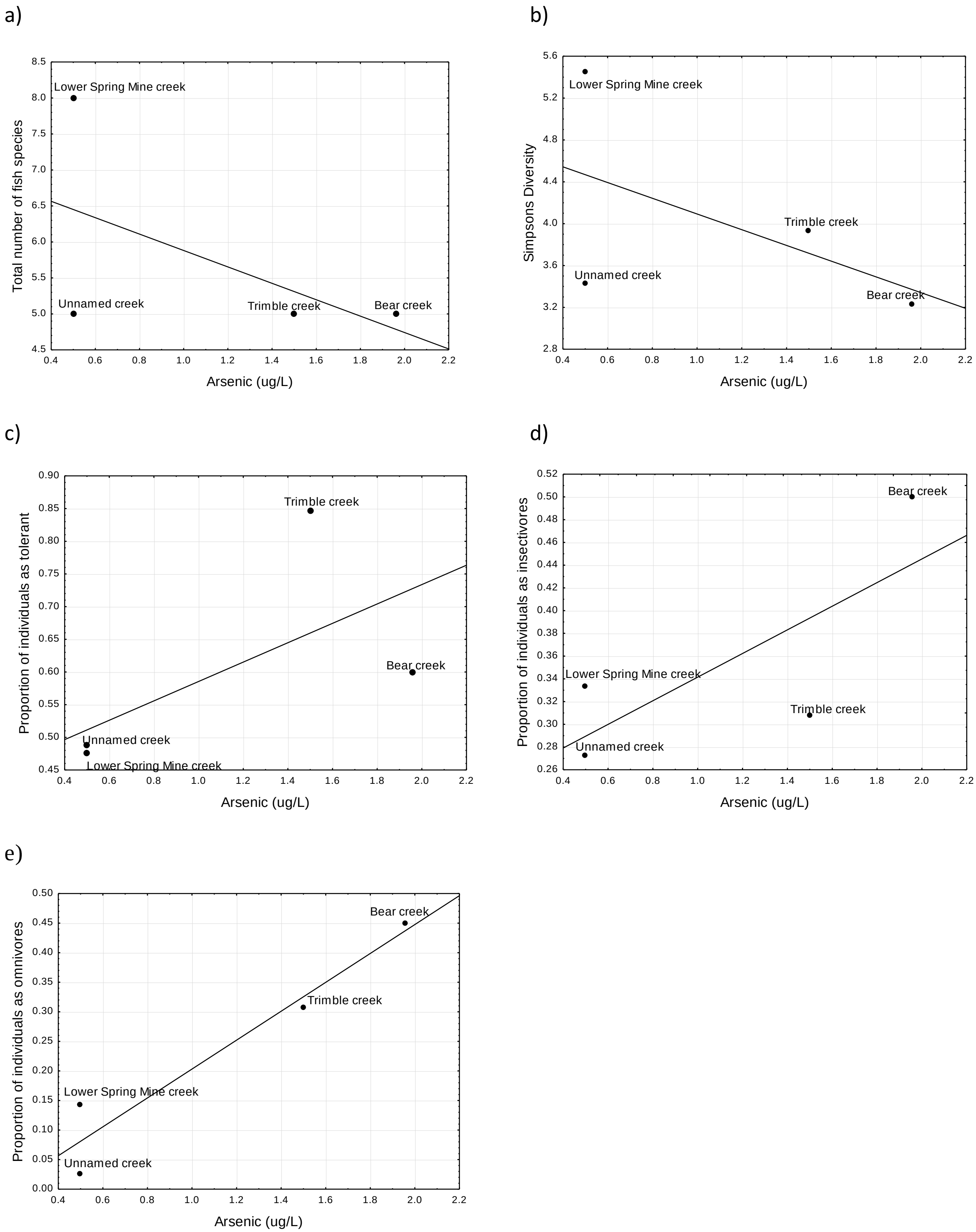
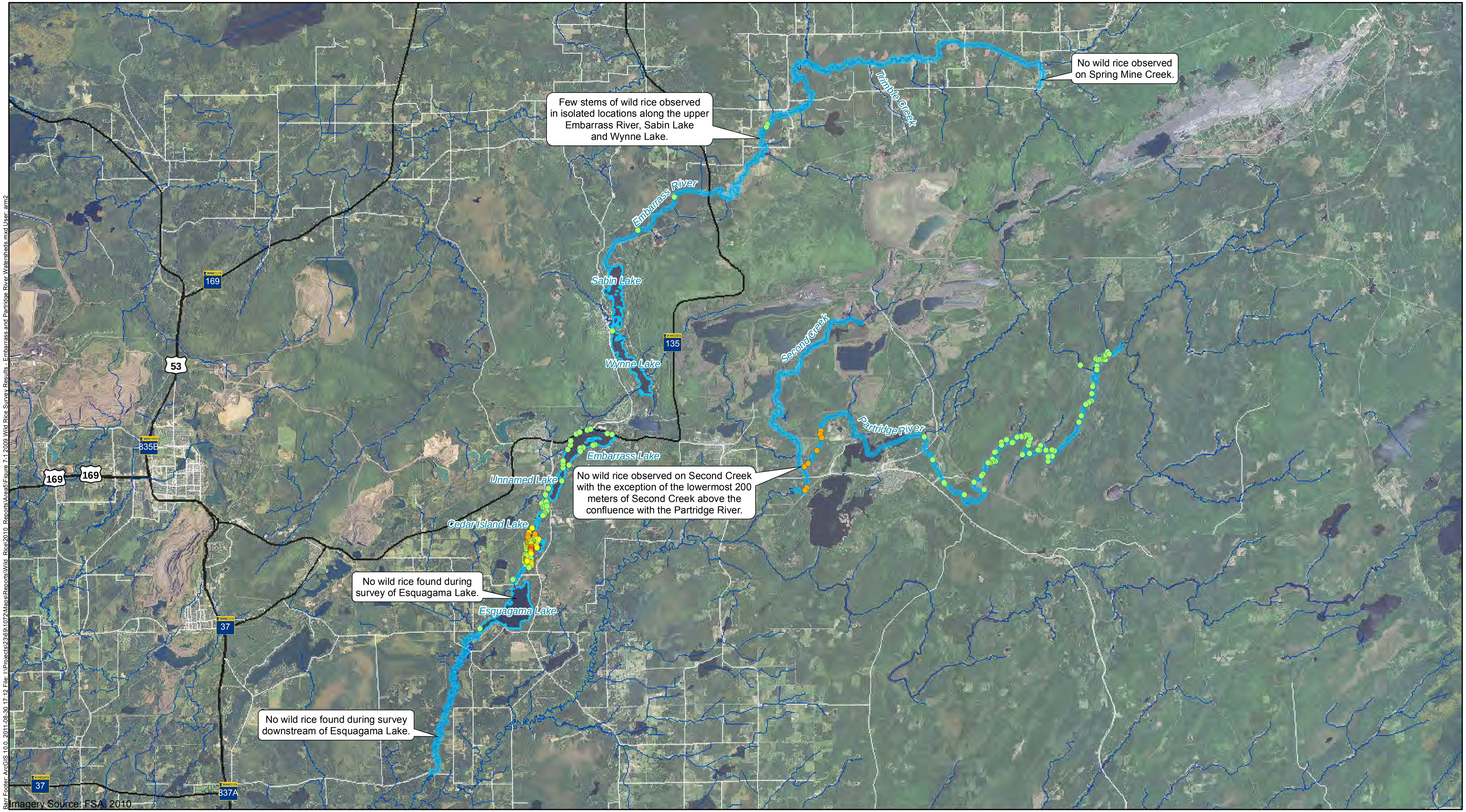


Figure 5-7 Relationship between fish community measures and arsenic concentration for the sites, Bear Creek, Unnamed Creek (PM11), Trimble Creek (PM19) and Lower Spring Mine Creek (PM 12.1).



Wild Rice Density

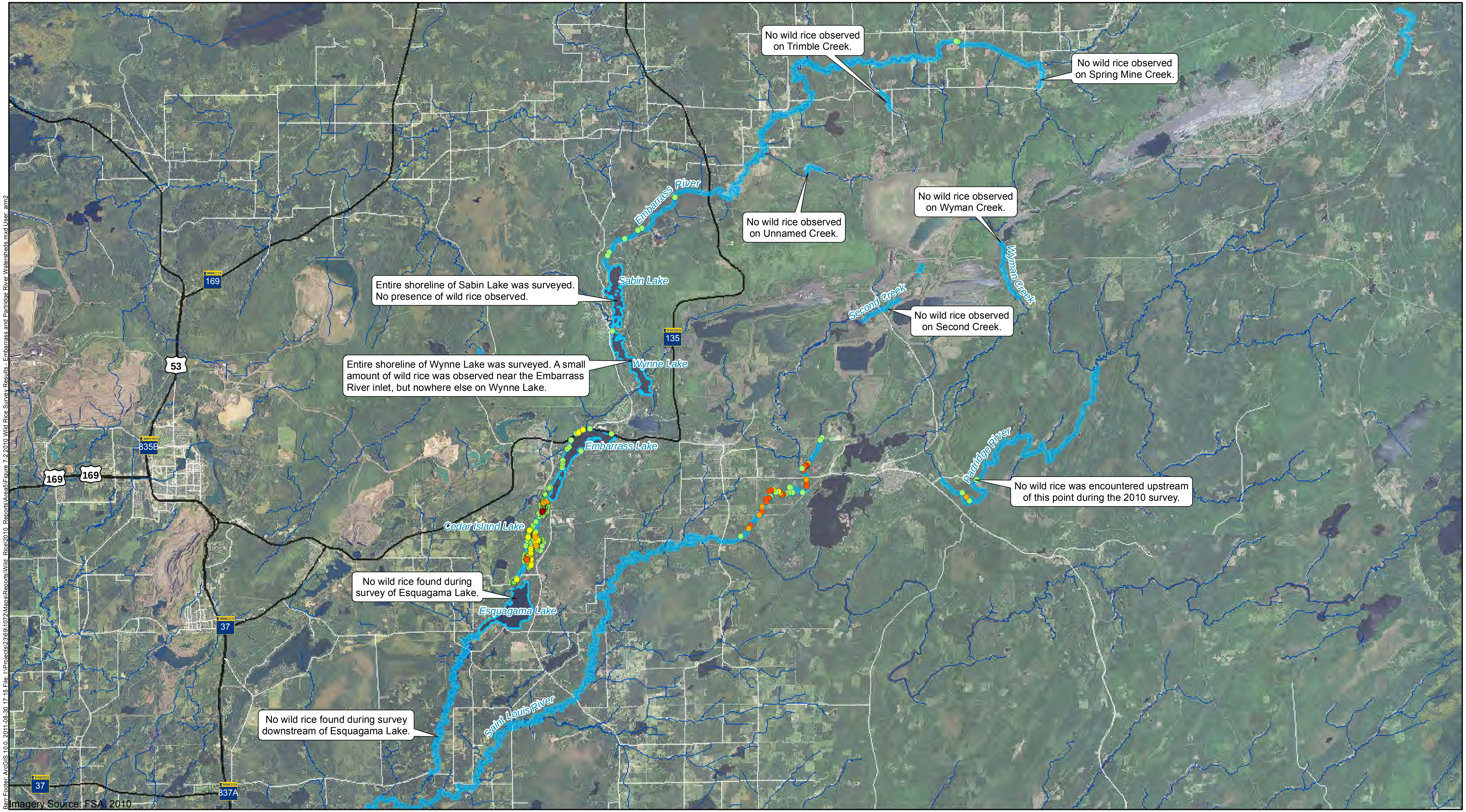
- 1 <10% Wild Rice Coverage
- 2
- 3
- 4
- 5 >75% Wild Rice Coverage
- Stream or Shoreline Segment Surveyed in 2009

0 1 2 4

Miles

Data Sources: *2009 Wild Rice Survey and Sulfate Monitoring*
Prepared for Steel Dynamics, Inc. and Mesabi Mining, LLC, October 2009
2009 Wild Rice and Sulfate Monitoring
Prepared for PolyMet Mining Inc. – NorthMet Project, September 2009

Figure 7-1
2009 WILD RICE SURVEY RESULTS -
EMBARRASS AND PARTRIDGE RIVER WATERSHEDS
Cliffs Erie, L.L.C. and
PolyMet Mining, Inc.
Hoyt Lakes, Minnesota



Wild Rice Density

- 1 <10% Wild Rice Coverage
- 2
- 3
- 4
- 5 >75% Wild Rice Coverage

Stream or Shoreline Segment Surveyed in 2010

Data Sources: *2010 Wild Rice Survey and Sulfate Monitoring*
Prepared for Mesabi Mining, LLC, March 2011
2010 Wild Rice and Water Quality Monitoring Report
Prepared for PolyMet Mining Inc. – NorthMet Project, January 2011

0 1 2 4
Miles

Figure 7-2
2010 WILD RICE SURVEY RESULTS -
EMBARRASS AND PARTRIDGE RIVER WATERSHEDS
Cliffs Erie, L.L.C. and
PolyMet Mining, Inc.
Hoyt Lakes, Minnesota

Appendices

Appendix 4-A

Photolog of Water Quality Monitoring

MS001

August 2010

August 2010

October 2010

April 2011

June 2011

MS002

August 2010

August 2010

August 2010

October 2010

April 2011

June 2011

MS003


August 2010


August 2010


August 2010


April 2011


June 2011

MS004

August 2010

August 2010

Wetland South of MS004 August 2010

October 2010

October 2010

April 2011

MS005

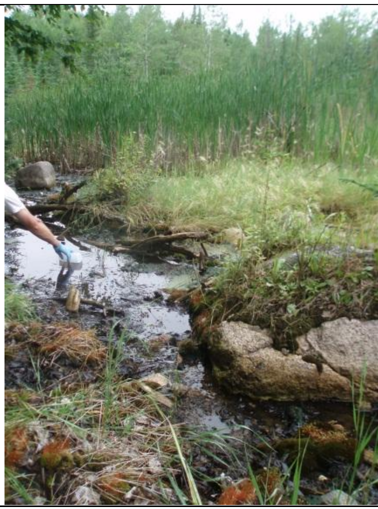
August 2010

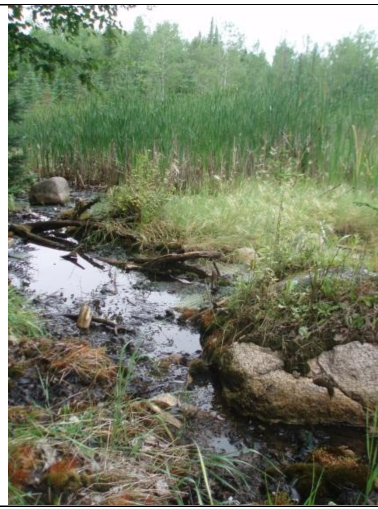
August 2010

October 2010

April 2011

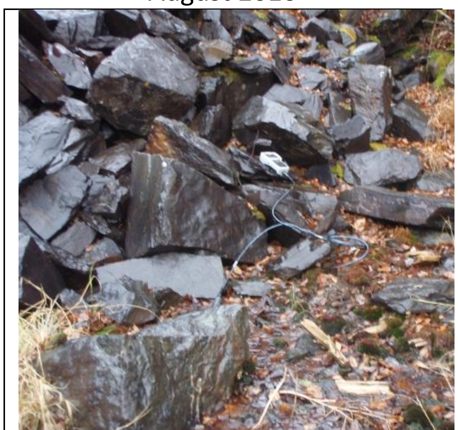
MS007


August 2010


August 2010


August 2010


August 2010


October 2010


April 2011


June 2011

MS009

October 2010

April 2011

June 2011

MS010

August 2010

A - August 2010

A – August 2010

B – August 2010

B – August 2010

B – August 2010

MS010 Continued

A – October 2010

A – October 2010

C – October 2010

A – April 2011

B – April 2011

C – April 2011

MS010 Continued

A – June 2011

B – June 2011

MS011

August 2010

August 2010

October 2010

October 2010

April 2011

MS012


August 2010


August 2010


October 2010


April 2011


June 2011

MS013

August 2010

August 2010

October 2010

B – October 2010

B – October 2010

April 2011

MS013 Continued

August 2010

MS014

August 2010

June 2011

MS015

August 2010

October 2010

April 2011

April 2011

June 2011

MS016


August 2010


October 2010


April 2011


April 2011


June 2011

MS017

August 2010

April 2011

April 2011

June 2011

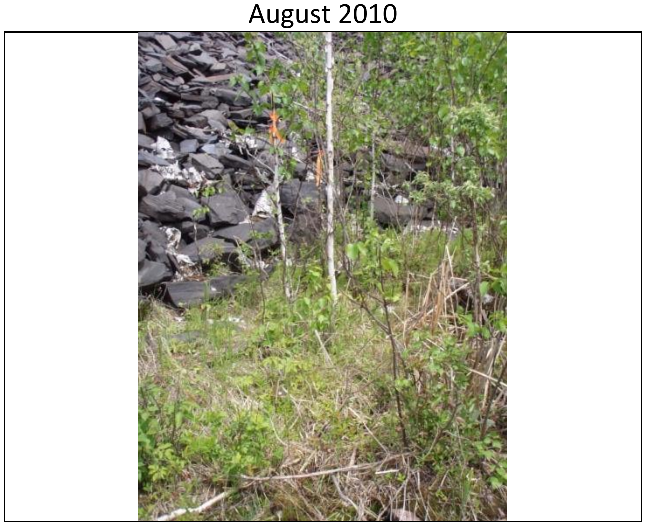
MS018

August 2010

August 2010

August 2010

April 2011



June 2011

MS019

August 2010

August 2010

August 2010

October 2010

October 2010

April 2011

MS019 Continued

June 2011

MS020

August 2010

August 2010

October 2010

October 2010

April 2011

June 2011

MS020 Continued

June 2011

MS021


October 2010


April 2011


June 2011

MS022

August 2010

August 2010

August 2010

MS023

August 2010

August 2010

August 2010

October 2010

April 2011

June 2011

MS024

August 2010

August 2010

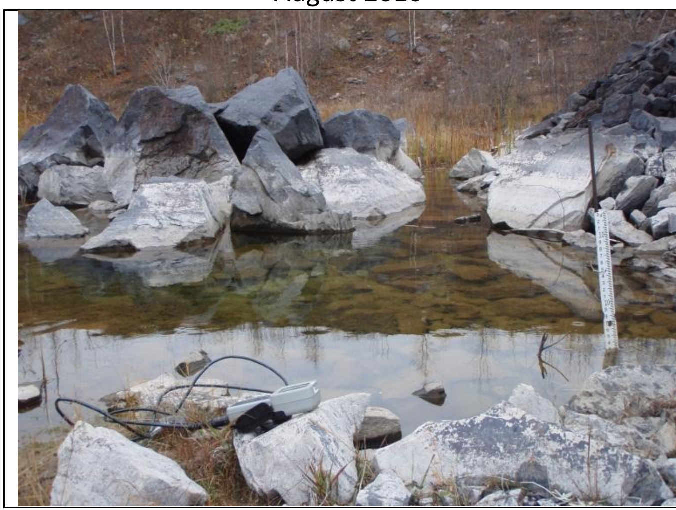
October 2010

April 2011

MS025

August 2010

August 2010



October 2010

April 2011

June 2011

MS027

October 2010

April 2011

June 2011

SD033

August 2010

August 2010

October 2010

October 2010

October 2010

April 2011

SD033

April 2011

SEEP

April 2011

April 2011

June 2011

Appendix 4-B

Summary of Pit Lake Water Quality Monitoring and Hydrodynamics

Appendix 4-B

Interpretation of Continuous Temperature and Conductivity Data – Area 5NE and Area 5NW Pits

Methodology

HOBO® water quality monitoring probes were installed at regular vertical intervals (approximately every 3-4 meters) at the deepest parts of the Area 5NE and Area 5NW pits. The water quality probes were attached to vertical lines suspended between an anchor at the bottom of the pit and a buoy at the water surface. The probes were programmed to record temperature and specific conductivity at 30-minute time intervals year-around. The probes were periodically downloaded, and provide a continuous record of temperature and conductivity with depth in the pits for the study period. The probes were installed in August, 2010, and removed in late July, 2011.

In general, the probes collected high-quality temperature and conductivity data over the period of study. One probe in the Area 5NW pit showed some drift in the conductivity sensor in 2011, and the data from that probe was not used in the isopleths for the Area 5NW pit specific conductivity. Sulfate, magnesium, and calcium have a positive correlation with specific conductivity in the pits. The near bottom specific conductivity measured in the Area 5NW pit during water sample collection on August 4 is not representative, and the probe may have been touching sediment on the bottom.

Area 5NE Pit

The Area 5NE Pit started to show mixing down to 14 meters in early November2010, as temperatures cooled and thermal stratification near the surface broke down (Figure 4-B-1). By early December, the entire water column was ~4 degrees Celsius. A small gradient in specific conductivity remained below 13 meters (Figure 4-B-2). The area of the pit that was monitored has a relatively small surface area, and is surrounded by high rock stockpiles and trees that may shelter the surface from the full force of the wind, so the pit may not fully mix during fall and spring turnover. The Area 5NE Pit had very low dissolved oxygen concentrations of just 1.3 mg/L at 1 meter below the surface. This may also be a function of the small pit surface footprint surrounded by high relief, limiting wind speed at the pit surface that would increase oxygen transfer, or may be an indication of high chemical oxygen demand within the pit.

Area 5NW Pit

The Area 5NW pit also began mixing from 0 to about 13 meters depth in early November 2010, as thermal stratification near the surface broke down (Figure 4-B-3). Below approximately 13 meters depth, the specific conductivity gradient is very stable year round, indicating little mixing is occurring below 13 meters depth (Figure 4-B-4). Additionally, water temperatures below 13 meters are nearly constant at 6 to 7 degrees Celsius year round. Data collected from the Area 5NW pit in 2010 and 2011 indicate that the pit experiences fall and spring mixing in the top several meters of the water column, but does not mix at depths greater than about 13 meters. A stable, year round chemocline exists below about 13 meters depth in the Area 5NW pit. During the summer and fall of 2010, the Area 5NW pit had an increased concentration of dissolved oxygen before decreasing substantially with depth. This is often observed in lakes, as phytoplankton accumulate at or near the thermocline and photosynthesis increases oxygen concentrations.

Figure 4-B-1
Area 5NE Pit Temperature (deg C) Isopleths

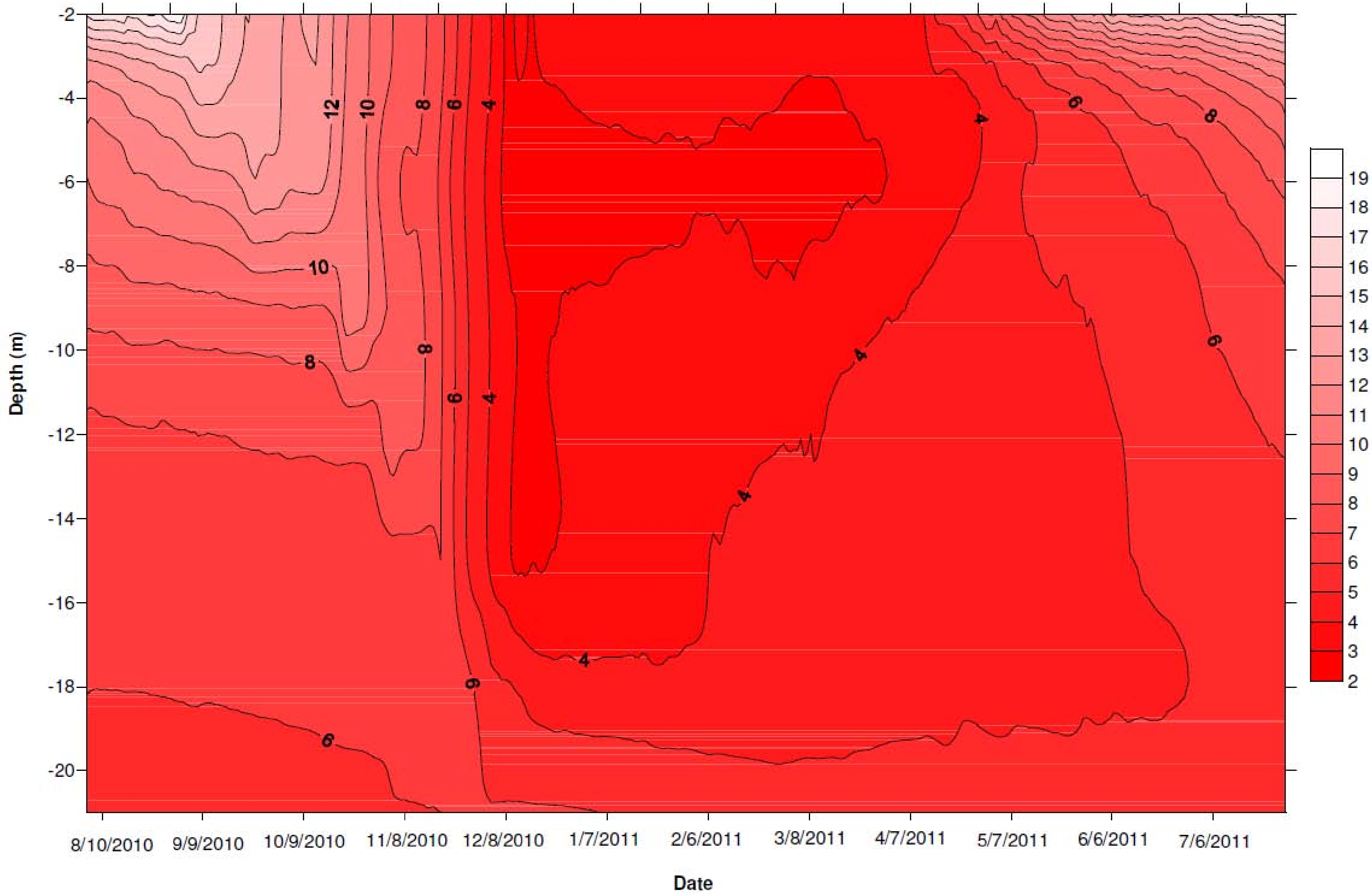


Figure 4-B-2
Area 5NE Pit Specific Conductivity (uS/cm) Isopleths

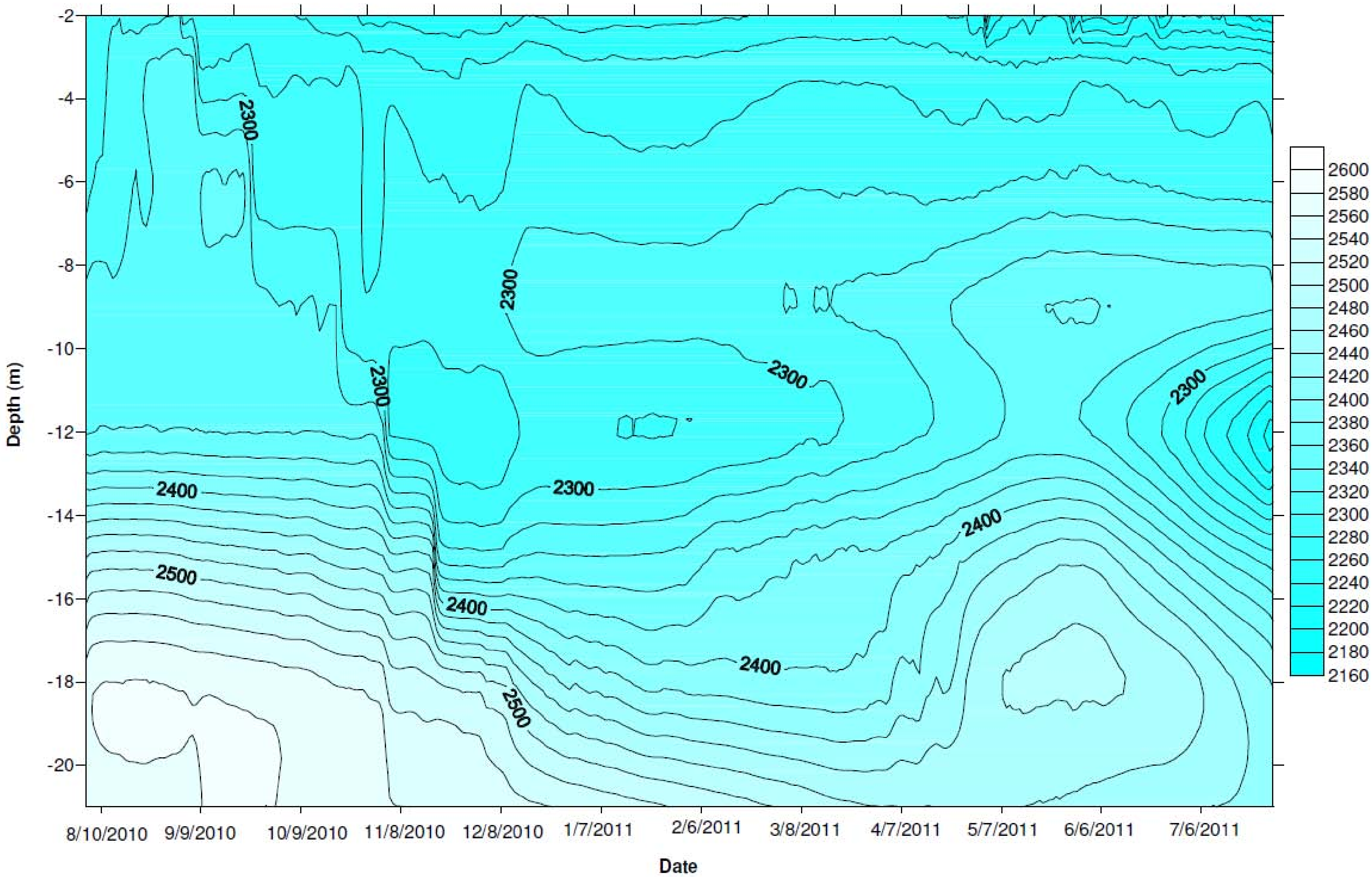


Figure 4-B-3
Area 5NW Pit Temperature (deg C) Isopleths

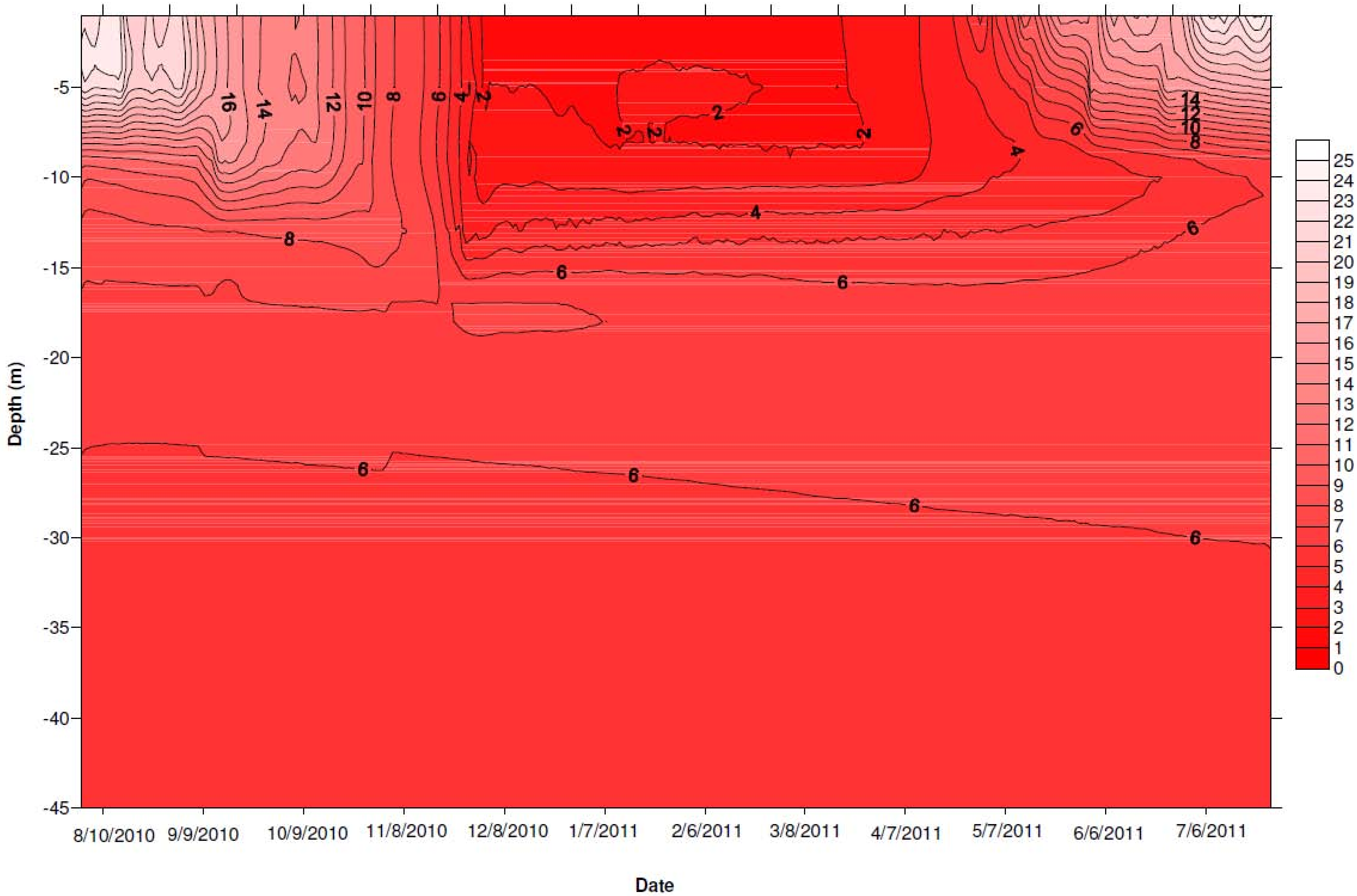
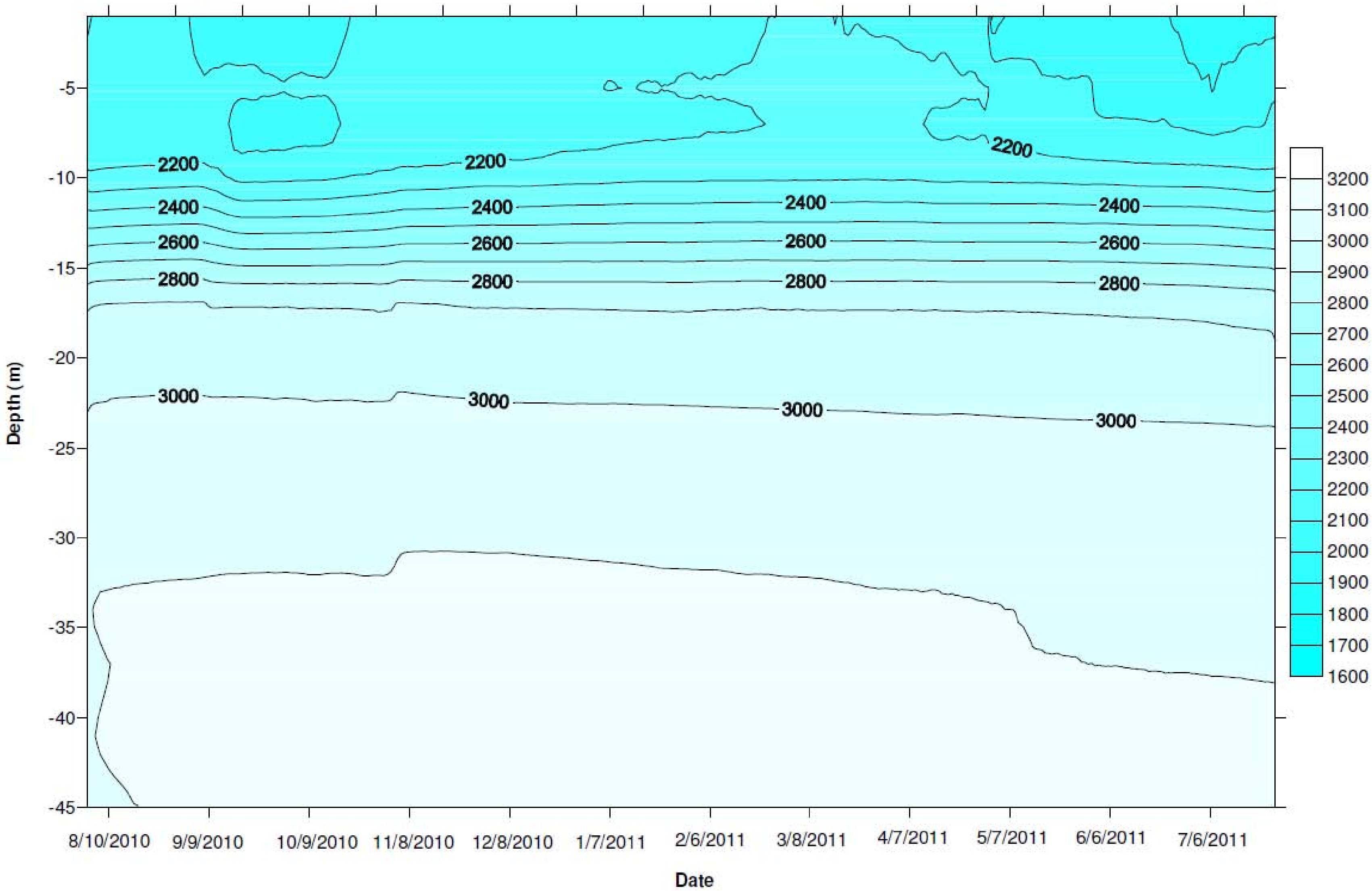


Figure 4-B-4
Area 5NW Pit Specific Conductivity (uS/cm) Isopleths



Appendix 5-A

Physical Habitat and Water Chemistry Assessment Protocol

PHYSICAL HABITAT AND WATER CHEMISTRY ASSESSMENT PROTOCOL FOR WADEABLE STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to collect physical habitat and water chemistry information at stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all wadeable monitoring sites for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a site vary, the physical habitat and water chemistry assessment protocols outlined in this document apply to all wadeable stream monitoring sites unless otherwise noted. For our purposes, wadeable sites constitute those that are sampled for fish utilizing a backpack electrofisher or stream electrofisher (see SOP--"***Fish Community Sampling Protocol for Stream Monitoring Sites***").

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. He or she must have a minimum of six months field experience in physical habitat sampling methodology. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/interns: A field technician/intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site.

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer's manuals.

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Ten percent of sites sampled in any given year are resampled as a means of determining sampling error and temporal variability.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment list: Verify that all necessary items are present before commencement of this procedure (Table 1).

B. Data collection method: The location and length of the sampling reach is determined during site reconnaissance (see SOP--"***Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites***"). Sampling is conducted during daylight hours within the summer index period of mid-June through mid-September. Sampling should occur when streams are at or near base-flow. Water chemistry is sampled immediately prior to fish sampling. The physical habitat assessment is conducted after fish sampling, so as not to disturb the fish community.

Habitat within a station is quantified utilizing the transect-point method (modified from: Simonson, T.D., Lyons, J., and Kanehl, P.D. 1994. Guidelines for Evaluating Fish Habitat in Wisconsin Streams. Gen. Tech. Rep. NC-164. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Experiment Station. 36 p.). Thirteen transects are established within the reach and four equally spaced points plus the thalweg are located along each transect. Measurements or visual estimates are made to characterize key components of the physical habitat structure important in influencing stream ecology. Key components include: channel morphology, substrate, cover, and riparian condition.

Three data sheets are required for the physical habitat and water chemistry assessment. One copy of the **Station Features** and **Visit Summary** form is needed for each site. One copy of the **Transect** form is needed for each of the thirteen transects (or only seven copies if forms are doubled-sided). Copies of these forms are attached. Guidelines for filling out each data sheet are described in the following pages.

C. Station Features Data Sheet

This data sheet describes the length and location of the major morphological features within a sampling station (bends, pools, riffles, runs, log jams, islands, and beaver dams). The **Station Features** data is collected in conjunction with the **Transect** data as you proceed from the downstream end to the upstream end of the station. The variables on this data sheet are as follows:

1) *Field Number* – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example: 02UM001).

2) *Date* – The date habitat sampling is conducted in month/day/year format (MM/DD/YY).

3) *Crew* – The personnel who collected the habitat data.

4) *Distance From Start* (column) – The distance from the downstream end of the station to the downstream end of each *stream feature*. Bends, log jams, and beaver dams are measured only to their midpoint because they are features that are located within one of the channel morphology types (i.e. riffle, run, or pool). Measure distances to the nearest tenth of a meter following the center of the stream channel. The first value is always "0" to indicate the *stream feature* at the beginning of the station. As you proceed upstream it is not necessary to continue to measure from the downstream end of the station, as each successive **Transect** data sheet has the distance of that transect from the downstream end of the station recorded. The last value in this column is the total length of the station.

5) *Stream Feature* (column) – Record the major morphological features encountered as you proceed upstream. If a cross-section of stream contains two or more channel morphology types (i.e. riffle, run, or pool) record the dominant type. Stream features recorded include:

   Riffles: Portions of the stream channel where water velocities are fast, water depths are relatively shallow, and substrates are typically coarse. Steeper stream gradient results in obvious surface turbulence. Areas of high gradient that are deep, fast, and turbulent are called **rapids**.

   Runs: Water velocities may be moderately fast to slow but the water surface typically appears smooth with little or no surface turbulence. Generally, runs are deeper than a riffle and shallower than a pool. Runs with very slow water velocities are sometimes called **glides**. For our purposes, if the channel type is not considered a riffle or pool it is defined as a run.

   Pools: Water is slow and generally deeper than a riffle or run. Water surface is smooth, no turbulence. A general rule that can be used to distinguish a pool is if two or more of the following conditions apply; the stream channel is wider, deeper, or slower than average.

   Bends: A change in the direction of the stream channel of at least 60 degrees.

   Islands: Areas of land within the stream channel that is surrounded on all sides by water and is dry even when the stream is experiencing bankfull flow. Areas with nearly all of the stream's flow on one side and just a trickle of water on the other are not considered islands. Islands usually contain vegetation. **Bars**, channel features below the bankfull flow level that are dry during baseflow conditions, are not recorded.

   Log Jams: Woody material that is of sufficient size to appreciably alter the direction of flow or change the morphology within the stream channel. Large log jams can be similar in effect and appearance to beaver dams.

   Beaver Dams: Structures constructed by beavers that span the entire stream channel and block flow. Beaver dams consist of sticks and mud, but older dams may be overgrown with vegetation.

   Other noteworthy features include: **bridges, culverts, dams**, and **tributaries**. The last feature noted in this column is the upstream **end of the reach**.

6) *Length* (column) – The length, measured to the nearest tenth of a meter, of each *stream feature* encountered within the reach. The length of bends, log jams, and beaver dams are not recorded. It is not necessary to complete this column while in the field as this information is derived from the *Distance from start* and *Stream feature* columns.

7) *Distance Between Bends* – The distance (m) between successive bends contained within the station. The first row is the distance between the mid-point of the first and second bend. The second row is the distance between the second and third, and so forth. These values can be derived using the information contained in the columns *Distance from start* and *Stream feature*. The "sum" and "mean" rows summarize all the distances between bends within the station.

8) *Distance Between Riffles* – The distance (m) between successive riffles contained within the station. The first row is the distance between the upstream end of the first riffle and the downstream end of the next riffle upstream, and so forth. Distances can be derived using the *Distance from start* and *Stream feature* columns. The "sum" and "mean" rows summarize these distances.

9) *Length of Individual Riffles, Pools, and Runs* – The individual length (m) of each riffle, pool, or run within the station, which can be derived using the *Stream feature* and *Length* columns. The sum of their lengths is also recorded here.

D. Transect Data Sheet

Record the data generated from each of the thirteen transects on this data sheet. One data sheet is needed for each transect. To determine the placement of each of the thirteen transects within the station divide the station length (determined during reconnaissance) by thirteen, this number is the *transect spacing* or distance between transects. The first transect is located one half of the transect spacing distance from the downstream end of the station. Each subsequent transect is then the distance of one transect spacing from the previous transect. All numbers are rounded to the nearest half meter.

For example, if the station length is 150 m, $150 \div 13 = 11.5$ (equals the transect spacing). The first transect would then be located a distance of 6 m from the downstream end of the station, $11.5 \div 2 = 5.75$ (equals 6 rounded to the nearest half meter). The second transect would then be located a distance of 17.5 m from the downstream end of the station, $6 + 11.5 = 17.5$, and so forth for subsequent transects.

Each transect consists of several measurements or visual estimates, made within 0.3 m x 0.3 m quadrates at set intervals, or along the transect line perpendicular to the stream channel. The variables on this data sheet are as follows:

D.1. Location Information

1) *Field Number* – Same as for **Stream Features** data sheet.

2) *Date* – Same as for **Stream Features** data sheet.

3) *Transect Number* – The number (1-13) of the current transect as you proceed upstream. The downstream most transect is number one, the next transect upstream is two, and so on.

4) *Crew* – Same as for **Stream Features** data sheet.

5) *Distance from Start* – The distance from the downstream end of the station to the current transect following the center of the stream channel, rounded to the nearest half meter.

6) *Stream Width* – The wetted width of the stream channel at the transect, measured to the nearest tenth of a meter. Exposed bars and boulders are included in the wetted width of the stream channel, but islands are not. Backwaters not in contact with the stream at the transect are also excluded. If a channel is split by an island(s), the wetted widths of each side channel should be combined so that a single number is recorded in *stream width*. In low gradient streams the wetted width is the defined portion of the stream channel, it does not include adjacent wetlands and areas of emergent vegetation.

7) *Channel Type* – Circle the predominant channel type at the transect. See the **Station Features** section for riffle, pool, and run definitions.

D.2. Transect Point Measurements: At each transect, measurements or visual estimates are made at five points along the transect. Variables quantified include: *water depth, depth of fines and water, embeddedness, substrate, percent algae, and percent macrophytes*. Four points are equally spaced across the stream channel and the fifth point is the thalweg, or deepest point along the transect line. Divide the *stream width* at the transect by five to determine the 1/5, 2/5, 3/5, and 4/5 locations across the wetted width of the stream channel. Measurements are made at each of these four locations moving from the right bank to the left bank along the transect. The right stream bank is on the right as you are facing downstream. For example, if the stream is 10 m wide, measurements are taken at the thalweg and along the transect at 2.0, 4.0, 6.0, and 8.0 m from the right bank. In some instances, the thalweg will occur at the same location as one of the four other points, in which case their measurement values will be the same.

1) *Water Depth* – The depth of the stream channel at each transect point. Measure the vertical distance of the water column from the streambed to the water surface to the nearest centimeter with a calibrated wading rod or meter stick. If the water depth is over 120 cm, record as >120 cm.

2) *Depth of Fines and Water* – The water depth plus the depth of fine sediments at each transect point. Fine sediments are those that are less than 2.0 mm in diameter and generally consist of sand, silt, clay, or detritus. Without using the weight of your body, push a wading rod into the sediment as far as possible, measure to the water surface to the nearest centimeter. This measurement is later converted to depth of fines by subtracting *water depth*.

3) *Embeddedness of Coarse Substrates* – The extent to which coarse substrates are surrounded by or covered with fine sediments. Coarse substrates consist of gravel, rubble/cobble, and boulders. If the dominant substrate within the quadrate is coarse, embeddedness should be visually estimated to the nearest 25%. Estimate the average percent embeddeness of coarse substrates within the 0.3 m x 0.3 m quadrate centered on the channel position. An embeddedness rating of 0% corresponds to very little or no fine sediments surrounding coarse substrates. Course substrate material completely surrounded and covered with sediment is considered 100% embedded. If the dominant substrate within a quadrate is anything other than gravel, rubble/cobble, or boulder then the column should be left null.

4) *Dominant Substrate* – The predominant substrate type within each quadrate. Visually estimate which substrate type is predominant within each quadrate and place a check mark in the appropriate column. If the stream bottom cannot be seen, use your hands and feet to determine the dominant substrate type. Choose from the following substrate types:

   Bedrock: A solid slab of rock, > 4000 mm in length (larger than a car).

   Boulder: Large rocks ranging from 250 mm to 4000 mm in diameter (basketball to car size).

   Rubble/Cobble: Rocks ranging in diameter from 64 mm to 250 mm (tennisball to basketball).

   Gravel: Rocks varying in diameter from 2 mm to 64 mm (BB to tennisball).

   Sand: Inorganic material that is visible as particles and feels gritty between the fingers. 0.06 mm to 2.0 mm in size.

   Silt: Fine inorganic material that is typically dark brown in color. Feels greasy between fingers and does not retain its shape when compacted into a ball. A person's weight will not be supported if the stream bottom consists of silt.

   Clay: Very fine inorganic material. Individual particles are not visible or are barely visible to the naked eye. Will support a person's weight and retains its shape when compacted.

   Detritus: Decaying organic material such as macrophytes, leaves, finer woody debris, etc. that may appear similar to silt when very fine.

   Other: Any substrate type not listed above, specify the type. Possibilities could include woody debris, culverts, tires, or mussel beds.

5) *Algae (%)* – Visually estimate the amount of algae within the quadrate, to the nearest 5 %. Algae can either be attached to the substrate in the form of a mat or crust; or filamentous algae, which forms dense mats of long, hair-like strands and is usually green in color.

6) *Macrophytes (%)* – Visually estimate the amount of aquatic vegetation within the quadrate, to the nearest 5 %. Aquatic macrophytes can be either submergent or emergent and are defined under *cover for fish*.

D.3. Cover and Land Use Characteristics

1) *Cover for Fish (%)* – The amount of cover or shelter available for fish along the transect. Visually estimate the percentage (nearest 5 %) occupied by each cover type along the transect within a 0.3 m band centered on the transect line. If a cover type is absent, enter a zero. In order to be considered cover, the water depth must be at least 15 cm where the cover type occurs. Cover for fish consists of objects or features dense enough to provide complete or partial shelter from the stream current or concealment from predators or prey.

   Undercut Banks: Stream banks where the stream channel has cut underneath the bank. The bank could overhang the water surface when water levels are low. The undercut bank must overhang (horizontally) the wetted stream channel a minimum of 15 cm and the bottom of the bank must be no more than 15 cm above the water level in order to be considered cover for fish.

   Overhanging Vegetation: Terrestrial vegetation overhanging the wetted stream channel that meets the same criteria for cover as undercut banks.

   Woody Debris: Logs, branches, or aggregations of smaller pieces of wood in contact with or submerged in water.

   Boulders: Large rocks as described under *Substrate*.

   Submergent Macrophytes: Vascular plants that have all of their biomass (except flowers) at or below the surface of the water. Examples include *Vallisneria*, *Elodea*, *Potamogeton*, *Nymphaea* and *Ceratophyllum*.

   Emergent Macrophytes: Vascular plants that typically have a significant portion of their biomass above the water surface. Examples include *Typha, Scirpus,* and *Zizania.*

   Other Debris: Additional objects that meet the criteria of cover, typically of human origin. Examples would include filamentous algae, culverts, docks, tires, discarded appliances, etc. Specify the type.

2) *Bank Erosion* – The amount of the stream bank that is exposed soil and therefore, susceptible to erosion. For each bank, along the transect line, use a wading rod or measuring tape to quantify the length (nearest 0.1 m) of bare soil. Measure the amount of exposed soil from the waters edge to the top of the stream bank, up to a maximum of 5 m. If there is no bare soil, record 0.

3) *Riparian Land Use* – The predominant land use within the riparian zone. For each bank, extending along the transect line, visually estimate the predominant land use within 30 m of the waters edge and place a check mark in the corresponding column. Repeat this same procedure for the riparian zone 30 – 100 m from the waters edge. Land use categories are as follows:

   Cropland: Land that is cultivated with crops for forage or cover. Includes those areas under intensive cropping or rotation, or that are regularly mowed for hay.

   Pasture: Land that is regularly grazed by livestock.

   Barnyard: Land associated with farmsteads and the adjoining farmyard area. Includes grain storage facilities, barns, farmhouses, and feedlots (areas used to confine and feed high densities of livestock).

   Developed: Land that has been modified (rural or urban) for commercial, industrial, or residential use. Includes commercial buildings/structures, parking lots, all roads, railroads, and power utilities. Also includes residential buildings, lawns, parks, golf courses, ball fields, etc. Specify the type in the space provided.

   Exposed Rock: Natural areas of rock outcrops that lack appreciable soil development or vegetative cover.

Meadow: Land dominated by grasses and forbs with little woody vegetation, which is not subject to regular mowing or grazing.

Shrub: Land consisting primarily of woody vegetation less than 3 m in height. Typical shrubs include alder, dogwood, and willows.

Woodland: Land dominated by deciduous or coniferous tree species, generally taller than 3 m.

Wetland: Low-lying areas that are saturated or inundated with water frequently or for considerable periods of time on an annual basis. Wetlands include bogs, marshes, and swamps and contain vegetation adapted for life in saturated conditions.

Other: If a land use category other than one of those listed above is predominant, specify the type.

4) *Riparian Buffer Width* – The amount of contiguous undisturbed land use within a 10 m buffer zone. For each bank, starting from the waters edge and extending out along the transect line 10 m, measure the width (nearest meter) of contiguous land that is considered undisturbed. Meadow, shrub, woodland, wetland, and exposed rock are considered undisturbed. If no undisturbed land uses are directly adjacent to the stream, then the riparian buffer width is 0 m. If more than 10 m is present, record it as >10 m.

5) *Canopy/Shading* – A measure of overhead canopy cover that is shading the stream channel. A concave spherical crown densiometer is utilized for this measurement. The densiometer must be taped as shown in Figure 1 to limit the number of grid intersections to 17. Hold the densiometer at elbow level in front of you, making sure the instrument is level using the bubble level, count and record the number (0 to 17) of grid intersections that have vegetation covering them. If the reflection of a tree, branch, or leaf overlies any of the intersection points, that particular intersection is counted as having cover. Perform this measurement from the center of the stream channel along the transect line in each of four directions; facing upstream, downstream, towards the left bank, and towards the right bank. In addition, perform the measurement at the wetted edge of both the left and right banks facing the stream bank.

E. Visit Summary Data Sheet

This data sheet contains location information, water chemistry data, and channel characteristics of the station. Some of the data is derived from maps or from the other data sheets. Record the following information on this data sheet:

E.1. <u>Location Information</u>

1) *Field Number* – Same as for **Station Features** data sheet.

2) *Date* – Same as for **Station Features** data sheet.

3) *Stream Name* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. "North Branch", "Creek", "River", "Co. Ditch", etc.).

4) *Location* – A general description of where the sampling station is located. Usually includes the nearest road crossing and town. For example, "0.5 mi. downstream of C.R. 30, 4 mi. SW of Northome".

5) *County* – The county in which the station is located.

6) *Visit Result* – The result of the sampling trip, typically as it pertains to fish collection. Circle only one of the available choices. A visit or sampling trip is considered "reportable" when sampling is conducted for the first time at a station and no problems are encountered that would render the data questionable. If subsequent sampling trips are made to the same station and no sampling problems occur, the *visit result* is considered a "replicate". Circle "other", and explain in the space provided, in the event that the data generated is questionable or unsuitable for use. Reasons might include equipment problems, poor sampling efficiency, excessive water velocity, poor fish taxis, or other sampling deficiencies.

7) *GPS File Name* – The unique identifier of a rover file assigned by the GPS unit. If a GPS file is taken (to record the location of a sampling site), the unit will assign an eight-digit code consisting of a file prefix, date stamp, and time stamp that uniquely identifies that file. In most instances, it is not necessary to take a GPS file during the sampling visit because sampling sites are located and flagged during site reconnaissance. However, circumstances may occur that necessitate a file be taken during the sampling visit. These include but are not limited to: original reconnaissance file unreliable or inaccurate, flagging cannot be located, initial site location determined to be incorrect, and GPS file not obtained during initial site reconnaissance. If sampling and initial site reconnaissance are conducted at the same time, the GPS information should be recorded as part of the reconnaissance protocol. Consult the GPS user's manual and SOP--"***Reconnaissance Procedures for Initial Site Visit to Stream Monitoring Sites***" for additional guidance on GPS operation and protocol.

8) *Type of GPS Fix* – If a GPS file is taken during the sampling visit, indicate the position mode (3D or 2D) in which the GPS file was recorded.

9) *PDOP* – If a GPS file is taken during the sampling visit, record the approximate Position Dilution of Precision (PDOP) value that was observed while the GPS file was being recorded.

10) *Data Source* – The source or entity that generated the data. For Minnesota Pollution Control Agency (MPCA) staff within the Biological Monitoring Unit this field should be recorded as "MPCA".

11) *Project* – The specific project that the data collection effort is associated with. Some possibilities include EMAP, biocriteria development, problem investigation, and longitudinal survey.

E.2. Field Water Chemistry: Water chemistry parameters should be sampled immediately prior to fish sampling. All water chemistry parameters are measured from the same general location at a representative stream cross-section within the sampling reach. Samples are taken at a point that is judged to represent the water quality of the total instantaneous flow at the cross-section. Avoid sampling areas that are poorly mixed, contain springs, or are upstream of or immediately adjacent to tributaries within the sampling reach. Water chemistry measurements and water samples are taken at an intermediate depth in the water column without disturbing substrate materials or collecting floating materials and constituents from the water surface. Refer to the manufacturer's owners manual for guidance concerning the calibration and operation of water quality meters.

1) *Time* – The time of day (24-hour clock) that field water chemistry parameters are measured.

2) *Air Temp* – The ambient air temperature (°C) at the time of sampling, measure to the nearest degree with a dry thermometer.

3) *Water Temp* – The water temperature (°C) of the station at the time of sampling, measure to the nearest tenth of a degree with a thermometer or water quality meter.

4) *Conductivity* – Temperature compensated conductivity, or *specific conductance*, is the parameter actually being determined and is a measure of the ability of water to carry an electrical current. Consult your conductivity meter's manual for guidance measuring specific conductance (measured in µmhos/cm) compensated for temperature to 25 °C.

5) *Dissolved Oxygen* – The amount of oxygen present in a water sample, expressed as milligrams of oxygen per liter of water (mg/L). Two water samples should be taken and measured for dissolved oxygen concentrations using a DO meter or the Winkler Titration Method.

6) *Turbidity* – The light scattering property associated with suspended particles in the water, measured with a turbidimeter in nephelometric turbidity units (NTUs). A turbid sample will appear cloudy. A water sample is taken in a 500-ml plastic bottle rinsed with stream water three times. Due to the sensitivity of the turbidimeter to road dust and other conditions encountered while in the field, place the sample on wet ice until days end and measure turbidity in a more suitable environment (office or hotel room).

7) *pH* – A measure of the negative log of the hydrogen ion $[H^+]$ concentration in the water. Pure water has a pH of 7.00 and is considered neutral. Measure pH utilizing a temperature compensating pH meter.

8) *Stream Flow* – Also known as discharge, it is the volume of water moving downstream per unit time, and is the product of current velocity and the dimensions of the stream channel. Measure the instantaneous flow rate (cubic meters/second) at a suitable stream cross-section using a current meter. Detailed guidelines for determining stream flow at a station are available from the USGS.

9) *Transparency* – A measure of water clarity, an indicator of the water's ability to transmit light. Stream transparency serves as an indirect measure of the amount of dissolved and suspended materials present. Measure (nearest cm) with a transparency tube, a clear tube 60 cm in length with a secci-type disk at the bottom.

10) *Water Level* – An estimation of water level as it relates to summer base flow expectations. Check the appropriate category and measure the vertical distance (nearest 0.1 m) above or below the normal water line. In most streams, the "normal" water level can be determined with relative ease by observing channel characteristics.

E.3 Lab Water Chemistry: Water samples taken for laboratory analyses typically include total phosphorus (P), total suspended solids (TSS), ammonia nitrogen (NH^3+NH^4), and nitrite-nitrate (NO^2+NO^3). Additional parameters may be measured in special circumstances. Samples taken for laboratory analyses are subject to the same general guidelines concerning sampling location and time as outlined above under *field water chemistry*. Sterilized sample bottles are obtained from the Minnesota Department of Health. Before collecting samples, label the containers with the *date* and *field number* with a waterproof pen or pencil. Collect a 250 ml nutrients sample and a one-liter general chemistry sample for laboratory analysis. The bottles should be lowered mouth down to an intermediate depth and then turned upstream to collect the sample, the Dept. of Health does not recommend rinsing their sample bottles. Immediately after sample collection, 5 ml of 10% sulfuric acid preservative solution is added to the nutrients sample. Both sample bottles must be stored at 4°C and shipped to the Dept. of Health Water Lab within the minimum holding times.

1) *Collection Time (field sample)* – The time of day (24-hour clock) that water samples for laboratory analysis are collected.

2) *Collection Time (field duplicate)* – A field duplicate is a second sample taken immediately following an initial sample in the same manner and location. Duplicate samples are taken at 10% of all sampling sites for quality assurance and control (QA/QC) purposes. If a duplicate water sample is taken, record the time (24 hour clock) here.

E.4 Channel Characteristics

1) *Transect Spacing* – Document the distance (m) that was used to space transects from one another (see **Transect** data sheet section).

2) *Station Length* – The actual length (m) of the sampling reach as determined during the physical habitat assessment. The station length should be recorded directly from the **Stream Features** data sheet, as measured from the start of the station to the upstream end of the reach, rounded to the nearest meter. This measurement of station length is considered more accurate than the measurement conducted during the initial site reconnaissance.

3) *Channel Condition* – The condition of the stream channel at the station, check the category that best describes the state of the stream channel: natural channel, old channelization, recent channelization, or concrete channel.

4) *Mean Distance Between Bends* – The average distance (m) between successive bends contained within the station. Obtained from the **Station Features** data sheet.

5) *Mean Distance Between Riffles* – The average distance (m) between successive riffles contained within the station. Obtained from the **Station Features** data sheet
6) *Total Length of Riffles, Pools, and Runs* – The sum of the lengths (m) for all riffles, pools, and runs contained within the station. Obtained from the **Station Features** data sheet.

7) *Total Number of Riffles, Pools, Runs, Bends, and Log Jams* – The number of each of these stream features contained within the station. Obtained from the **Station Features** data sheet.

E.5. <u>Comments/Notes</u>: Record any additional information about the station in the space provided.

Table 1. Equipment List – This table identifies all equipment needed in the field in order to implement the sampling protocol as described.

Physical Habitat Sampling

Measuring tape (m) – for measuring distances

Wading rod – for measuring depths and short distances

Spherical crown densiometer (concave) – to measure canopy cover

Water Chemistry Sampling

Thermometer – for measuring air and water temperature

Conductivity meter – for measuring conductivity

Turbidimeter – for measuring turbidity

D.O. meter or Winkler-Titration kit – for measuring dissolved oxygen

pH meter – for measuring pH

Current meter – for measuring stream discharge

Transparency tube – for measuring stream water transparency

1-L plastic bottle – to collect general chemistry sample for lab analysis

250-ml plastic bottle – to collect nutrients sample for lab analysis

500-ml plastic bottle – to collect turbidity sample

5-ml of 10% sulfuric acid – for preserving nutrients sample

Cooler and ice – for holding and preserving water samples

Miscellaneous

Clipboard – to store forms and record data

Forms – for recording data

Pencil – for filling out forms

GPS – to locate and document sampling location (if necessary)

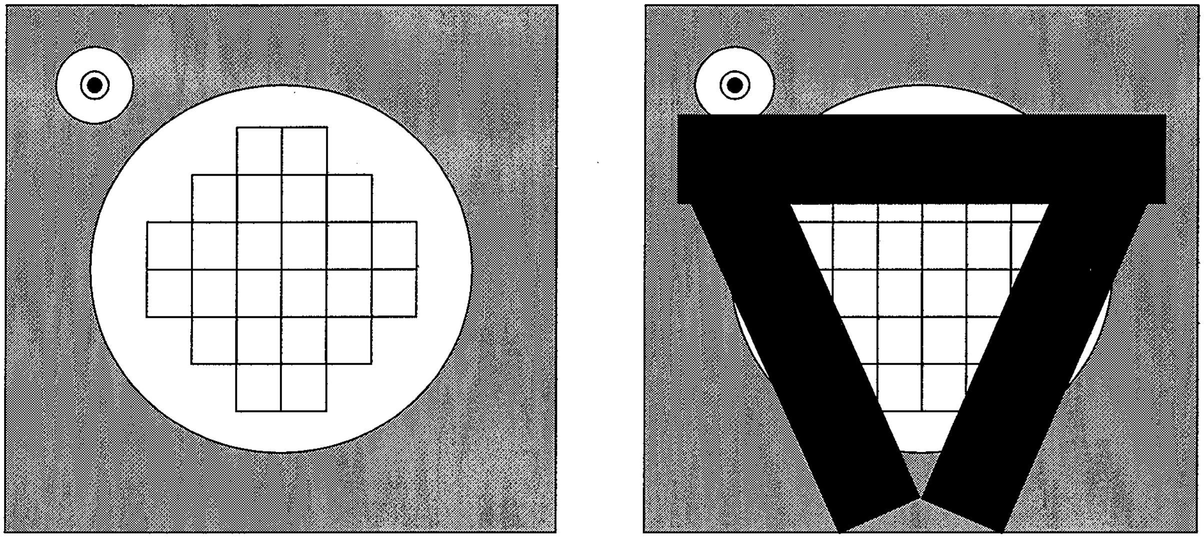


Figure 1. Illustration depicting how a spherical crown densiometer should be taped to limit the number of grid intersections to 17.

STATION FEATURES

MPCA

Field Number:________________ Date(mm/dd/yy):______________ Crew:__________________

DISTANCE FROM START (m)	STREAM FEATURE (Riffle, Pool, Run, Bend Log Jam, etc.) *	LENGTH (m)
0		

DISTANCE SUMMARY

Distance Between Bends(m):

1st - 2nd:______________
2nd - 3rd:______________
3rd - 4th:______________
4th - 5th:______________
5th - 6th:______________
6th - 7th:______________
7th - 8th:______________
8th - 9th:______________
9th - 10th:______________
10th - 11th:______________
11th - 12th:______________
12th - 13th:______________
13th - 14th:______________
14th - 15th:______________

Sum:______________

Mean:______________

Distance Between Riffles(m):

1st - 2nd:______________
2nd - 3rd:______________
3rd - 4th:______________
4th - 5th:______________
5th - 6th:______________
6th - 7th:______________
7th - 8th:______________
8th - 9th:______________
9th - 10th:______________
10th - 11th:______________
11th - 12th:______________
12th - 13th:______________
13th - 14th:______________
14th - 15th:______________

Sum:______________

Mean:______________

Length (m) Of Individual Riffles, Pools, And Runs:

1st Riffle:________	1st Pool:________	1st Run:________
2nd Riffle:________	2nd Pool:________	2nd Run:________
3rd Riffle:________	3rd Pool:________	3rd Run:________
4th Riffle:________	4th Pool:________	4th Run:________
5th Riffle:________	5th Pool:________	5th Run:________
6th Riffle:________	6th Pool:________	6th Run:________
7th Riffle:________	7th Pool:________	7th Run:________
8th Riffle:________	8th Pool:________	8th Run:________
9th Riffle:________	9th Pool:________	9th Run:________
10th Riffle:________	10th Pool:________	10th Run:________
11th Riffle:________	11th Pool:________	11th Run:________
12th Riffle:________	12th Pool:________	12th Run:________
13th Riffle:________	13th Pool:________	13th Run:________
14th Riffle:________	14th Pool:________	14th Run:________
15th Riffle:________	15th Pool:________	15th Run:________
Sum:________	Sum:________	Sum:________

* For riffles, runs, and pools note distance from start at beginning of feature. For bends, log jams, etc., note center-point.

(Revised Dec. 2002)

Station Features Continued:

DISTANCE FROM START (m)	STREAM FEATURE (Bend, Riffle, Pool, Run, Log Jam, etc.) *	LENGTH (m)
0		

TRANSECT

MPCA

Field Number:________________________ Date (mm/dd/yy):________________ Transect Number (1-13):________

Crew:____ Distance from Start (m):____________

Stream Width (m):________________________ Channel Type (circle one): Riffle Pool Run

Channel Position (fifths of wetted stream width and deepest point, 0 = rightbank *)	1/5	2/5	3/5	4/5	Deep
Water Depth (cm)					
Depth of Fines and Water (cm)					
Embeddedness of Coarse Substrates (nearest 25%)					

Check Dominant Substrate Type in Quadrate:

Channel Position (fifths of wetted stream width and deepest point, 0 = rightbank *)	1/5	2/5	3/5	4/5	Deep
Bedrock (solid slab)					
Boulder (basketball or bigger)					
Rubble/Cobble (tennis ball to basketball)					
Gravel (BB to tennis ball)					
Sand (gritty, visible, < BB)					
Silt					
Clay					
Detritus					
Other (specify)					

Note Amount Observed on Quadrate:

Channel Position (fifths of wetted stream width and deepest point, 0 = rightbank *)	1/5	2/5	3/5	4/5	Deep
Algae (attached & filamentous., nearest 5%)					
Macrophytes (nearest 5%)					

Cover for Fish: *Percent length of transect* ***(over at least 15 cm water depth)*** *with:*
___Undercut Banks _____Overhanging Vegetation _____Woody Debris _____Boulders
___Submergent Macrophytes _____Emergent Macrophytes _____Other (specify):______________________

Bank Erosion: *Length (nearest 0.1 m) of bare soil,* ***within 5 m of waters edge,*** *along transect:*
LEFT BANK *: __________(m) RIGHT BANK *: __________ (m)

Riparian Land Use: *Dominant land use* ***within 30 m of stream edge*** *(along transect):* ***(L / R)*** *
___/___Cropland ___/___Pasture ___/___Barnyard ___/___Developed ___/___Exposed Rock
___/___Meadow ___/___Shrubs ___/___Woodland ___/___Wetland ___/___Other (specify):___________

Riparian Land Use: *Dominant land use* ***from 30 to 100 m of stream edge*** *(along transect):* ***(L / R)*** *
___/___Cropland ___/___Pasture ___/___Barnyard ___/___Developed ___/___Exposed Rock
___/___Meadow ___/___Shrubs ___/___Woodland ___/___Wetland ___/___Other (specify):___________

Riparian Buffer Width: *Length (nearest meter) of undisturbed land use along transect,* ***within 10 m of stream:***
LEFT BANK *: __________(m) RIGHT BANK *: __________ (m)

Canopy/Shading (Densiometer reading, note #/17 that are shaded):

___Center Upstream ___Center Left ___Center Downstream ___Center Right ___Left Bank * ___Right Bank *

* Right Bank and Left Bank identified while facing downstream.

(Revised Dec 2002)

VISIT SUMMARY MPCA

LOCATION INFORMATION ==

Field Number:___________ Date (mm/dd/yy):__________ Stream Name:_________________________

Location:____ County:____________________

Visit Result (circle one): Reportable - Replicate - Other (explain)_________________________

GPS File Name:______________________ Type of GPS Fix: ☐ 2D ☐ 3D PDOP:__________
(only if GPS taken during visit)

Data Source:_______________________________ Project:_____________________________________

FIELD WATER CHEMISTRY ==

Time (24 hr clock):______________ Air Temp.(°C):_____________ Water Temp.(°C):____________

Conductivity (umhos@25°C):__________________ Dissolved Oxygen (mg/l):__________________

Turbidity (ntu):_________________ pH:_______________ Stream Flow (m^3/s):_______________

Transparency Tube (cm):______ Water Level: ☐ Normal ☐ Below______(m) ☐ Above______(m)

LAB WATER CHEMISTRY ==

Collection Time (field sample):_______________ Collection Time (field duplicate):_______________

CHANNEL CHARACTERISTICS ==

Transect Spacing (m):___________ Station Length (m) (from stream features form):_____________

Channel Condition (check appropriate box):

☐ Natural Channel ☐ Old Channelization ☐ Recent Channelization ☐ Concrete Channel

Mean Distance Between Bends (m):____________ Mean Distance Between Riffles (m):____________

Total Length (Sum) of All (m): Riffles:_____________ Pools:_____________ Runs:_____________

Total Number of: Riffles:_______ Pools:_______ Runs:_______ Bends:_______ Log Jams:______

COMMENTS/NOTES: ____

____

____

(Revised Dec. 2002)

Appendix 5-B

Stream Habitat and Evaluation Form

MPCA STREAM HABITAT ASSESSMENT (MSHA) PROTOCOL FOR STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to collect qualitative physical habitat information at stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all river and stream monitoring sites for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a site vary, the MSHA protocol described in this document applies to all monitoring sites unless otherwise noted.

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. He or she must have a minimum of six months field experience in physical habitat sampling methodology. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/interns: A field technician/intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site.

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel.

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Ten percent of sites sampled in any given year are resampled as a means of determining sampling error and temporal variability.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment list: Verify that either a form and pencil, or a field computer is present before commencement of this procedure.

B. Data collection method: The location and length of the sampling reach is determined during site reconnaissance (see SOP--"***Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites***"). Unless otherwise instructed, observations of physical habitat characteristics should be limited to the sampling reach. Sampling is conducted during daylight hours within the summer index period of mid-June through mid-September. Sampling should occur when streams are at or near base-flow. The habitat evaluation is conducted immediately after fish sampling in order to provide the evaluator a perspective of the fish habitat within the reach.

Habitat characteristics are recorded using a qualitative, observation based method (modified from: Rankin 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application. Ohio EPA, Division of Water Quality Planning and Assessment, Ecological Analysis Section, Columbus, Ohio.). The Ohio QHEI is a physical habitat index designed to provide an empirical evaluation of the lotic macrohabitat characteristics that are important to fish communities and which are generally important to other aquatic life. Although similar to the Ohio QHEI, the MSHA has been modified to more adequately assess important characteristics influencing Minnesota streams. The MSHA incorporates measures of watershed land use, riparian quality, bank erosion, substrate type and quality, instream cover, and several characteristics of channel morphology.

Observations are recorded on the **MPCA Stream Habitat Assessment Worksheet**. A copy is attached and guidelines for filling out this data sheet are described in the following pages.

C. MPCA Stream Habitat Assessment Data Sheet

This data sheet describes the presence and abundance of instream and riparian characteristics within the sampling reach. The variables recorded are as follows:

C.1. Stream Documentation

A) *Stream* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. South Branch Wild Rice River).

B) *County* – The county in which the station is located.

C) Date – The date habitat sampling is conducted in month/day/year format (MM/DD/YY).
D) Field Number – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example: 02UM001).

E) Person Scoring – The personnel completing the MSHA. This person(s) should have walked or boated the entire stream reach paying particular attention to habitat features.

F) Site Location – A general description of where the sampling station is located. Usually includes the nearest road crossing and town. For example, "0.5 mi. downstream of C.R. 30, 4 mi. SW of Northome".

C.2. Surrounding Land Use: Record the predominant land use on each bank within approximately 2 to 3 square miles, not just the surrounding area of the site. The emphasis should be on upstream land use. Check either the most predominant land use, or choose two and average the scores. A land use or aerial map can be used for this assessment if available. Land use categories are as follows:

Forest, Wetland, Prairie, Shrub: Land that is dominated by trees, low-lying areas saturated with water, grasses and forbs, or woody vegetation less than 3 m. in height.

Old Field/Hay Field: Land that is used for agricultural purposes other than row crops or pasture.

Fenced Pasture: Land that is regularly grazed by livestock, but is fenced to prevent livestock from entering streams.

Conservation Tillage, No Till: Land that is currently in agricultural production, but retains the vegetative material from the previous year's crop to protect the soil.

Residential/Park: Land that has been modified for residential use (i.e. backyards, city parks).

Urban/Industrial: Land that has been modified for commercial or industrial use (i.e. parking lots, malls).

Open Pasture: Land that is regularly grazed by livestock, but is not fenced to prevent livestock from entering streams.

Row Crop: Land that is currently in intensive agricultural production, and doesn't use any conservation tactics (i.e. corn, soybeans, beets, potatoes).

C.3. Riparian Zone (Check the most appropriate category for each bank)

A) Riparian Width – Estimate the width of the undisturbed vegetative zone adjacent to the stream. Beneficial vegetation types include stable grasses, trees, and shrubs with low runoff potential. Disturbed vegetation is not included in the riparian width (i.e. mowed grass).

B) Bank Erosion – Estimate the percentage of the stream bank that is actively eroding. To be considered as erosion, the banks must be actively eroding through break down, soil sloughing, or false banks. False banks are natural banks that have been cut back, usually by livestock trampling.

C) Shade – Estimate the percentage of overhead canopy cover that is shading the stream channel. Professional judgment may be required to rate stream shading characteristics in larger streams and rivers as 100% shade cover would not be expected in these systems even in the absence of disturbance. The general intent of the rating is to evaluate the condition of stream canopy characteristics.

C.4. Instream Zone

A) Substrate – Document the two predominant substrate types for each channel type present within the reach. One substrate type may be recorded where > 80% of the channel is dominated by a single substrate type. For each channel type present within the reach, estimate the percent of the stream channel represented by that channel type. The percentages should add up to 100. For example, if the majority of your reach was a run, with a few pools and one riffle, the percentage could be 75% run, 20% pool, and 5% riffle. The definitions for each channel and substrate type are as follows:

Channel Types

Pool: Water is slow and generally deeper than a riffle or run. Water surface is smooth, no turbulence. A general rule that can be used to distinguish a pool from a run or riffle is if two or more of the following conditions apply; the stream channel is wider, deeper, or slower than average.

Riffle: Higher gradient areas where the water is fast and turbulent, water depths are relatively shallow, and substrates are typically coarse. Water surface is visibly broken.

Run: The water may be moderately fast to slow but the water surface typically appears smooth with little or no surface turbulence. Generally, runs are deeper than a riffle and shallower than a pool.

Glide: Similar to a run, but where there is no visible flow and the channel is too shallow for a pool. Examples include a channelized stream with a uniform depth and flow. This term should not be used in conjunction with pools, riffles, and runs in a natural stream setting.

Substrate Types

Boulder: Large rocks ranging from 250 mm to 4000 mm in diameter (basketball to car size).

Cobble: Rocks ranging in diameter from 64 mm to 250 mm (tennisball to basketball).

Gravel: Rocks varying in diameter from 2 mm to 64 mm (BB to tennisball).

Sand: Inorganic material that is visible as particles and feels gritty between the fingers, 0.06 to 2.0 mm in size.

Clay: Very fine inorganic material. Individual particles are not visible or are barely visible to the naked eye. Will support a person's weight and retains its shape when compacted.

Bedrock: A solid slab of rock, > 4000 mm in length (larger than a car).

Silt: Fine inorganic material that is typically dark brown in color. Feels greasy between fingers and does not retain its shape when compacted into a ball. A person's weight will not be supported if the stream bottom consists of silt.

Muck: A fine layer of black completely decomposed vegetative organic matter.

Detritus: Decaying organic material such as macrophytes, leaves, finer woody debris, etc. that may appear similar to silt when very fine.

Sludge: A thick layer of organic matter of animal or human origin, often originating from wastewater.

B) *Embeddedness* – Indicate the percentage to which coarse substrates are surrounded by or covered with fine sediments throughout the reach. Coarse substrates consist of gravel, cobble, and boulders. An embeddedness rating of 0% corresponds to very little or no fine sediments surrounding coarse substrates. Course substrate material completely surrounded and covered with sediment is considered 100% embedded. If course substrates are not present in the reach, check "no course substrate".

C) *Substrate Types* – Record the number of substrate types present within the reach, either less than or equal to 4, or greater then 4.

D) *Water Color* – Record the predominant color of the water by checking the appropriate category. Definitions are as follows:

Clear: Water is transparent, and objects are clearly visible underwater.

Stained: Water is colored due to minerals in the water, but objects are still visible.

Turbid: Water is colored and not transparent; brown due to silt, green due to algae, or other.

E) *Cover Type* – Indicate the types of cover available to fish within the reach (check all that apply). Cover for fish consists of objects or features dense enough to provide complete or partial shelter from the stream current or concealment from predators or prey. In order to be considered cover, the water depth must be at least 10 cm where the cover type occurs. Definitions are as follows:

Undercut Banks: Stream banks where the stream channel has cut underneath the bank. The bank could overhang the water surface when water levels are low. The undercut bank must overhang (horizontally) the wetted stream channel a minimum of 15 cm and the bottom of the undercut bank must be no more than 15 cm above the water level in order to be considered cover for fish.

Overhanging Vegetation: Terrestrial vegetation overhanging the wetted stream channel. Vegetation must be no more than 15 cm above the water level to be considered cover for fish.

Deep Pools: Area where the channel is particularly deep, often near a bend.

Logs or Woody Debris: Logs, branches, or aggregations of smaller pieces of wood in contact with or submerged in water.

Boulders: Large rocks as described under *Substrate Types.*

Rootwads: Aggregation of tree roots that extend into the stream.

Emergent Macrophytes: Vascular plants that typically have a significant portion of their biomass above the water surface. Examples include *Typha*, *Scirpus*, and *Zizania*.

Floating Leaf Macrophytes: Vascular plants with a significant amount of their biomass floating on the water in the form of leaves and flowers. Examples include duckweed and water lily.

Submergent Macrophytes: Vascular plants that have all of their biomass (except flowers) at or below the surface of the water. Examples include *Vallisneria*, *Elodea*, *Potamogeton*, *Nymphaea* and *Ceratophyllum*.

F) *Cover Amount* – Estimate the total percentage of fish cover within the reach. If the channel is completely filled with aquatic vegetation, check the “choking vegetation only” option.

C.5. <u>Channel Morphology (Check the most appropriate category for each)</u>

A) *Depth Variability* – The difference in thalweg depth between the shallowest stream cross section and the deepest stream cross section. The thalweg depth is the deepest point along a stream cross section. Indicate the degree to which the thalweg depths vary within the stream reach.

B) *Channel Stability* – The ability of a stream channel to maintain its bed and banks, without eroding or moving particles downstream. A riffle that forms diagonally across the channel and has a high amount of fine substrates that change location is indicative of an unstable stream bed. Channelized streams often have high bank stability but low bed stability as the substrate is typically comprised of fine materials that are susceptible to moving downstream. Ratings are as follows:

High: Channel with stable banks and substrates, little or no erosion of the banks, and little or no bedload within the stream. Artificial channels (i.e. concrete) exhibit a high degree of stability even though they typically have a negative effect on biological communities.

Moderate/High: Channel has the ability to maintain stable riffle, run, and pool characteristics. A minor amount of bank erosion and/or bedload is present.

Moderate: Channel that exhibits some instability, characterized by erosion, bedload, or shows the effects of wide fluctuations in water level.

Low: Channels that have a high degree of bedload and severely eroding banks. A homogenous stream bed characterized by shifting sand substrates has low stability.

C) *Velocity Types* – Indicate which flow types are present within the reach (check all that apply). The definitions are as follows:

Torrential: Extremely turbulent and fast flow; water surface is broken, usually limited to gorges and dam spillways.

Fast: Mostly non-turbulent flow with small standing waves in riffle-run areas, water surface may be partially broken.

Moderate: Non-turbulent flow that is detectable (i.e. floating objects are visibly moved downstream).

Slow: Water flow is detectable, but barely perceptible.

Eddies: Areas of circular motion within the current, usually formed in pools immediately downstream of riffles/runs.

Interstitial: Water flow that infiltrates a streambed, and moves through gravel substrates in riffle-run areas.

Intermittent: No flow is present, with standing pools separated by dry reaches.

D) *Sinuosity* – Indicate the degree to which the stream meanders. Sinuosity is defined as the ratio of stream channel distance to straight line distance between two points on a stream. For wide streams or rivers it may be necessary to consider a longer stream reach, as the true meander cycle is often not adequately represented in these systems within the sampling reach. Ratings are as follows:

Excellent: Streams exhibiting a high degree of meandering. Presence of 2 or more well defined bends (deep areas outside and shallow areas on the inside of the bend).

Good: Stream with more than 2 bends, with at least one well defined bend.

Fair: Channel with 1 or 2 poorly defined outside bends, or slight meandering within a modified reach.

Poor: Straight channel with no bends in the reach. Channelized streams or ditches are often rated as poor.

E) *Pool Width/Riffle Width* – Indicate the ratio of pool width to riffle width within the reach. If there is no riffle at the site select “no riffle”.

F) *Channel Development* – Indicate the complexity of the stream channel or the degree to which the stream has developed different channel types, creating sequences of riffles, runs, and pools. In small streams, riffles, runs, and pools must occur more than once within the sampling reach. The ratings of channel development are as follows:

Excellent: Well defined riffles present with gravel, cobble, or boulder substrates; pools vary in depth, and there is a clear transition between pools, riffles, and runs. Multiple sequences of riffles, runs, and pools are present within the reach.

Good: Riffles, runs, and pools are all present, but with less frequency, and are less distinct. Riffles have large substrates (gravel, rubble, or boulder), and pools have variation in depth.

Fair: Riffles are absent or poorly developed (shallow with sand and fine gravel substrates). Some deeper pools may exist, but transitions are generally not abrupt.

Poor: Riffles are absent; pools if present are shallow or lack variation in depth. Channelized streams generally have poor channel development.

G) Present Water Level – An estimation of water level as it relates to summer base flow expectations. In most streams, the "normal" water level can be determined with relative ease by observing channel characteristics.

D. Scoring the MSHA

Following are instructions on how to score the completed MSHA form. The maximum score is 100.

D.1. <u>Surrounding Land Use</u>: Average the scores of the two banks. For example, if residential/park was the land use selected on the left bank, and forest, wetland, prairie, shrub was selected on the right bank, then the land use score would be (2+5)/2=3.5. In the case of two land uses selected for one bank, the two scores are averaged together, and then averaged with the score of the other bank. The maximum land use score is 5.

D.2. <u>Riparian Zone</u>: Average the scores of the two banks for Riparian Width, Bank Erosion, and Shade; then add the three scores. For example, if moderate riparian width (3) was chosen for the left bank and very narrow (1) on the right bank; little bank erosion (4) on the left bank, and moderate (3) on the right bank; heavy shade (5) on the left bank, and substantial (4) on the right bank; the riparian zone score would be: [(3+1)/2] + [(4+3)/2] + [(5+4)/2] = 10. The maximum riparian score is 15.

D.3. <u>Instream Zone</u>

A) Substrate, Embeddedness, and Substrate Types – Add the scores of substrate, embeddedness, and substrate type. The substrate score is calculated by adding the two substrate scores for each channel type, multiplying by the percentage of the channel type, and adding the scores for each channel type present. If only one substrate type is chosen because it makes up more than 80% of the channel type, multiply the one substrate score by 2 before multiplying it by the percentage of the channel type. The maximum substrate score is 27.

B) Cover Type and Cover Amount – Add the scores of cover type and cover amount. The cover score can range from 1 to 8. The highest macrophyte score is 1, even if all three macrophyte types are present. The maximum cover score is 17.

D.4. <u>Channel Morphology</u>: Add the scores of Depth Variability, Channel Stability, Velocity Types, Sinuosity, Pool Width/Riffle Width, and Channel Development. The maximum channel morphology score is 36.

D.5. <u>Total Score</u>: Add the Surrounding Land Use, Riparian Zone, Instream Zone, and Channel Morphology scores together to get the total MSHA score for the site.

MPCA STREAM HABITAT ASSESSMENT

(revised 3-07)

1. Stream Documentation

Stream ____________________

County ____________________ Date ____________________

Field Number ____________________ Person Scoring ____________________

Site Location ____________________

MSHA SCORE ☐ **Max = 100**

2. Surrounding Land Use (check the most predominant or check two and average scores) **[L=left bank/R =right bank, facing downstream]**

L	R			L	R		
☐	☐	Forest, Wetland, Prairie, Shrub	[5]	☐	☐	Residential/Park	[2]
☐	☐	Old Field/Hay Field	[3]	☐	☐	Urban/Industrial	[0]
☐	☐	Fenced Pasture	[2]	☐	☐	Open Pasture	[0]
☐	☐	Conservation Tillage, No Till	[2]	☐	☐	Row Crop	[0]

Land Use ☐ **Max=5**

3. Riparian Zone (check the most predominant)

A. Riparian Width

L	R			
☐	☐	Extensive	> 300’	[5]
☐	☐	Wide	150’-300’	[4]
☐	☐	Moderate	30’-150’	[3]
☐	☐	Narrow	15’-30’	[2]
☐	☐	Very Narrow	3’-15’	[1]
☐	☐	None		[0]

B. Bank Erosion

L	R			
☐	☐	None		[5]
☐	☐	Little	5-25%	[4]
☐	☐	Moderate	25-50%	[3]
☐	☐	Heavy	50-75%	[1]
☐	☐	Severe	75-100%	[0]

C. Shade

L	R			
☐	☐	Heavy	>75%	[5]
☐	☐	Substantial	50-75%	[4]
☐	☐	Moderate	25-50%	[2]
☐	☐	Light	5-25%	[1]
☐	☐	None		[0]

Riparian ☐ **Max=15**

4. Instream Zone

A. Substrate (check two for each channel type)

	Boulder [10]	Cobble [9]	Gravel [8]	Sand [7]	Clay [5]	Bedrock [5]	Silt [2]	Muck [1]	Detritus [1]	Sludge [0]	Channel Type %
Pool	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Riffle	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Run	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____
Glide	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	____

B. Embeddedness

- ☐ None [5]
- ☐ Light 25-50% [3]
- ☐ Moderate 50-75% [1]
- ☐ Severe 75-100% [-1]
- ☐ No coarse substrate [0]

C. Substrate Types

- ☐ >4 [2]
- ☐ <=4 [0]

D. Water Color

- ☐ Clear
- ☐ Stained

Turbid

- ☐ Brown
- ☐ Green
- ☐ Other

Substrate ☐ **Max=27**

E. Cover Type (check all that apply)

- ☐ Undercut Banks [1]
- ☐ Overhanging Vegetation [1]
- ☐ Deep Pools [1]
- ☐ Logs or Woody Debris [1]
- ☐ Boulders [1]
- ☐ Rootwads [1]
- ☐ Macrophytes: [1]
  - ☐ Emergent
  - ☐ Floating Leaf
  - ☐ Submergent

F. Cover Amount (check one)

- ☐ Extensive >50% [10]
- ☐ Moderate 25-50% [7]
- ☐ Sparse 5-25% [3]
- ☐ Nearly Absent [0]
- ☐ Choking Vegetation only [-1]

Cover ☐ **Max=17**

5. Channel Morphology

A. Depth Variability

- ☐ Greatest Depth >4X Shallow Depth [6]
- ☐ Greatest Depth 2-4X Shallow Depth [3]
- ☐ Greatest Depth <2X Shallow Depth [0]

B. Channel Stability

- ☐ High [9]
- ☐ Moderate/High [6]
- ☐ Moderate [3]
- ☐ Low [0]

C. Velocity Types (check all that apply)

- ☐ Torrential [-1]
- ☐ Fast [1]
- ☐ Moderate [1]
- ☐ Slow [1]
- ☐ Eddies [1]
- ☐ Intermittent [-2]
- ☐ Interstitial [-1]

D. Sinuosity

- ☐ Excellent [6]
- ☐ Good [4]
- ☐ Fair [2]
- ☐ Poor [0]

E. Pool Width/Riffle Width

- ☐ Pool Width > Riffle Width [2]
- ☐ Pool Width = Riffle Width [1]
- ☐ Pool Width < Riffle Width [0]
- ☐ No Riffle [0]

F. Channel Development

- ☐ Excellent [9]
- ☐ Good [6]
- ☐ Fair [3]
- ☐ Poor [0]

G. Present Water Level

- ☐ Flood
- ☐ High
- ☐ Normal
- ☐ Low
- ☐ Interstitial

Channel Morphology ☐ **Max=36**

Appendix 5-C

EMAP SOP4 Invertebrate Sampling Procedures

Subject: Invertebrate Sampling Procedures

I. PURPOSE

To describe methods used in the collection of stream invertebrates for the purpose of developing biological criteria used in assessing water quality.

II. REFERENCES

A. Source Documents

U.S. Environmental Protection Agency (USEPA). 1994. Environmental Monitoring and Assessment Program - Surface Waters and Region 3 Regional Environmental Monitoring and Assessment Program: 1994 pilot field operations and methods manual for streams. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory. Cincinnati, OH. EPA/620/5-94/004.

Barbour, M. T., J. Gerritsen, and J. S. White. 1996. Development of the Stream Condition Index (SCI) for Florida. Florida Department of Environmental Protection, Tallahassee, Florida. 105 pp.

B. Other References

U.S. Environmental Protection Agency (USEPA). 1996. Biological Criteria: Technical Guidance for Streams and Small Rivers. Revised Edition. Office of Water, Washington DC. EPA/822/B-96/001.

U.S. Environmental Protection Agency (USEPA). 1997. Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers (Draft). Office of Water, Washington D.C. EPA/841/D-97/002.

III. SCOPE/LIMITATIONS

This procedure applies to all site visits in which stream invertebrates are to be collected for the development of biological criteria and/or the assessment of water quality.

IV. DEFINITIONS

Integrated monitoring A stream monitoring technique to assess water quality using chemical, biological and physical indicators.

Environmental Monitoring and Assessment Program (EMAP): U.S. Environmental Protection Agency program designed to determine the status, extent, changes, and trends in the condition of our national ecological resources on regional and national scales.

Biological Criteria: Narrative expressions or numerical values that describe the reference biological integrity of a specified habitat. Biological criteria are the benchmarks for judging the condition of aquatic communities.

Qualitative Multihabitat Sample (QMH): A method of sampling invertebrates which involves sampling a variety of invertebrate habitats, including the following substrata: rocky substrates, vegetation, undercut banks, snags, leafpacks, and soft sediment.

V. GENERAL INFORMATION

The methods described herein are to be applied to all wadeable streams included in the MPCA's integrated stream condition monitoring program. This document is not meant to be used by itself, consult one of the documents indicated in the box below if any of the described situations apply. For most efficient use of time and resources, crew leaders must be in constant communication with crews sampling for fish, preventing duplication of effort. It must be understood that this method is not to be applied to streams sampled for fish that are not wadeable.

Data generated from samples collected using the described method can be used for any of the following reasons: 1) Development of regional biological criteria, 2) Calibration of biological criteria, 3) Ambient water quality assessment, 4) Water quality assessment of sites suspected of a having a problematic source of pollution.

NOTE

SOP1 - Site Reconnaissance: A site reconnaissance should be done by the first crew to visit a site. After the initial recon has been done, no more are required. One must be done before any sampling can take place.

SOP2 - Chemical Assessment: A chemical assessment should be done by the first crew to visit a site following a site reconnaissance. These procedures can be completed during a single site visit.

VI. REQUIREMENTS

SOP3 - Habitat Assessment: A habitat assessment should be done during the same visit as the chemical assessment. If a habitat assessment is to be done during the same visit as an invertebrate collection, the invertebrate collection should be done first.

A. Qualifications of Crew Leaders
A crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in biology with an aquatic entomology, invertebrate, zoology, fisheries, or closely related specialization. Additionally, they must have at least 6 months experience working under a macroinvertebrate biologist in the areas of invertebrate sampling methodology and taxonomy.

B. Qualifications of field technicians/interns
A field technician/intern must have at least one year of college education and had coursework in environmental and/or biological science.

C. General Qualifications
All personnel conducting this procedure must have excellent map reading skills and a demonstrated proficiency in the use of a GPS receiver and an orienteering compass.
Because sites may be located miles from the nearest vehicle assessable road, it is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a site. Personnel conducting this procedure must have the physical ability to accomplish this.

VII. RESPONSIBILITIES

A. Field Crew Leader
Ensures that data generated using this procedure meet the standards and objectives of the integrated condition monitoring program. Carries out the procedures outlined in the action steps.

B. Technical personnel
Carries out the procedures outlined in the action steps, including maintenance and stocking of equipment, date collection and recording.

VII. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer manuals.

VII. QUALITY ASSURANCE AND QUALITY CONTROL (continued)

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the QA/QC requirements for this protocol are as follows:

A. Control of Deviations
Deviations from the procedure shall be sufficiently documented to allow repetition of the activity as actually performed.

B. QC Samples
Ten percent of all sites sampled on any given year are resampled as a means of determing sampling error.

C. Verification
The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following the procedures according to this SOP.

IX. TRAINING

A. All personnel will receive training annually from a trainer designated by the program manager. Major revisions in this procedure will require that all personnel be retrained in the revised procedure by an authorized trainer.

B. Training activities will include instruction in the field as well as a field test to ensure that personnel can implement this procedure.

X. ACTION STEPS

A. Equipment List

Ensure that all of the following items are presents before implementing this procedure:

Two D-frame dipnets with 500 micron mesh nets, preferably Wildco, turtox design
Two sieve buckets with 500 micron sieves
Stream Invertebrate Visit Form
Stream verification form, previously completed with attached copies of 1:24,000 USGS topographical map
Minnesota Atlas and Gazateer (Delorme)
Pencils
Permanent/Alcohol proof markers

A. Equipment List (continued)

Labeling tape
Invertebrate sample identification labels
100% reagent alcohol, enough to preserve one days worth of samples, ca. 1 gallon/site
Waterproof notebook
Chest-high waders
Rain-gear
Jars or bottles in which sample is to be preserved; preferably non-breakable synthetic, minimum 1 litre capacity
Box or crate to store sample bottles
Canoe
Backpack

B. Method

The multihabitat method entails collecting a composite sample from up to five different habitat types. The goal of this method is to get a sample representative of the invertebrate community of a particular sampling reach, it is also to collect and process that sample in a time and cost effective manner. For that reason the habitats described below are relatively non-specific, being chosen to represent broad categories rather than microhabitats. Every broad category includes numerous microhabitats, some of which will not be sampled. It is to the discretion of the sampler which microhabitats are to be sampled. As a general rule, sample in manner that reflects the most common microhabitat of any given broad habitat category. The habitats to be sampled include:

Hard bottom (riffle/cobble/boulder)
This category is intended to cover all hard, rocky substrates, not just riffles. Runs and wadable pools often have suitable “hard” substrates, and should not be excluded from sampling. The surfaces of large boulders and areas of flat, exposed bedrock are generally quite unproductive, avoid including these habitats in the sampling area if possible. This is a general rule, if a particular stream has productive exposed bedrock, or boulder surfaces, those habitats should be considered sampleable.

Aquatic Macrophytes (submerged/emergent vegetation)
Any vegetation found at or below the water surface should be considered in this category. Emergent vegetation is included because all emergent plants have stems that extend below the water surface, serving as suitable substrate for macroinvertebrates. Do not sample the emergent portion of any plant.

B. Method (continued)

Undercut Banks (undercut banks/overhanging veg)

This category is meant to cover in-bank or near-bank habitats, shaded areas away from the main channel that typically are buffered from high water velocities.

Snags (snags/rootwads)

Snags include any piece of large woody debris found in the stream channel. Logs, tree trunks, entire trees, tree branches, large pieces of bark, and dense accumulations of twigs should all be considered snags. Rootwads are masses of roots extending from the stream bank.

Leaf Packs

Leaf packs are dense accumulations of leaves typically present in the early spring and late fall They are found in deposition zones, generally near stream banks, around logjams, or in current breaks behind large boulders.

Sampling consists of dividing 20 sampling efforts equally among the dominant, productive habitats present in the reach. If 2 habitats are present, each habitat should receive 10 sampling efforts. If 3 habitats are present, the two most dominant habitats should receive 7 jabs, the third should receive 6 jabs. If a productive habitat is present in a reach but not in great enough abundance to receive an equal proportion of sampling efforts, it should be thoroughly sampled and the remaining samples should be divided among the remaining habitat types present.

A sample effort is defined as taking a single dip or sweep in a common habitat. A sweep is taken by placing the D-net on the substrate and disturbing the area directly in front of the net opening equal to the net width, ca. $1ft^2$. The net should be swept several times over the same area to ensure that an adequate sample is collected. Each effort should cover approximately $.09m^2$ of substrate. Total area sampled is ca. $1.8m^2$.

Once a site reach has been found or newly established, invertebrate sampling should follow. If a habitat assessment and chemical analysis is to be done it should follow invertebrate sampling.

NOTE

Before leaving the vehicle be sure that the following equipment is brought to the site: two d-frame dipnets, one (or two) sieve buckets, habitat partition form, site file, compass, GPS receiver, backpack filled with sample bottles (optional), alcohol (optional)

B. Method (continued)

1. Before sampling can begin, the Crew Leader and field tech must determine which habitats are present in the reach. This should be a cooperative effort. This is done by walking the length of the stream and determining which productive habitats dominate the stream reach. A site visit form should be filled out during this process. Ideally the stream should be viewed from the top of the stream bank, but this is generally the exception rather than the rule. For this reason, great care must be taken to walk gingerly along the stream edge, or any streamside exposed areas. If this is not possible, stay to one side of the stream so as to disturb as little substrate as possible.

NOTE

Since sampling should be conducted in a downstream to upstream fashion, it will save time to start the initial visual inspection of the stream from the upstream end of the sampling reach, and walk downstream. This will allow you to start sampling at the down stream end of the reach as soon the inspection is completed.

It is difficult to estimate total stream coverage of certain habitats due to their linear or three dimensional natures. Undercut banks and overhanging vegetation appear linear, snags are three dimensional, as are vegetation mats, and emergent vegetation. For these reasons best professional judgment must be used to determine what level of effort is adequate to equal one “sample effort” for any given substrate. Keep in mind that this method is considered semiquantitative, rulers and grids are not necessary to effectively implement this procedure. Following are some suggestions as to how approach each habitat for the perspective of

Hard bottom: Riffles are basically two dimensional areas, and should be thought of as such when trying to determine how dominant the riffle habitat is in a stream. It must be kept in mind that the riffle is likely to be the most productive and diverse habitat in the reach, relatively speaking. The field personnel must not get overzealous, the purpose of this method is to get a representative sample. The temptation will undoubtedly exist to spend all day in the riffle areas, this must be avoided. Sampling in this habitat type is relatively simple. The D-net should be place firmly, and squarely on the substrate downstream of the area to be sampled. If the water is shallow enough, the area directly in front of the net should be disturbed with the hands, taking care to wash large rock off directly into the net. If the water

is too deep for this, kicking the substrate in front of the net is adequate. Watch for stoneflies trying to crawl out of the net!

Vegetation: Aquatic vegetation is either completely submerged, mostly submerged and partially floating on the waters surface, or partially submerged and mostly extended above the waters surface. Things like Potamageton sp., coontail, and milfoil tend to clump and float at the waters surface. These types of plants should be sampled with an upward sweep of the net. If the net fills with weeds, the weeds should be hand washed vigorously or jostled in the net for a few moments and then discarded. Emergent plants such as reed canary grass and various plants in the rush family, should be sampled with horizontal and vertical sweeps of the net until it is felt that the area being swept has been adequately sampled. Plants like floating bur reed, and water celery tend to float in long strands with the current. They can be floating on the surface of completely submerged. These plants should be sample as emergent plants with horizontal and vertical sweeps in a downstream to upstream motion.

Undercut banks/ Overhanging Vegetation: Undercut banks and overhanging vegetation follow the line of the stream bank. Undercut banks can vary in how undercut they are. An additional problem is that many banks appear undercut, but when investigated prove not to be. For these reasons banks should be prodded to determine how deeply they are undercut. Overhanging vegetation should be treated the same way. Sampling should consist of upward thrusts of the net, beating the undercut portion of the bank or the overhanging vegetation, so as to dislodge any clinging organisms.

Snags: Snags and rootwads can be large or small, long or wide, simple or twisted masses of logs or twigs that don't have any consistent shape. Best professional judgment must be used to determine what a "sampling effort" is. Approximating the amount of sampleable surface area is a sensible method with larger tree trunks or branches. Where as masses of smaller branches and twigs must be given a best guess. Given their variable nature, there is not one best method for sampling snags. Using something like a toilet brush works well for large pieces of wood, whereas kicking and beating with the net works best for masses of smaller branches. The person taking the sample must determine the best method for each particular situation.

B. Method (continued)

Leaf packs: Leaf packs are simple, but messy to sample. One square foot of leaf pack surface area that has two cubic feet of leaf underneath should be sampled near the surface. Whereas a shallow leafpack can be sampled in it's entirety. Sweeping to the bottom of every leafpack could create a disproportionately large amount of sample volume being collected for relatively small sample area. In most situations leaf packs will not be dominate enough to be included in a sample. If leaf packs are sampled, it is suggested that time be spent streamside washing invertebrates off of leaves and discarding the leaves, as a leaf pack sample can easily become overwhelmingly large.

2. After the number of productive, sampleable habitats have been determined, the sampling team should proceed in a downstream to upstream manner, sampling the various habitats present.

NOTE

In order to get complete samples, the contents of the D-net should be emptied into a sieve bucket frequently. This prevents the back flow of water resulting from a clogged net. In larger streams it is convenient for each sampler to have a sieve bucket. This allows samplers to sample independent of each other, avoiding frequent stream crossings which can alter the stream bed.

NOTE

While sampling it may become necessary to clean the sample of muddy, fine sediment. This can be done by filling the sieve bucket with clean water and allowing the resulting mucky water to drain. Care must be taken not twist and turn the bucket to much, this creates a washing machine action which separates insects from their delicate parts quite effectively.

B. Method (continued)

3. Once sampling is complete the sample material should be preserved as quickly as possible. Transfer the sample material from the sieve bucket to the sample containers. Fill sample containers to the top with 100% reagent alcohol. Be sure to thoroughly clean the bucket as well as sampling nets of all invertebrates. The use of forceps might be necessary to dislodge some of the smaller organisms.

4. With labeling tape, label the outside of the container with field number, date, site name, initials of those who collected samples, and number of containers, i.e 1 of 3, and Place a properly filled out sample label in each sample container.

XI. REQUIRED RECORDS

Stream Invertebrate Visit Form

A. The Stream Invertebrate Visit Form should be filled out during the streamside survey, or notes should be taken on field note books and transferred to visit form. This information will be placed in the biological database.

Quantitative Riffle Sample (optional):

These samples are being taken by the MPCA as a means to determining the best method for sampling streams with dominant riffle/run features.

If a riffle is present in the sampling reach, or in close proximity to the reach, a riffle sample should be taken. This should be a "quality" riffle, that is, a riffle that consists of gravel and/or cobble of varying sizes, and has adequate flow for sampling. The flow should be fast enough to wash dislodged organisms into the sampling net.

Three quantitative riffle samples should be taken. They do not need to be side by side. They should be spread throughout the riffle area.

Appendix 5-D

Invertebrate Identification and Enumeration

SOP BMIP03
Invertebrate Identification and Enumeration

STEP

Materials:

1. Waterproof paper labels and water/solvent proof marker
2. 80 percent ethanol
3. Squeeze bottles (for ethanol and water)
4. 4 oz. jars, with plastic or foam-line cap
5. Dissecting scope with a 10x minimum power
6. Fine tipped forceps, watchmaker type
7. Vials, with polyseal caps -2,4, and 8 dram

Methods:

Sort sample according to SOP BMIP03, placing the picked organisms in 2 or 4 dram vials

Mulit-habitat sub-sample / quantitative sample:

Empty contents of vial(s) into a petri-dish

When sorting, chironomids should be counted and separated into their own individual vial. Chironmids are not identified past the family level, they are sent to an external lab for identification. It is imperative that they be enumerated correctly. In the chironomid vial include a label with a Site ID number, site name, latitude, longitude, collection date. An additional label including taxonomic identification, and number of individuals in the vial should also be included

To facilitate identification, sort organisms according to major taxonomic groups, i.e. stoneflies, caddisflies, bottles. Different groups can be placed in separate, 60mm petri-dishes or kept separate in several larger petri-dishes.

Identify organisms to the lowest practical taxonomic level. The desired level is genus. Organisms should be counted as they are identified, and removed to another dish or placed back in the sample vial to avoid miscounting.

Final identifications are to be made by experienced taxonomists. Preliminary identifications made by interns, or inexperienced taxonomists must be verified by a staff member whose name appears on the invertebrate QC list. The lab maintains a library of taxonomic reference materials. When making identifications, the taxonomist should refer to the taxonomic reference list for the preferred reference for each major group. The lab also maintains a reference collection the can be used to check identifications. Many taxonomic references contain high quality pictures, **identifications are never to be made using pictures alone**. The proper way to make an identification includes taking a specimen through a dichotomous key, checking range distribution, checking habitat preference, and checking for seasonal emergence and growth patterns. If any questions remain about the identity of a specimen, consult another staff taxonomist, or a regional or taxonomic group specialist. A list of regional and group specialists is maintained in the lab.

When large numbers of individual taxa are present a laboratory counter should be used to keep a running total. Counters should be labeled to avoid confusion if using more than one counter.

If an organism is encountered for the first time in the laboratory, remove it to it's own vial for inclusion in the reference collection. Make a note of this on the Invertebrate Identification and Enumeration Sheet.

When adding an organism to the reference collection, place it in a 4 dram vial with two labels. One label including a taxonomic identification, taxonomist name and date of identification. The other including, Site ID number, site name, state, county, latitude and longitude - or a brief location description- and collection date.

Large/Rare Sample:

The Large/Rare sample should be identified and enumerated separate from the main sub-sample.

Sort organisms according to major taxonomic groups, i.e. stoneflies, caddisflies, beetles Different groups can be placed in separate, 60mm petri dishes or kept separate in several larger petri-dishes.

Identify organisms to the lowest practical taxonomic level. The goal is to identify organisms to Genus. Organisms should be counted as they are identified, and removed to another dish or placed back in the sample vial to avoid miscounting.

Record numbers of Large/Rare organisms in the Large/Rare column of the Invertebrate Identification and Enumeration Sheet.

It is imperative that organisms which are a part of the large/rare sample are kept separate from the multihabitat subsample, and quantitative sample.
Large/rare organisms are only used in taxa richness measures, so it is most important that there presence is noted.

Macroinvertebrate Identification Lab Bench Sheet

Field Number	**Sample Date**
Site Name	**Taxonomist:**
Sample Type QMH* QR HD other________	**Date of Sample ID:** ____/____/____

*A processed QMH sample consists of 2 parts, the subsample(ss) and large/rare (l/r), both parts must be identified

Order/Family	Genus	Species/Notes	ss	l/r
Ephemeroptera				
Baetiscidae	Baetisca			
Caenidae	Bracycercus			
	Caenis			
Ephemerellidae	Attenella			
	Ephemerella			
	Serratella			
Ephemeridae	Ephemera			
	Hexagenia			
Leptohyphidae	Tricorythodes			
Leptophlebiidae	Leptophlebia			
	Paraleptophlebia			
Polymitarcidae	Ephoron			
Potamanthidae	Anthopotamus			
Heptageniidae	Epeorus			
	Heptagenia			
	Stenacron			
	Stenonema			
Isonychiidae	Isonychia			
Ametropodidae	Ametropus			
Baetidae	Acerpenna			
	Baetis			
	Callibaetis			
	Heterocloeon			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	l/r
Plecoptera				
Leuctridae				
Taeniopterygidae				
Perlidae	Acroneuria			
	Agnetina			
	Attaneuria			
	Neoperla			
	Paragnetina			
	Perlinella			
Perlodidae				
Pteronarcyidae	Pteronarcys			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	l/r
Lepidoptera				
Pyralidae	Paraponyx			
	Petrophila			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	l/r
Megaloptera				
Corydalidae	Chauliodes			
	Corydalus			
	Nigronia			
Sialidae	Sialis			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	l/r
sopoda				
\sselidae	Asselus			

otes/additional taxa

Order/Family	Genus	Species/Notes	ss	
Odonata				
Calopterygidae	Calopteryx			
	Hetaerina			
Coenagrionidae	Argia			
	Enallagma			
	Nehalennia			
Lestidae	Lestes			
Aeshnidae	Aeschna			
	Anax			
	Basiaeschna			
	Boyeria			
Cordulegastridae	Cordulegaster			
Corduliidae	Cordulia			
	Dorocordulia			
	Epitheca			
	Somatochlora			
Gomphidae	Dromogomphus			
	Gomphurus			
	Gomphus			
	Hagenius			
	Ophiogomphus			
	Phanogomphus			
	Progomphus			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	
Hemiptera				
Belostomatidae	Belstoma			
	Corixidae			
Corixidae	Hesperocorixa			
	Sigara			
	Trichocorixa			
Nepidae	Ranatra			
Notonectidae	Buenoa			
	Notonecta			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	
Amphipoda				
Talitridae	Hyallela	azteca		
Gammaridae	Gammarus			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	
Decapoda				
Cambaridae	Cambarus			
	Orconectes			
	Procambarus			

notes/additional taxa

Order/Family	Genus	Species/Notes	ss	
Pelecypoda				
Sphaeriidae				
Corbiculidae				
Unionidae				

notes/additional taxa

ntered into DataInverts by_____ --- (initials) date________

Trichoptera				
Dipseudopsidae	Phylocentropus			
Hydropsycidae	Ceratopsyche			
	Cheumatopsyche			
	Diplectrona			
	Hydropsyche			
	Potamyia			
Philopotamidae	Chimarra			
	Dolophilodes			
Polycentropodidae	Cernotina			
	Cyrnellus			
	Neureclipsis			
	Paranyctiophylax			
	Polycentropus			
Psychomyiidae	Lype			
	Psychomyia			
Glossosomatidae	Agapetus			
	Glossosoma			
	Protoptila			
Hydroptilidae	Hydroptila			
	Leucotrichia			
	Mayatrichia			
	Oxyethira			
	Orthotrichia			
Rhyacophilidae	Rhyacophila			
Brachyecentridae	Brachycentrus			
	Micrasema			
Helicopsychidae	Helicopsyche			
Lepidostomatidae	Lepidostoma			
Leptoceridae	Ceraclea			
	Leptocerus			
	Mystacides			
	Nectopsyche			
	Oecetis			
	Trianodes			
Limnephilidae	Limnephilus			
	Hydatophylax			
Molannidae	Molanna			
Phryganeidae	Phryganea			
	Ptilostomis			
Sericostomatidae	Agarodes			

notes/additional taxa

Gastropoda				
Ancylidae	Ferrissia			
Planorbidae	Helisoma			
	Promentus			
	Planorbula			
	Gyraulus			
Viviparidae	Campeloma			
Lymnaeidae	Lymnaea			
	Bulimnea			
	Fossaria			
Hydrobiidae	Amnicola			
Pleuroceridae	Pleurocera			
Physidae	Physa			

notes/additional taxa

Diptera				
Ceratopogonidae	Alluaudomyia			
	Atrichopogon			
	Bezzia			
	Ceratopogon			
	Culicoides			
	Nilobezzia			
	Palpomyia			
	Probezzia			
	Sphaeromias			
Chironomidae	G.			
Dixidae	Dixa			
	Dixella			
Simuliidae	Simulium			
Tipulidae	Antocha			
	Dicranota			
	Hexatoma			
	Limnophila			
	Limonia			
	Pilaria			
	Tipula			
Athericidae	Atherix			
Empididae	Hemerodromia			
Tabanidae	Chrysops			
	Tabanus			

notes/additional taxa

Coleoptera				
Dytiscidae	Agabus			
	Laccophilus			
	Liodessus			
Gyrinidae	Dineutus			
	Gyrinus			
Elmidae	Ancyronyx			
	Dubiraphia			
	Macronychus			
	Optioservus			
	Stenelmis			
Hydrophilidae	Berosus			
	Helocombus			
	Laccobius			
	Sperchopsis			
	Tropisternus			
Annelida	Oligochaeta			
	Hirudinea			

notes/additional taxa

Hydracarina (trombidoformes, acarina)				
Nematoda				

notes/additional taxa

-MPCA Biological Monitoring Program-

Macroinvertebrate Identification QC Form

Field Number	Sample Date	Identifiers' Initials		Discrepancies		Comments	Total # of Conflicts	Total # of Taxa	Precision	
		Original ID	QC ID	Original Identification	QC Identification				Original ID	QC ID

Appendix 5-E

Fish Community Sampling Protocol

FISH COMMUNITY SAMPLING PROTOCOL FOR STREAM MONITORING SITES

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to collect fish community information at stream monitoring sites for the purpose of assessing water quality and developing biological criteria.

II. SCOPE/LIMITATIONS

This procedure applies to all monitoring sites for which an integrated assessment of water quality is to be conducted. An integrated assessment involves the collection of biological (fish and macroinvertebrate communities), physical habitat, and chemical information to assess stream condition.

III. GENERAL INFORMATION

Sites may be selected for assessment for a number of reasons including: 1) sites randomly selected for condition monitoring as part of the Environmental Monitoring and Assessment Program (EMAP), 2) sites selected for the development and calibration of biological criteria, and 3) sites selected to evaluate a suspected source of pollution. Although the reasons for monitoring a site vary, the fish community sampling protocol described in this document applies to all monitoring sites unless otherwise noted.

IV. REQUIREMENTS

A. <u>Qualifications of crew leaders</u>: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. He or she must have a minimum of six months field experience in fish community sampling methodology and fish taxonomy. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. <u>Qualifications of field technicians/interns</u>: A field technician/intern must have at least one year of college education and coursework in environmental and/or biological science.

C. <u>General qualifications</u>: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site

V. RESPONSIBILITIES

A. <u>Field crew leader</u>: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. <u>Technicians/interns</u>: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

Compliance with this procedure will be maintained through annual internal reviews. Technical personnel will conduct periodic self-checks by comparing their results with other trained personnel. Calibration and maintenance of equipment will be conducted according to the guidelines specified in the manufacturer's manuals.

In addition to adhering to the specific requirements of this sampling protocol and any supplementary site specific procedures, the minimum QA/QC requirements for this activity are as follows:

A. Control of deviations: Deviation shall be sufficiently documented to allow repetition of the activity as performed.

B. QC samples: Ten percent of sites sampled in any given year are re-sampled as a means of determining sampling error and temporal variability.

C. Verification: The field crew leader will conduct periodic reviews of field personnel to ensure that technical personnel are following procedures in accordance with this SOP.

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by experienced personnel.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment list: Verify that all necessary items are present before commencement of this procedure (Table 1).

B. Data collection method: The location and length of the sampling reach is determined during site reconnaissance (see SOP--"***Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites***"). The reach length, 35 times the mean stream width (MSW), is based on the distance necessary to capture a representative and repeatable sample of the fish community within a stream segment (following: Lyons, J. 1992. The length of stream to sample with a towed electrofishing unit when fish species richness is estimated. North American Journal of Fisheries Management. 16:241-256.). Sampling is conducted during daylight hours within the summer index period of mid-June through mid-September. Sampling should occur when streams are at or near base-flow because flood or drought events can have a profound effect on fish community structure and sampling efficiency.

For wadeable streams, fish community sampling is conducted in conjunction with the physical habitat assessment protocol (see SOP--"***Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites***"). Fish sampling should be conducted before the physical habitat assessment so as not to disturb the fish community prior to sampling. Sample all habitat types available to fish within the reach in the approximate proportion that they occur. An effort is made to collect all fish observed. Fish < 25 mm in total length are not counted as part of the catch.

All fish that are alive after processing should be immediately returned to the stream, unless they are needed as voucher specimens. Considerable effort should be expended to minimize handling mortality, such as using a live well, quickly sorting fish into numerous wet containers, and replacing their water supply.

Fish survey results are recorded on the **Fish Survey Record** data sheet. A copy is attached and guidelines for filling out this data sheet are described in the following pages.

C. Fish Survey Record Data Sheet

This data sheet summarizes the location, sampling characteristics, and fish community composition of the sampling site. The variables recorded are as follows:

C.1. Location and Sampling Characteristics

1) *Field Number* – A seven-digit code that uniquely identifies the station. The first two digits identify the year of sampling, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example 02UM001).

2) *Date* – The date fish sampling is conducted in month/day/year format (MM/DD/YY).

3) *Stream Name* – The name of the stream as shown on the most recent USGS 7.5" topographic map. Include all parts of the name (i.e. "North Branch", "Creek", "River", "Ditch", etc.).

4) *County* – The county in which the station is located.

5) *Location* – A general description of where the sampling station is located. Usually includes the nearest road crossing and town. For example, "0.5 mi. downstream of C.R. 30, 4 mi. SW of Northome".

6) *Crew* – The personnel who conducted fish community sampling.

7) *Gear Type* – The specific type of electrofisher utilized for fish collection. The MPCA's Biological Monitoring Program utilizes four electrofishing gear types. Care is taken to select the gear type that will most effectively sample the fish community. Gear selection is dictated by stream width, depth, and accessibility. General guidelines for determining the appropriate gear type and their use are as follows:

   Backpack: Generally used in small, wadeable streams (typically < 8 m MSW and < 50 mi^2 drainage area). A single electrofishing run is conducted in an upstream direction. In very small streams (<2 m wide) it is possible to sample most of the available habitat but in larger streams it is often necessary to meander between habitat types. Two personnel are necessary; one to carry the unit and operate the anode and another to collect the fish.

   Stream-shocker: Used in larger, wadeable streams and rivers (typically > 8 m MSW and 50-500 mi^2 drainage area). The stream-shocker is a towable unit that can effectively sample larger streams because it has additional power capabilities and employs two anodes, thus increasing the electrified zone. Five personnel are required for operation, one to control the electrofisher, two to direct the anodes, and two to net fish. A single electrofishing run is conducted in an upstream direction weaving between habitat types. When stream-shocker access is too difficult or the site is a wide, shallow riffle it may be necessary to sample larger streams utilizing two backpack electrofishers simultaneously.

   Mini-boom: Used in non-wadeable streams and rivers that are either too small or that do not afford the access necessary to utilize a boom-shocker. The mini-boom electrofisher is a jon-boat that is light enough to be portaged, yet provides a stable work platform. Personnel consist of one person to operate the boat, monitor the control box, and ensure the safety of a single fish collector on the bow. A single electrofishing run is conducted in a downstream direction weaving between habitat types.

   Boom-shocker: Used in large, accessible rivers. Three electrofishing runs are made in a downstream direction, one each along the right bank, left bank, and mid-channel. Personnel consist of one person to drive the boat, monitor the control box, and ensure the safety of the two fish collectors on the bow.

8) *Channel Position* – If the site is sampled with a boom-shocker, circle the appropriate channel position of the electrofishing run (determined while facing downstream); right bank, left bank, or mid-channel. A separate **Fish Survey Record** data sheet is used for each of the three runs.

9) *Distance* – The length of stream sampled for fish, measured to the nearest meter following the center of the stream channel. If the entire reach is electrofished, the distance sampled for fish is the same as the *station length* recorded on the **Visit Summary** data sheet (see SOP--"***Physical Habitat and Water Chemistry Assessment Protocol for Wadeable Stream Monitoring Sites***"). In the event the entire station cannot be electrofished, measure the portion of the reach that was not sampled and subtract this distance from the

station length to calculate the distance sampled for fish. Possible explanations include the occurrence of a culvert or beaver impoundment within the reach.

10) *Time Fished* – The number of seconds electrofished. Reset the timer on the electrofisher before each sampling event.

11) *Identified By* – The person(s) who field identified the fish collected, must meet the minimum requirements of a field crew leader described previously.

C.2. <u>Fish Community Composition</u>

1) *Species* – The common name of each fish species collected during the electrofishing run. If a fish cannot be identified to species with certainty, identify to the lowest possible taxon (e.g. to genus) and voucher for later lab identification.

2) *Length Range* – The minimum and maximum length for each fish species collected (fish < 25 mm are excluded). Measure to the nearest millimeter using <u>Maximum Total Length</u> protocol: the distance from the anterior-most part of the fish to the posterior-most tip of the caudal fin while it is being compressed. If only one individual of a fish species is captured, record the length as both the minimum and maximum total length.

3) *Weight* – The total wet weight of each fish species collected. Together, weigh all individuals of the same species to the nearest 0.5 gram. Multiple batch weights may be necessary if scale capacity is exceeded; these can be recorded on the back of the data sheet in the space provided. Only species totals should be recorded here.

4) *No.* – The total number of individuals of each fish species.

5) *Anomalies* – Record the total number and type of anomalies observed on all individuals of a fish species. Recognized anomalies and their codes are located on the bottom of the **Fish Survey Record** data sheet.

6) *Voucher* – The number of specimens of each fish species retained for verification and deposition in the Minnesota Bell Museum of Natural History. For fish that are identified with certainty to species level, several individuals of each species should be preserved in 10% formalin solution (37% formaldehyde:water) in the "A- jar". For each species of fish, document the number of individuals preserved in this data field.

   All fish that could not be identified to the species level should be preserved in a separate container (B-jar) in 10% formalin solution. Record the number preserved.

   Voucher containers should be labeled externally and internally. On the outside of the jar write the field number, sampling date, and jar identification (A or B) with a permanent marker. Place a label inside each jar identifying the field number, sampling date, stream name, jar identification, county, gear type, and collectors. Write this information on an index weight label in pencil or a solvent proof marker. If an "A" and "B" jar are used, tape them together.

   For specimens that are too large to preserve, a photograph may be taken to serve as a voucher. Place a card with the site field number and sampling date visibly into the picture frame with the fish positioned in a manner that allows key characteristics to be identified.

C.3. <u>Individual or Batch Measurements</u>: Often times it is necessary to weigh large fish individually or conduct multiple batch weights for a species of fish, these measurements can be recorded in this section of the data sheet. The data fields are the same as those described above. After fish processing is complete, combine the information for fish of the same species so that only species totals are recorded in the previous section.

Table 1. <u>Equipment List</u> – This table identifies all equipment needed in the field in order to implement the sampling protocol as described.

Electrofisher – for sampling the fish community, use appropriate gear type
(includes control box, generator, anode(s), and cathode)

Nets – for collection of fish; 1/8" mesh, fiberglass handles

Rubber gloves – for safety during electrofishing; electrically rated

Holding tank – for holding fish during electrofishing; of sufficient size to minimize stress

Wet containers – for holding fish during processing; of sufficient size and number to minimize stress

Balance or spring scales – for weighing fish

Measuring board – for measuring total length of fish

Waders – for safety during electrofishing

Polarized sunglasses – for aid in capturing fish

Clipboard – to store forms and record data

Forms – for recording data

Pencil – for filling out forms

Permanent marker – for labeling voucher bottle

Taxonomic key – to assist in identifying fish

Voucher bottle – for storing preserved specimens

Formalin – for preserving voucher specimens

Labels – to label voucher jars

Camera – to document fish species collected that are too large to preserve

FISH SURVEY RECORD

MPCA

Field Number:	Date (mm/dd/yy):
Stream Name:	County:
Location:	Crew:

Gear Type: (circle one) Backpack Stream-Shocker Boom-Shocker Mini-Boom

Channel Position: (circle one if boom-shocking site) Right Bank Mid-Channel Left Bank

Distance (m):	Time Fished (sec):	Identified By:

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies	Voucher
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					

Anomalies: A-anchor worm; B-black spot; C-leeches; D-deformities; E-eroded fins; F-fungus; L-lesions; N-blind; P=parasites; PL-parasite lesion; Y-popeye; S-emaciated; W-swirled scales; T-tumors; Z-other. (Heavy (H) or Light (L) code may be combined with above codes.)

(Cont.)

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies	Voucher
28.					
29.					
30.					
31.					
32.					
33.					
34.					
35.					
36.					
37.					

INDIVIDUAL OR BATCH MEASUREMENTS

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies	Voucher
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					

Appendix 5-F1

WET Test Results, July 2010, Report 10-151

TOXICITY TEST RESULTS

POLYMET MINING

Report Date: August 12, 2010

Project No. 10-151

Prepared for:

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PROJECT: **WHOLE EFFLUENT TOXICITY TESTING POLYMET MINING**

PROJECT NUMBER: 10-151

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on July 28, 2010. The samples identified as SD026 and SD033 were from the PolyMet Mining facility and were collected by employees from Northeast Technical Services. Chronic toxicity testing was conducted on the water samples using Bear Creek water as dilution water. The scope of our services was limited to conducting chronic toxicity tests on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Testing was started on 7/28/10, approximately 24 hours after sample collection.

RESULTS:

Toxicity test results are summarized in Tables 1and 2, test conditions are summarized in Table 3.

Both SD026 and SD033 were toxic to *Ceriodaphnia dubia* reproduction.

In the SD026 test, the number of *C. dubia* young produced in the 100% concentration (18.2) was significantly less than the number produced in the control (30.3). The 25% Inhibition Concentration (IC25), the calculated concentration which would exhibit a 25% decrease in the measured effect from the control, for reproduction was 82.6% effluent resulting in 1.21 TUc (Chronic Toxic Units). The NOEC (No-Observable Effect Concentration) was 75% effluent.

In the SD033 test, the number of *C. dubia* young produced in the 100% concentration (20.2) and 75% concentration (22.4) was significantly less than the number produced in the control (30.3). The IC25 for reproduction was 72.5% effluent resulting in 1.38 TUc (Chronic Toxic Units). The NOEC (No-Observable Effect Concentration) was 50% effluent.

Both water samples were not toxic to *C. dubia* survival.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.661 g/l NaCl	7/16/10

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. Survival and Reproduction of *Ceriodaphnia dubia* Tested With SD026 Water.

Concentration (%)	% Survival	Mean # of Young Produced
Control	100	30.3
12.5%	100	34.1
25%	100	28.1
50%	100	23.9
75%	100	29.6
100%	80	18.2
IC25		82.6%
NOEC	100%	75%
TUc		1.21

Table 2. Survival and Reproduction of *Ceriodaphnia dubia* Tested With SD033 Water.

Concentration (%)	% Survival	Mean # of Young Produced
Control	100	30.3
12.5%	100	30.3
25%	90	29.2
50%	90	25.6
75%	90	22.4
100%	100	20.2
IC25		72.5%
NOEC	100%	50%
TUc		1.38

Table 3. Summary of Chemical and Physical Data of Toxicity Tests

Sample: SD026

% effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	6.95 - 8.04	8.1 - 9.0	25	68	52	95
12.5	7.41 - 8.18	8.1 - 9.0	25			
25	7.73 - 8.40	8.1 - 9.0	25			
50	8.04 - 8.61	8.0 - 9.2	25			
75	8.14 - 8.73	8.0 - 9.4	25			
100	8.16 - 8.62	8.0 - 10.0	25	640	548	1186

Sample: SD033

% effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	6.95 - 8.04	8.1 - 9.0	25	68	52	95
12.5	7.36 - 8.23	8.1 - 9.0	25			
25	7.55 - 8.27	8.1 - 9.1	25			
50	7.84 - 8.46	8.0 - 9.2	25			
75	7.99 - 8.59	8.0 - 9.4	25			
100	8.00 - 8.65	7.9 - 9.9	25	1236	360	2360

EPA Methods:

Parameter	EPA Method Number
Dissolved Oxygen (mg/L)	360.1
pH	150.1
Total Hardness (as mg/$CaCO_3$/L)	130.2
Total Alkalinity (as mg/$CaCO_3$/L)	310.2
Specific Conductivity (µmhos/cm)	120.1

BIOASSAY TEST CONDITIONS

Client: BARR Engineering	Project No.: 10-151
Type of sample: Grab	Test type: Chronic
Test length: 6 days Species: Ceriodaphnia dubia	Organism age: <24 h
# of treatments: 6 # of replicates: 10	mL/replicate: 15
Organisms/rep.: 1	Organisms/treatment: 10
Temperature (°C): 25 Light intensity: 60 ft-c	Photoperiod: 16/8
Type of dilution water: Receiving	Source: Bear Creek
Collection date/time of sample/effluent:	

TEST SOLUTION PREPARATION

Nominal conc. or % effluent	0	12.5	25	50	75	100	
mL of effluent or stock	0	25	50	100	150	200	
mL of dilution water	200	175	150	100	50	0	
TOTAL mL	200	200	200	200	200	200	

Comments:

Analyst: KM

Reviewed by: Walter Kraut

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering – SD 026 Project No.: 10-151
Test Dates/Time • Initiation: 1440 7/28/10 Termination: 1045 8/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	4	4	0	4	0	4	3	0	
	4	0	0	9	0	4	0	0	0	0	3	
	5	10	10	0	11	9	8	11	11	0	6	
	6	20	18	20	20	16	16	20	17	19	18	
						JK						
	Total	34	32	33	35	~~33~~ 29	28	31	32	22	27	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	3	0	0	6	5	0	3	0	
	4	0	3	0	4	2	0	0	3	0	4	
	5	13	13	12	8	11	13	10	10	10	11	
	6	19	16	22	22	18	20	21	21	17	18	
	Total	35	32	37	34	31	39	36	34	30	33	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	6	0	0	0	3	3	0	3	4	
	4	4	0	5	2	0	0	8	6	8	0	
	5	10	10	11	10	4	10	17	11	0	8	
	6	18	16	15	14	4	17	0	18	17	19	
	Total	32	32	31	26	8	30	28	35	28	31	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM Reviewed By: [signature]

Bio.105

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering - SD026 Project No.: 10-151
Test Dates/Time ● Initiation: 1440 7/28/10 Termination: 1045 8/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	3	3	0	0	0	0	4	4	3	
	4	0	0	0	3	5	0	5	0	0	0	
	5	8	11	0	10	10	7	7	5	4	10	
	6	0	15	14	14	15	12	11	16	20	18	
	Total	10	29	17	27	30	19	23	25	28	31	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	3	3	3	2	3	1	2	0	3	
	4	0	0	0	0	0	0	0	0	4	0	
	5	10	7	7	10	9	12	10	10	11	10	
	6	17	17	20	18	18	16	18	16	16	18	
	Total	29	27	30	31	29	31	29	28	31	31	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	4	
	4	6	2	4	0	0	4	4	X	0	0	
	5	11	8	6	4	6	7	8		5	9	
	6	13	0	13	16	10	12	12		6	~~[illegible]~~	12
	Total	30	10	23	20	16	23	24	0	11	25	

✓ = Alive   # = No. of Live Young (-#) = No. of Dead Young   0 = No Young   X = Dead   y = Male   M= Missing

Analyst: Km   Reviewed By: Walter Kresh

Bio.105

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	34	35	32	10	29	30
Response 2	32	32	32	29	27	10
Response 3	33	37	31	17	30	23
Response 4	35	34	26	27	31	20
Response 5	29	31	8	30	29	16
Response 6	28	39	30	19	31	23
Response 7	31	36	28	23	29	24
Response 8	32	34	35	25	28	0
Response 9	22	30	28	28	31	11
Response 10	27	33	31	31	31	25

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: PolyMet SD026
Test Start Date: 7/28/10 Test Ending Date: 8/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 6 Days
DATA FILE:
OUTPUT FILE: ICPout.i25

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	30.300	3.889	32.200
2	10	12.500	34.100	2.767	32.200
3	10	25.000	28.100	7.505	28.100
4	10	50.000	23.900	6.724	26.750
5	10	75.000	29.600	1.430	26.750
6	10	100.000	18.200	8.967	18.200

The Linear Interpolation Estimate: 82.6023 Entered P Value: 25

Number of Resamplings: 80
The Bootstrap Estimates Mean: 81.8037 Standard Deviation: 7.6860
Original Confidence Limits: Lower: 49.0252 Upper: 89.1500
Resampling time in Seconds: 0.00 Random_Seed: 373956

Ceriodaphnia Reproduction
File: PolyMet SD026 Transform: NO TRANSFORMATION

STEELS MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	0	30.300				
2	12.5	34.100	133.50	75.00	10.00	
3	25	28.100	95.50	75.00	10.00	
4	50	23.900	73.00	75.00	10.00	*
5	75	29.600	91.50	75.00	10.00	
6	100	18.200	63.00	75.00	10.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Ceriodaphnia Reproduction
File: PolyMet SD026   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	5	10	23	21	1

Calculated Chi-Square goodness of fit test statistic = 6.8069
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia Reproduction
File: PolyMet SD026   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 30.56
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data FAIL homogeneity test at 0.01 level. Try another transformation.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: BARR Engineering	Project Number: 10-151
Test Type: Chronic - SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	7.01	7.54	7.83	8.07	8.19	8.23	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.7	8.7	8.8	9.6	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/28/10	Conductivity (µmhos)	95					1186	
Analyst:	Total Alkalinity (mg/l)	52					548	
KM	Total Hardness (mg/l)	68					640	
	Total Ammonia (mg/l)							
Day: 1 OLD	pH	7.74	8.18	8.40	8.60	8.71	8.54	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.6	8.5	8.7	8.6	
Date:	Temperature (°C)	24.8	24.8	24.8	24.8	24.8	24.8	
7/29/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 1 New	pH	6.95	7.41	7.73	8.04	8.14	8.16	
	Dissolved Oxygen (mg/l)	8.8	8.9	9.0	9.1	9.4	10.0	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/29/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 2 OLD	pH	7.86	8.15	8.39	8.60	8.73	8.60	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.5	8.5	8.5	8.6	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
7/30/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 2 NEW	pH	7.07	7.63	7.90	8.22	8.23	8.22	
	Dissolved Oxygen (mg/l)	8.8	9.0	9.0	9.2	9.4	9.8	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/30/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							

Reviewed by: [signature] Date: 8/11/10

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: BARR Engineering	Project Number: 10-151
Test Type: Chronic - SD-026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 Old	pH	7.90	8.16	8.34	8.60	8.72	8.58	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.1	8.1	8.2	8.3	
Date: 7/31/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.19	7.65	7.89	8.15	8.20	8.22	
	Dissolved Oxygen (mg/l)	8.8	8.7	8.8	8.8	8.9	9.2	
Date: 7/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 Old	pH	7.99	8.18	8.38	8.61	8.70	8.55	
	Dissolved Oxygen (mg/l)	8.1	8.2	8.1	8.0	8.0	8.0	
Date: 8/1/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	6.99	7.59	7.78	8.09	8.18	8.19	
	Dissolved Oxygen (mg/l)	9.0	8.9	8.8	8.9	9.1	9.5	
Date: 8/1/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	8.04	8.16	8.36	8.59	8.70	8.62	
	Dissolved Oxygen (mg/l)	8.30	8.1	8.1	8.2	8.4	8.4	
Date: 8/2/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: JK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walt Kursch   Date: 8/11/10

Bio.102(2)

Toxicity Test
Daily Chemistries

Client: BARR Engineering	Project Number: 10-151
Test Type: Chronic - SD-026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5	pH	7.30	7.78	8.04	8.26	8.32	8.32	
New	Dissolved Oxygen (mg/l)	8.9	8.8	8.6	8.7	8.8	8.9	
Date:	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
8/12/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
JK	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6	pH	7.87	8.07	8.30	8.55	8.68	8.53	
Final	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.0	8.1	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
8/13/10	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Koenig   Date: 8/11/10

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering - SD 033 Project No.: 10-151
Test Dates/Time ● Initiation: 1445 7/28/10 Termination: 1130 8/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	4	4	0	4	0	4	3	0	
	4	0	0	9	0	4	0	0	0	0	3	
	5	10	10	0	11	9	8	11	11	0	6	
	6	20	18	20	20	16	16	20	17	19	18	
	Total	34	32	33	35	29	28	31	32	22	27	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	5	0	0	0	0	3	0	3	3	3	
	4	0	3	0	3	4	8	4	0	0	0	
	5	7	10	7	11	11	0	10	11	10	9	
	6	21	17	16	18	16	14	20	18	21	17	
	Total	33	30	23	32	31	25	34	32	34	29	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	4	0	5	2	4	5	0	0	
	4	4	5X	0	4	0	0	0	0	4	4	
	5	13		11	9	12	10	7	11	9	10	
	6	16		19	17	18	18	19	19	17	16	
	Total	33	5	34	30	35	30	30	35	30	30	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM Reviewed By: [signature]

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering - SD 033 Project No.: 10-151
Test Dates/Time • Initiation: 1445 7/28/10 Termination: 1130 8/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	0	3	5	0	3	2	4	3	
	4	0	0	4	0	0	4	X	4	0	0	
	5	8	10	10	9	9	9		0	12	11	
	6	16	17	15	13	16	13		17	17	18	
	Total	24	31	29	25	30	26	3	23	33	32	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	0	3	4	5	3	0	4	0	4	
	4	0	5	0	0	6	0	3	0	3	8	
	5	6	5	5	0	X	3	8	6	6	18	
	6	18	14	16	14		12	15	16	12	0	
	Total	26	24	24	18	11	18	26	26	21	30	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	0	0	0	0	0	0	2	0	
	4	0	1	0	3	2	2	0	3	0	5	
	5	8	4	11	5	8	5	6	5	2	6	
	6	14	12	8	12	10	12	12	15	12	14	
	Total	25	17	19	20	20	19	18	23	16	25	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM Reviewed By: [signature]

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	34	33	33	24	26	25
Response 2	32	30	5	31	24	17
Response 3	33	23	34	29	24	19
Response 4	35	32	30	25	18	20
Response 5	29	31	35	30	11	20
Response 6	28	25	30	26	18	19
Response 7	31	34	30	3	26	18
Response 8	32	32	35	23	26	23
Response 9	22	34	30	33	21	16
Response 10	27	29	30	32	30	25

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: PolyMet SD033
Test Start Date: 7/28/10 Test Ending Date: 8/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 6 Days
DATA FILE:
OUTPUT FILE: ICPout.i25

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	30.300	3.889	30.300
2	10	12.500	30.300	3.713	30.300
3	10	25.000	29.200	8.779	29.200
4	10	50.000	25.600	8.669	25.600
5	10	75.000	22.400	5.502	22.400
6	10	100.000	20.200	3.155	20.200

The Linear Interpolation Estimate: 72.4609 Entered P Value: 25

Number of Resamplings: 80Those resamples not used had estimates above the highest concentration/ %Effluent.

The Bootstrap Estimates Mean: 68.5090 Standard Deviation: 13.0316

No Confidence Limits can be produced since the number of resamples generated is not a multiple of 40.
Resampling time in Seconds: 0.05 Random_Seed: 24746844

Ceriodaphnia Reproduction
File: PolyMet SD033 Transform: NO TRANSFORMATION

STEELS MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	0	30.300				
2	12.5	30.300	105.50	75.00	10.00	
3	25	29.200	110.00	75.00	10.00	
4	50	25.600	84.50	75.00	10.00	
5	75	22.400	64.00	75.00	10.00	*
6	100	20.200	58.00	75.00	10.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Ceriodaphnia Reproduction
File: PolyMet SD033   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	5	8	27	18	2

Calculated Chi-Square goodness of fit test statistic = 5.7420
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia Reproduction
File: PolyMet SD033   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 16.70
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data FAIL homogeneity test at 0.01 level. Try another transformation.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 10-151
Test Type: Chronic - SD 033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	7.01	7.43	7.63	7.92	8.05	8.00	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.7	8.9	8.9	9.3	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/28/10	Conductivity (μmhos)	95					2360	
Analyst:	Total Alkalinity (mg/l)	52					360	
Km	Total Hardness (mg/l)	68					1236	
	Total Ammonia (mg/l)							
Day: 1 OLD	pH	7.74	8.13	8.25	8.46	8.57	8.65	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.5	8.5	8.5	8.6	
Date:	Temperature (°C)	24.8	24.8	24.8	24.8	24.8	24.8	
7/29/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 1 New	pH	6.95	7.36	7.55	7.84	7.99	8.04	
	Dissolved Oxygen (mg/l)	8.8	8.9	9.0	9.1	9.3	9.9	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/29/10	Conductivity (μmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	7.86	8.09	8.21	8.43	8.54	8.63	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.4	8.4	8.4	8.5	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
7/30/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
Km	Total Hardness (mg/l)							
Day: 2 NEW	pH	7.07	7.48	7.66	7.89	8.05	8.08	
	Dissolved Oxygen (mg/l)	8.8	9.0	9.1	9.2	9.4	9.8	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
7/30/10	Conductivity (μmhos)							
Analyst: WK.	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kornt Date: 8/11/10

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 10-151
Test Type: Chronic - SD-033	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 Old	pH	7.90	8.23	8.27	8.44	8.57	8.65	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.2	8.1	8.2	8.3	
Date: 7/31/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.19	7.64	7.71	7.99	8.09	8.10	
	Dissolved Oxygen (mg/l)	8.8	8.8	8.9	9.0	9.0	9.3	
Date: 7/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.99	8.20	8.23	8.43	8.59	8.65	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.0	8.0	7.9	
Date: 8/1/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	6.99	7.55	7.71	7.95	8.07	8.08	
	Dissolved Oxygen (mg/l)	9.0	8.9	8.9	9.0	9.1	9.5	
Date: 8/1/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	8.04	8.17	8.27	8.43	8.56	8.65	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.3	8.3	8.4	8.3	
Date: 8/2/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: JK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kuent Date: 8/11/10

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 10-151
Test Type: Chronic - SD-033	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	7.30	7.77	7.80	8.07	8.18	8.20	
	Dissolved Oxygen (mg/l)	8.9	8.7	8.8	8.8	8.8	8.9	
Date: 8/12/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: JK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	7.87	8.15	8.18	8.39	8.52	8.60	
	Dissolved Oxygen (mg/l)	8.1	8.2	8.2	8.3	8.1	8.2	
Date: 8/13/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walt Kraft   Date: 8/11/10

Bio.102(2)

Appendix 5-F2

WET Test Results, October 2010, Report 10-234

TOXICITY TEST RESULTS

POLYMET MINING

Report Date: November 8, 2010

Project No. 10-234

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: <u>CHRONIC TOXICITY TESTING</u>
<u>POLYMET MINING</u>

PROJECT NUMBER: 10-234

TOXICITY TEST RESULTS

<u>INTRODUCTION</u>:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on October 27, 2010. The samples identified as SD026, SD033, Bear Creek, PM 12.1, and PM 17 were from the PolyMet Mining facility and were collected by employees from Northeast Technical Services on October 26, 2010. Chronic toxicity testing was conducted on the water samples using Reconstituted Water, Embarrass River water and Partridge River water as dilution water. The scope of our services was limited to conducting chronic toxicity tests on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

<u>TEST METHODS</u>:

Tests were conducted in accordance with the procedures outlined in <u>Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms</u>, Fourth Edition, EPA-821-R-02-013.

SD026, SD033, and Bear Creek were tested using Reconstituted Water as dilution water. Additionally, SD033 and SD026 were tested using Embarrass River and Partridge River water, respectively.

Testing was started on 10/27/10, approximately 24 hours after sample collection.

<u>RESULTS</u>:

Toxicity test results are summarized in Tables 1, test conditions are summarized in Table 2.

The samples were not toxic to *Ceriodaphnia dubia* reproduction and survival.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.836 g/l NaCl	10/12/10

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst

Walter Koenst
Bioassay Manager

Table 1. **Survival and Reproduction of *Ceriodaphnia dubia*.**

Test: Reconstituted Water/SD033		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	18.3
12.5%	100	16.8
25%	100	18.4
50%	100	15.4
75%	100	15.3
100%	100	17.0
IC25		>100%
NOEC	100%	100%
TUc		<1.0

Test: Reconstituted Water/SD026		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	18.3
12.5%	100	17.9
25%	100	16.3
50%	100	16.7
75%	100	21.5
100%	100	18.6
IC25		>100%
NOEC	100%	100%
TUc		<1.0

Table 1(Continued). Survival and Reproduction of *Ceriodaphnia dubia*.

Test: Reconstituted Water/Bear Creek		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	18.3
12.5%	100	19.2
25%	100	19.4
50%	100	22.7
75%	100	20.9
100%	100	22.2
IC25		>100%
NOEC	100%	100%
TUc		<1.0

Test: Embarrass River/SD033		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	16.7
12.5%	100	16.2
25%	100	17.4
50%	90	13.9
75%	100	14.0
100%	100	17.0
IC25		>100%
NOEC	100%	100%
TUc		<1.0

Table 1(Continued). Survival and Reproduction of *Ceriodaphnia dubia*.

Test: Partridge River/SD026		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	22.1
12.5%	100	22.5
25%	100	20.7
50%	100	20.1
75%	100	18.8
100%	100	18.6
IC25		>100%
NOEC	100%	50%
TUc		<1.0

Screen Test: PM 12.1, PM 17		
Sample ID	**% Survival**	**Mean # of Young Produced**
Control	100	18.3
PM 12.1	100	20.3
PM 17	100	20.7

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

Test: Reconstituted Water/SD033						
% effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.95 - 8.20	8.0 - 8.6	25	92	88	286
12.5	7.90 - 8.29	8.1 - 8.8	25			
25	7.88 - 8.43	8.0 - 8.7	25			
50	7.83 - 8.57	8.0 - 8.8	25			
75	7.81 - 8.66	8.0 - 8.9	25			
100	7.74 - 8.73	7.9 - 9.2	25	1288	384	2420

Test: Reconstituted Water/SD026						
% effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.95 - 8.20	8.0 - 8.6	25	92	88	286
12.5	8.09 - 8.49	8.1 - 8.7	25			
25	8.07 - 8.54	8.0 - 8.8	25			
50	8.04 - 8.71	8.0 - 8.8	25			
75	8.01 - 8.76	8.0 - 8.9	25			
100	7.95 - 8.69	7.9 - 9.2	25	608	504	1125

Test: Reconstituted Water/Bear Creek						
% effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.95 - 8.20	8.0 - 8.6	25	92	88	286
12.5	7.90 - 8.14	7.9 - 8.8	25			
25	7.75 - 8.13	7.9 - 8.8	25			
50	7.54 - 8.06	7.8 - 8.9	25			
75	7.37 - 8.00	7.9 - 9.0	25			
100	7.13 - 7.97	7.8 - 9.3	25	56	44	97

Table 2 (Continued). Summary of Chemical and Physical Data of Toxicity Tests

Test: Embarrass River/SD033						
% effluent	**pH**	**Dissolved Oxygen (mg/L)**	**Temperature (°C)**	**Total Hardness (mg/L)**	**Total Alkalinity (mg/L)**	**Conductivity (μmhos/cm)**
Control	7.04 - 8.00	7.9 - 9.3	25	80	52	135
12.5	7.29 - 8.24	7.9 - 9.3	25			
25	7.54 - 8.37	7.8 - 9.3	25			
50	7.72 - 8.57	7.9 - 9.2	25			
75	7.81 - 8.69	7.9 - 9.2	25			
100	7.74 - 8.73	7.9 - 9.2	25	1288	384	2420

Test: Partridge River/SD026						
% effluent	**pH**	**Dissolved Oxygen (mg/L)**	**Temperature (°C)**	**Total Hardness (mg/L)**	**Total Alkalinity (mg/L)**	**Conductivity (μmhos/cm)**
Control	7.78 - 8.13	7.9 - 9.5	25	156	72	336
12.5	7.92 - 8.39	7.9 - 9.5	25			
25	7.98 - 8.57	7.9 - 9.5	25			
50	8.00 - 8.70	7.9 - 9.4	25			
75	8.01 - 8.77	7.8 - 9.3	25			
100	7.95 - 8.69	7.9 - 9.2	25	608	504	1125

Screen Test: PM 12.1, PM 17						
% effluent	**pH**	**Dissolved Oxygen (mg/L)**	**Temperature (°C)**	**Total Hardness (mg/L)**	**Total Alkalinity (mg/L)**	**Conductivity (μmhos/cm)**
Control	7.95 - 8.20	8.0 - 8.6	25	92	88	286
PM 12.1	7.86 - 8.53	8.0 - 9.3	25	408	180	876
PM 17	7.87 - 8.74	8.0 - 9.3	25	632	356	1116

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon | SD033 Project No.: 10-234

Test Dates/Time ● Initiation: 1505 10/27/10 Termination: 1015 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	3	4	3	3	4	4	4	4	4	
	5	5	7	5	7	4	8	7	6	6	6	
	6	0	12	6	8	10	0	0	0	0	10	
	7	10	0	0	0	0	9	6	8	8	0	
Total		17	22	15	18	17	21	17	18	18	20	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	4	3	4	3	3	3	4	2	4	
	5	5	6	6	7	3	2	5	5	6	5	
	6	9	7	9	0	0	0	0	0	8	0	
	7	0	0	0	8	10	9	8	9	0	7	
Total		18	17	18	19	16	14	16	18	16	16	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	3	2	0	0	0	
	4	0	4	3	4	5	0	0	4	3	4	
	5	6	7	6	6	6	8	8	6	8	6	
	6	9	9	7	11	6	8	0	10	0	6	
	7	0	0	0	0	0	0	10	0	9	0	
Total		15	20	16	21	17	19	20	20	20	16	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM Reviewed By: WK

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon/SD033 Project No.: 10-234

Test Dates/~~Time~~ • Initiation: 1505 10/27/10 Termination: 1015 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	3	3	0	4	2	4	2	3	4	
	5	6	7	5	0	7	6	6	5	7	5	
	6	0	0	8	0	0	0	8	10	0	6	
	7	9	6	0	0	10	6	0	0	10	0	
Total		17	16	16	0	21	14	18	17	20	15	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	2	4	2	3	2	3	4	1	4	
	5	4	5	6	6	6	7	6	0	5	6	
	6	6	0	0	8	6	1X	8	8	8	10	
	7	0	10	0	0	0		0	10	0	0	
Total		12	17	10	16	15	10	17	22	14	20	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	1	0	0	2	3	3	4	3	0	
	5	5	8	6	4	7	7	5	6	5	5	
	6	0	10	0	5	0	8	0	0	10	10	
	7	6	0	9	0	7	0	9	7	0	12	
Total		14	19	15	9	16	18	17	17	18	27	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	17	18	15	17	12	14
Response 2	22	17	20	16	17	19
Response 3	15	18	16	16	10	15
Response 4	18	19	21	0	16	9
Response 5	17	16	17	21	15	16
Response 6	21	14	19	14	10	18
Response 7	17	16	20	18	17	17
Response 8	18	18	20	17	22	17
Response 9	18	16	20	20	14	18
Response 10	20	16	16	15	20	27

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Recon SD033
Test Start Date: 10/27/10 Test Ending Date: 11/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 7 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	18.300	2.111	18.300
2	10	12.500	16.800	1.476	17.600
3	10	25.000	18.400	2.171	17.600
4	10	50.000	15.400	5.816	15.900
5	10	75.000	15.300	3.974	15.900
6	10	100.000	17.000	4.522	15.900

*** No Linear Interpolation Estimate can be calculated from the input data since none of the (possibly pooled) group response means were less than 75% of the control response mean.

Ceriodaphnia reproduction
File: Recon SD033 Transform: NO TRANSFORMATION

STEELS MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	0	18.300				
2	12.5	16.800	85.00	75.00	10.00	
3	25	18.400	105.50	75.00	10.00	
4	50	15.400	84.00	75.00	10.00	
5	75	15.300	78.50	75.00	10.00	
6	100	17.000	89.50	75.00	10.00	

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Toxicity Test
Daily Chemistries

Client: Poly Met	Project Number: 10-234
Test Type: Chronic - Recon/SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.05	7.91	7.89	7.83	7.81	7.75	
	Dissolved Oxygen (mg/l)	8.0	8.1	8.1	8.2	8.3	8.6	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/27/10	Conductivity (µmhos)	286					2420	
Analyst:	Total Alkalinity (mg/l)	88					384	
KM	Total Hardness (mg/l)	92					1288	
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.00	8.13	8.39	8.54	8.63	8.69	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.3	8.3	8.3	8.4	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
10/28/10	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.95	7.90	7.88	7.83	7.81	7.74	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	8.3	8.3	8.5	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/28/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 2 old	pH	7.98	8.16	8.37	8.53	8.63	8.67	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.6	8.6	8.6	8.6	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
10/29/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 2 New	pH	8.02	8.08	7.97	7.90	7.87	7.80	
	Dissolved Oxygen (mg/l)	8.5	8.8	8.7	8.8	8.9	9.2	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/29/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							

Reviewed by: Walter Tovant Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic- Recon / SD033	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	8.06	8.24	8.38	8.53	8.60	8.65	
	Dissolved Oxygen (mg/l)	8.5	8.5	8.4	8.4	8.4	8.3	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.01	8.11	7.97	7.91	7.89	7.82	
	Dissolved Oxygen (mg/l)	8.4	8.5	8.6	8.7	8.8	9.2	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	8.06	8.25	8.39	8.55	8.63	8.69	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.1	8.0	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.12	8.12	8.02	7.92	7.88	7.80	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.3	8.3	8.7	9.2	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	8.13	8.29	8.41	8.57	8.66	8.73	
	Dissolved Oxygen (mg/l)	8.4	8.5	8.5	8.3	8.3	8.3	
Date: 11/01/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: [illegible]	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: [signature] Date: 11/6/10

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic - Recon / SD033	Species: C. Dubia

Day/Date/Analyst	Parameter	Concentration						Remarks
		0	12.5	25	50	75	100	
Day: 5 New	pH	8.20	8.05	8.04	7.91	7.90	7.85	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.3	8.3	8.4	8.6	
Date: 11/01/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: DDL	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Old	pH	8.09	8.25	8.59	8.57	8.66	8.73	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.6	8.5	8.4	8.5	
Date: 11/2/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	8.12	8.06	8.00	7.90	7.88	7.82	
	Dissolved Oxygen (mg/l)	8.5	8.5	8.6	8.6	8.8	8.9	
Date: 11/2/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 Final	pH	8.09	8.28	8.43	8.56	8.65	8.69	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.0	8.0	8.0	7.9	
Date: 11/3/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Krantz   Date: 11/6/10

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon | SD026 Project No.: 10-234
Test Dates/~~Time~~ • Initiation: 1510 10/27/10 Termination: 1030 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	3	4	3	3	4	4	4	4	4	
	5	5	7	5	7	4	8	7	6	6	6	
	6	0	12	6	8	10	0	0	0	0	10	
	7	10	0	0	0	0	9	6	8	8	0	
Total		17	22	15	18	17	21	17	18	18	20	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	4	0	0	0	0	0	
	4	4	2	4	0	0	3	2	4	4	2	
	5	7	6	8	5	5	6	5	7	7	8	
	6	10	0	0	4	8	0	0	8	8	0	
	7	0	9	13	8	0	9	7	0	0	2	
Total		21	17	25	17	17	18	14	19	19	12	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	4	0	3	4	3	2	3	2	4	
	5	5	4	4	6	7	7	6	7	5	6	
	6	0	0	11	8	0	0	6	0	0	10	
	7	0	10	0	0	9	8	0	10	7	0	
Total		7	18	15	17	20	18	14	20	14	20	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM Reviewed By: WK

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon / SD026 Project No.: 10-234

Test Dates/Time ● Initiation: 1510 10/27/10 Termination: 1030 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	4	0	0	0	0	0	0	
	4	2	2	4	0	3	2	3	4	2	3	
	5	3	7	8	6	5	6	8	6	7	6	
	6	8	0	0	10	10	10	0	0	8	8	
	7	0	0	0	0	0	0	12	10	0	0	
Total		13	9	12	20	18	18	23	20	17	17	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	4	0	0	4	0	0	
	4	4	0	4	4	0	2	4	0	4	4	
	5	8	7	8	9	7	5	8	7	8	7	
	6	0	10	0	12	11	0	12	7	12	10	
	7	10	0	12	0	0	11	0	0	0	0	
Total		22	17	24	25	22	18	24	18	24	21	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	3	2	0	0	
	4	3	3	4	3	2	4	0	0	2	4	
	5	4	6	9	6	6	8	7	6	7	6	
	6	0	10	11	8	11	9	8	6	11	9	
	7	8	0	0	0	0	0	0	0	0	0	
Total		15	19	24	17	19	21	18	14	20	19	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: Km Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	17	21	7	13	22	15
Response 2	22	17	18	9	17	19
Response 3	15	25	15	12	24	24
Response 4	18	17	17	20	25	17
Response 5	17	17	20	18	22	19
Response 6	21	18	18	18	18	21
Response 7	17	14	14	23	24	18
Response 8	18	19	20	20	18	14
Response 9	18	19	14	17	24	20
Response 10	20	12	20	17	21	19

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Recon SD026
Test Start Date: 10/27/10 Test Ending Date: 11/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 7 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	18.300	2.111	18.300
2	10	12.500	17.900	3.573	18.200
3	10	25.000	16.300	4.029	18.200
4	10	50.000	16.700	4.218	18.200
5	10	75.000	21.500	2.915	18.200
6	10	100.000	18.600	2.875	18.200

*** No Linear Interpolation Estimate can be calculated from the input data since none of the (possibly pooled) group response means were less than 75% of the control response mean.

Ceriodaphnia reproduction
File: Recon SD026 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	170.083	34.017	3.001
Within (Error)	54	612.100	11.335	
Total	59	782.183		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: Recon SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	18.300	18.300		
2	12.5	17.900	17.900	0.266	
3	25	16.300	16.300	1.328	
4	50	16.700	16.700	1.063	
5	75	21.500	21.500	-2.125	
6	100	18.600	18.600	-0.199	

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: Recon SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.478	19.0	0.400
3	25	10	3.478	19.0	2.000
4	50	10	3.478	19.0	1.600
5	75	10	3.478	19.0	-3.200
6	100	10	3.478	19.0	-0.300

Ceriodaphnia reproduction
File: Recon SD026 Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	6	12	25	14	3

Calculated Chi-Square goodness of fit test statistic = 1.8788
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: Recon SD026 Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 5.25
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic - Recon / SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.05	8.11	8.07	8.04	8.03	7.95	
	Dissolved Oxygen (mg/l)	8.0	8.2	8.2	8.2	8.4	8.8	
Date: 10/27/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	286					1125	
Analyst: WK	Total Alkalinity (mg/l)	88					504	
	Total Hardness (mg/l)	92					608	
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.00	8.49	8.53	8.67	8.74	8.63	
	Dissolved Oxygen (mg/l)	8.3	8.4	8.4	8.4	8.4	8.4	
Date: 10/28/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.95	8.10	8.10	8.06	8.05	7.98	
	Dissolved Oxygen (mg/l)	8.2	8.4	8.4	8.4	8.4	8.6	
Date: 10/28/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	7.98	8.30	8.52	8.69	8.75	8.69	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.5	8.5	8.6	8.6	
Date: 10/29/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.02	8.09	8.07	8.06	8.01	7.96	
	Dissolved Oxygen (mg/l)	8.5	8.7	8.8	8.8	8.9	9.2	
Date: 10/29/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: [signature] Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic - Recon | SD026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	8.06	8.36	8.50	8.66	8.73	8.59	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.4	8.4	8.4	8.3	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.01	8.14	8.10	8.07	8.04	7.99	
	Dissolved Oxygen (mg/l)	8.4	8.6	8.7	8.7	8.8	9.2	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	8.06	8.34	8.47	8.65	8.73	8.62	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.0	7.9	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.12	8.23	8.20	8.17	8.16	8.09	
	Dissolved Oxygen (mg/l)	8.1	8.2	8.2	8.2	8.2	8.2	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLd	pH	8.13	8.35	8.49	8.67	8.73	8.64	
	Dissolved Oxygen (mg/l)	8.4	8.3	8.2	8.2	8.1	8.2	
Date: 11/01/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: [illegible]	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kord [signature] Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic Recon / SD 026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	8.20	8.28	8.22	8.18	8.19	8.15	
	Dissolved Oxygen (mg/l)	8.2	8.5	8.4	8.5	8.6	8.4	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
11/1/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 OLD	pH	8.09	8.35	8.50	8.67	8.76	8.65	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.5	8.5	8.5	8.5	
Date:	Temperature (°C)	25.3	25.3	25.3	8.3	8.3	8.3	
11/2/10	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	8.12	8.22	8.21	8.18	8.18	8.14	
	Dissolved Oxygen (mg/l)	8.5	8.6	8.6	8.6	8.7	8.7	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
11/2/10	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 7 Final	pH	8.09	8.39	8.54	8.71	8.75	8.62	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.0	8.0	8.0	8.0	
Date:	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
11/3/10	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walt Kurt Date: 11/6/10

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon / Bear Creek Project No.: 10-234

Test Dates/Time ● Initiation: 1515 10/27/10 Termination: 1040 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	3	4	3	3	4	4	4	4	4	
	5	5	7	5	7	4	8	7	6	6	6	
	6	0	12	6	8	10	0	0	0	0	10	
	7	10	0	0	0	0	9	6	8	8	0	
Total		~~[illegible]~~	22	15	18	17	21	17	18	18	20	
		17										
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	0	0	0	0	0	0	0	0	
	4	0	3	3	1	3	4	2	3	2	4	
	5	5	5	6	6	7	6	8	5	7	7	
	6	12	0	8	11	10	0	10	8	0	0	
	7	0	11	0	0	0	11	0	0	10	11	
Total		20	19	17	18	20	21	20	16	19	22	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	1	2	3	3	4	2	4	3	4	
	5	8	8	7	6	7	7	8	6	9	6	
	6	0	12	12	8	0	0	8	0	0	10	
	7	10	0	0	0	12	7	0	2	12	0	
Total		21	21	21	17	22	18	18	12	24	20	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon | Bear Creek Project No.: 10-234
Test Dates/~~Time~~ • Initiation: 1515 10/27/10 Termination: 1040 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	3	0	3	0	2	2	1	0	4	
	5	10	7	4	7	6	8	9	8	8	10	
	6	0	9	12	0	10	0	10	12	14	0	
	7	14	0	0	14	14	10	0	0	0	13	
Total		27	19	16	24	30	20	21	21	22	27	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	5	2	2	2	3	1	2	4	1	
	5	10	8	8	6	5	7	7	7	7	9	
	6	0	0	10	10	0	10	14	11	12	15	
	7	0	15	0	0	14	0	0	0	0	0	
Total		12	28	20	18	21	20	22	20	23	25	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	3	0	0	0	0	2	
	4	0	3	0	1	0	4	1	2	2	0	
	5	8	7	6	7	8	9	10	7	7	9	
	6	14	0	12	10	11	0	0	0	14	14	
	7	0	14	0	0	0	14	10	13	0	0	
Total		22	24	18	18	22	27	21	22	23	25	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: Km Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	17	20	21	27	12	22
Response 2	22	19	21	19	28	24
Response 3	15	17	21	16	20	18
Response 4	18	18	17	24	18	18
Response 5	17	20	22	30	21	22
Response 6	21	21	18	20	20	27
Response 7	17	20	18	21	22	21
Response 8	18	16	12	21	20	22
Response 9	18	19	24	22	23	23
Response 10	20	22	20	27	25	25

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Recon Bear Creek
Test Start Date: 10/27/10 Test Ending Date: 11/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 7 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	18.300	2.111	20.450
2	10	12.500	19.200	1.814	20.450
3	10	25.000	19.400	3.340	20.450
4	10	50.000	22.700	4.270	20.450
5	10	75.000	20.900	4.254	20.450
6	10	100.000	22.200	2.821	20.450

*** No Linear Interpolation Estimate can be calculated from the input data since none of the (possibly pooled) group response means were less than 75% of the control response mean.

Ceriodaphnia reproduction
File: Recon Bear Creek   Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	156.150	31.230	2.966
Within (Error)	54	568.700	10.531	
Total	59	724.850		

Critical F value =   2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: Recon Bear Creek   Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	18.300	18.300		
2	12.5	19.200	19.200	-0.620	
3	25	19.400	19.400	-0.758	
4	50	22.700	22.700	-3.032	
5	75	20.900	20.900	-1.792	
6	100	22.200	22.200	-2.687	

Dunnett table value = 2.31   (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: Recon Bear Creek   Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2   Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.352	18.3	-0.900
3	25	10	3.352	18.3	-1.100
4	50	10	3.352	18.3	-4.400
5	75	10	3.352	18.3	-2.600
6	100	10	3.352	18.3	-3.900

Ceriodaphnia reproduction
File: Recon Bear Creek   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	5	11	29	10	5

Calculated Chi-Square goodness of fit test statistic = 4.3510
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: Recon Bear Creek   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 9.98
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic - Recon / Bear Creek	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.05	8.02	7.75	7.54	7.37	7.13	
	Dissolved Oxygen (mg/l)	8.0	8.1	8.1	8.2	8.3	8.4	
Date: 10/27/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	286					97	
Analyst: KM	Total Alkalinity (mg/l)	88					44	
	Total Hardness (mg/l)	92					56	
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.00	8.06	8.08	8.06	8.00	7.93	
	Dissolved Oxygen (mg/l)	8.3	8.4	8.4	8.4	8.3	8.3	
Date: 10/28/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.95	7.90	7.79	7.60	7.47	7.27	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.3	8.4	8.5	8.6	
Date: 10/28/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 OLD	pH	7.98	8.05	8.13	8.00	7.95	7.91	
	Dissolved Oxygen (mg/l)	8.6	8.8	8.8	8.8	8.7	8.8	
Date: 10/29/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.02	8.10	7.85	7.60	7.42	7.14	
	Dissolved Oxygen (mg/l)	8.5	8.7	8.8	8.9	9.0	9.3	
Date: 10/29/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Koenst Date: 11/6/10

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic - Recon/Bear Creek	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	8.06	8.10	8.05	7.97	7.91	7.86	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.4	8.4	8.3	8.2	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.01	7.98	7.87	7.74	7.59	7.36	
	Dissolved Oxygen (mg/l)	8.4	8.6	8.6	8.7	8.8	9.0	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	8.06	8.10	8.07	8.00	7.96	7.90	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.0	8.0	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.12	8.03	7.88	7.74	7.56	7.34	
	Dissolved Oxygen (mg/l)	8.1	8.4	8.4	8.5	8.5	8.6	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	8.13	7.99	7.94	7.99	7.94	7.91	
	Dissolved Oxygen (mg/l)	8.4	8.1	8.0	8.0	8.1	8.1	
Date: 11/01/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: [illegible]	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Koenst — Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic Recon/Bear Creek	Species: C. dubia

Day/Date/Analyst	Parameter	0	12.5	25	50	75	100	Remarks
		Concentration						
Day: 5 New	pH	8.20	8.02	7.86	7.65	7.47	7.27	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.3	8.4	8.5	8.6	
Date: 11/1/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Old	pH	8.09	8.14	8.11	8.01	7.97	7.90	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.5	8.4	8.4	8.3	
Date: 11/2/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	8.12	8.02	7.86	7.63	7.40	7.26	
	Dissolved Oxygen (mg/l)	8.5	8.6	8.6	8.7	8.9	9.0	
Date: 11/2/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 Final	pH	8.09	8.13	8.07	8.01	7.99	7.97	
	Dissolved Oxygen (mg/l)	8.1	7.9	7.9	7.8	7.9	7.8	
Date: 11/3/10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Karnt Date: 11/6/10

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Embarrass/SD033 Project No.: 10-234

Test Dates/~~Time~~ • Initiation: 1520 10/27/10 Termination: 1045 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	2	0	0	0	0	
	4	3	3	4	3	2	0	4	4	2	3	
	5	2	4	3	6	3	6	5	5	3	2	
	6	0	0	0	0	5	8	0	8	0	0	
	7	10	10	12	10	0	0	10	0	10	15	
Total		15	17	19	19	10	16	19	17	15	20	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	4	4	4	4	3	3	1	3	0	
	5	4	4	5	4	4	3	5	4	3	5	
	6	0	0	0	0	0	0	8	0	0	0	
	7	10	12	10	11	11	10	0	4	10	6	
Total		17	20	19	19	19	16	16	9	16	11	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	4	2	5	4	3	3	2	0	2	
	5	4	3	5	4	4	5	3	4	7	4	
	6	8	0	0	0	0	0	0	8	9	0	
	7	0	7	9	12	10	9	9	0	10	12	
Total		15	14	16	21	18	17	15	14	26	18	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Embarrass / SD033 Project No.: 10-234

Test Dates/Time • Initiation: 1520 10/27/10 Termination: 1045 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	2	3	4	1	4	3	4	2	2	
	5	7X	4	3	5	2	6	5	3	6	3	
	6		9	0	8	0	8	6	0	8	0	
	7		0	10	0	0	0	0	8	0	8	
Total		10	15	16	17	3	18	14	15	16	13	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	4	3	3	4	3	5	3	3	4	
	5	6	4	4	2	3	5	4	0	4	4	
	6	10	7	8	0	0	10	0	0	0	0	
	7	0	0	0	8	8	0	7	8	0	4	
Total		18	15	15	13	15	18	16	11	7	12	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	1	0	0	2	3	3	4	3	0	
	5	5	8	6	4	7	7	5	6	5	5	
	6	0	10	0	5	0	8	0	0	10	10	
	7	6	0	9	0	7	0	9	7	0	12	
Total		14	19	15	9	16	18	17	17	18	27	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM

Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	15	17	15	10	18	14
Response 2	17	20	14	15	15	19
Response 3	19	19	16	16	15	15
Response 4	19	19	21	17	13	9
Response 5	10	19	18	3	15	16
Response 6	16	16	17	18	18	18
Response 7	19	16	15	16	16	17
Response 8	17	9	14	15	11	17
Response 9	15	16	26	16	7	18
Response 10	20	11	18	13	12	27

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Embarass SD033
Test Start Date: 10/27/10 Test Ending Date: 11/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 7 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	16.700	2.946	16.767
2	10	12.500	16.200	3.615	16.767
3	10	25.000	17.400	3.718	16.767
4	10	50.000	13.900	4.433	14.967
5	10	75.000	14.000	3.367	14.967
6	10	100.000	17.000	4.522	14.967

*** No Linear Interpolation Estimate can be calculated from the input data since none of the (possibly pooled) group response means were less than 75% of the control response mean.

Ceriodaphnia reproduction
File: Embarrass SD033 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	117.933	23.587	1.627
Within (Error)	54	783.000	14.500	
Total	59	900.933		

Critical F value = 2.45 (0.05,5,40)
Since F < Critical F FAIL TO REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: Embarrass SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	16.700	16.700		
2	12.5	16.200	16.200	0.294	
3	25	17.400	17.400	-0.411	
4	50	13.900	13.900	1.644	
5	75	14.000	14.000	1.585	
6	100	17.000	17.000	-0.176	

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: Embarrass SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.934	23.6	0.500
3	25	10	3.934	23.6	-0.700
4	50	10	3.934	23.6	2.800
5	75	10	3.934	23.6	2.700
6	100	10	3.934	23.6	-0.300

Ceriodaphnia reproduction
File: Embarrass SD033   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	5	11	28	14	2

Calculated Chi-Square goodness of fit test statistic =   3.2518
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: Embarrass SD033   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic =   2.28
Table Chi-square value =   15.09   (alpha = 0.01)
Table Chi-square value =   11.07   (alpha = 0.05)

Average df used in calculation ==>   df (avg n - 1) =   9.00
Used for Chi-square table value ==>   df (#groups-1) =   5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic - Embarrass / SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	7.25	7.43	7.55	7.72	7.81	7.75	
	Dissolved Oxygen (mg/l)	8.5	8.6	8.5	8.5	8.5	8.6	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/27/10	Conductivity (μmhos)	135					2420	
Analyst:	Total Alkalinity (mg/l)	52					384	
KM	Total Hardness (mg/l)	80					1288	
	Total Ammonia (mg/l)							
Day: 1 OLD	pH	7.95	8.24	8.37	8.53	8.63	8.69	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.3	8.2	8.3	8.4	
Date:	Temperature (°C)	25.3	25.3	25.3	25.5	25.3	25.3	
10/28/10	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.30	7.57	7.68	7.79	7.84	7.74	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.6	8.6	8.5	8.5	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/28/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 2 Old	pH	7.88	8.20	8.34	8.52	8.63	8.67	
	Dissolved Oxygen (mg/l)	8.7	8.6	8.6	8.6	8.7	8.6	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
10/29/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 2 New	pH	7.10	7.40	7.57	7.77	7.86	7.80	
	Dissolved Oxygen (mg/l)	9.3	9.3	9.2	9.2	9.2	9.2	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/29/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							

Reviewed by: Walter Ford   Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic - Embarrass R. / SD033	Species: C. dubia

Day/Date/Analyst	Parameter	0	12.5	25	50	75	100	Remarks
		Concentration						
Day: 3 OLD	pH	7.97	8.18	8.35	8.54	8.64	8.65	
	Dissolved Oxygen (mg/l)	8.4	8.4	8.3	8.3	8.3	8.3	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.32	7.48	7.63	7.80	7.84	7.82	
	Dissolved Oxygen (mg/l)	9.1	9.1	9.1	9.0	9.0	9.2	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.94	8.13	8.32	8.51	8.61	8.69	
	Dissolved Oxygen (mg/l)	8.1	8.0	8.0	8.0	8.0	8.0	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	7.20	7.39	7.60	7.78	7.86	7.80	
	Dissolved Oxygen (mg/l)	8.7	8.7	8.8	8.8	8.8	9.2	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	7.98	8.17	8.30	8.49	8.60	8.73	
	Dissolved Oxygen (mg/l)	8.1	8.0	7.9	7.9	8.0	8.3	
Date: 11/1/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kount   Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymer	Project Number: 10.234
Test Type: Chronic- Embarrass R/SD033	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 NEW	pH	7.46	7.60	7.73	7.92	7.96	7.85	
	Dissolved Oxygen (mg/l)	8.6	8.7	8.7	8.6	8.6	8.6	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
11/01/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 OLD	pH	7.98	8.19	8.31	8.54	8.69	8.73	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.2	8.3	8.4	8.5	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.5	25.3	
11/2/10	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	7.04	7.29	7.54	7.74	7.84	7.82	
	Dissolved Oxygen (mg/l)	9.1	9.2	9.3	9.1	9.0	8.9	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
11/2/10	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 FINAL	pH	8.00	8.16	8.37	8.57	8.66	8.69	
	Dissolved Oxygen (mg/l)	7.9	7.9	7.8	7.9	7.9	7.9	
Date:	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
11/3/10	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kvent   Date: 11/6/10

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet- Partridge/SD026 Project No.: 10-234
Test Dates/~~Time~~ • Initiation: 1525 10/27/10 Termination: 1100 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	4	3	4	2	4	3	4	4	3	
	5	8	8	9	9	6	6	6	7	8	8	
	6	0	10	0	11	11	10	10	0	0	12	
	7	13	0	10	0	0	0	0	10	14	0	
Total		25	22	22	24	19	20	19	21	26	23	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	4	1	0	3	4	5	4	0	3	
	5	6	7	7	8	6	6	10	9	7	7	
	6	10	10	10	12	10	0	0	12	9	0	
	7	0	0	0	0	0	12	14	0	16	11	
Total		18	21	18	20	19	22	29	25	32	21	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	0	4	0	2	3	3	2	4	4	
	5	7	7	9	8	6	6	6	10	8	10	
	6	9	10	0	14	12	9	0	0	12	12	
	7	0	0	12	0	0	0	1	14	0	0	
Total		19	17	25	22	20	18	10	26	24	26	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: Km Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet – Partridge / SD026 Project No.: 10-234

Test Dates/Time ● Initiation: 1525 10/27/10 Termination: 1100 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	3	2	3	3	4	3	3	4	3	
	5	5	7	7	7	6	5	7	6	7	8	
	6	10	0	12	10	12	0	0	0	11	0	
	7	0	9	0	0	0	12	9	9	0	10	
Total		19	19	21	20	21	21	19	18	22	21	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	1	3	4	3	2	4	4	2	0	3	
	5	8	5	7	7	9	6	5	6	7	7	
	6	0	8	0	10	8	10	8	10	10	0	
	7	12	0	8	0	0	0	0	0	0	11	
Total		21	16	19	20	19	20	17	18	17	21	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	3	2	0	0	
	4	3	3	4	3	2	4	0	0	2	4	
	5	4	6	9	6	6	8	7	6	7	6	
	6	0	10	11	8	11	9	8	6	11	9	
	7	8	0	0	0	0	0	0	0	0	0	
Total		15	19	24	17	19	21	18	14	20	19	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	25	18	19	19	21	15
Response 2	22	21	17	19	16	19
Response 3	22	18	25	21	19	24
Response 4	24	20	22	20	20	17
Response 5	19	19	20	21	19	19
Response 6	20	22	18	21	20	21
Response 7	19	29	10	19	17	18
Response 8	21	25	26	18	18	14
Response 9	26	32	24	22	17	20
Response 10	23	21	26	21	21	19

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Partridge SD026
Test Start Date: 10/27/10 Test Ending Date: 11/3/10
Test Species: Ceriodaphnia dubia
Test Duration: 7 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	22.100	2.424	22.300
2	10	12.500	22.500	4.743	22.300
3	10	25.000	20.700	5.012	20.700
4	10	50.000	20.100	1.287	20.100
5	10	75.000	18.800	1.751	18.800
6	10	100.000	18.600	2.875	18.600

*** No Linear Interpolation Estimate can be calculated from the input data since none of the (possibly pooled) group response means were less than 75% of the control response mean.

Ceriodaphnia reproduction
File: Partridge SD026 Transform: NO TRANSFORMATION

STEELS MANY-ONE RANK TEST - Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	RANK SUM	CRIT. VALUE	df	SIG
1	0	22.100				
2	12.5	22.500	99.00	75.00	10.00	
3	25	20.700	98.50	75.00	10.00	
4	50	20.100	79.50	75.00	10.00	
5	75	18.800	69.00	75.00	10.00	*
6	100	18.600	71.50	75.00	10.00	*

Critical values use k = 5, are 1 tailed, and alpha = 0.05

Ceriodaphnia reproduction
File: Partridge SD026   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	4	16	19	18	3

Calculated Chi-Square goodness of fit test statistic =   1.9142
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: Partridge SD026   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic =   22.31
Table Chi-square value =   15.09 (alpha = 0.01)
Table Chi-square value =   11.07 (alpha = 0.05)

Average df used in calculation ==>   df (avg n - 1) =   9.00
Used for Chi-square table value ==>   df (#groups-1) =   5

Data FAIL homogeneity test at 0.01 level. Try another transformation.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic- Partridge / SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	7.80	7.94	7.98	8.00	8.02	7.95	
	Dissolved Oxygen (mg/l)	9.1	9.0	8.9	8.8	8.6	8.8	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
~~18~~ 10/27/10	Conductivity (μmhos)	336					1125	
Analyst:	Total Alkalinity (mg/l)	72					504	
WK	Total Hardness (mg/l)	156					608	
	Total Ammonia (mg/l)							
Day: 1 Old	pH	8.13	8.37	8.51	8.66	8.75	8.63	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.3	8.3	8.3	8.4	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
10/28/10	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.79	8.00	8.02	8.03	8.01	7.98	
	Dissolved Oxygen (mg/l)	9.0	8.9	8.8	8.7	8.6	8.6	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/28/10	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
WK	Total Hardness (mg/l)							
Day: 2 Old	pH 8.02	~~7.84~~	8.31	8.46	8.65	8.74	8.69	
	Dissolved Oxygen (mg/l)	8.5	8.3	8.3	8.4	8.4	8.6	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
10/29/10	Conductivity (μmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	7.92	7.99	8.08	8.12	8.12	7.96	
	Dissolved Oxygen (mg/l)	9.5	9.5	9.5	9.4	9.3	9.2	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
10/29/10	Conductivity (μmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Koenst Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic - Partridge R./SD024	Species: C.dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	8.10	8.35	8.48	8.64	8.71	8.59	
	Dissolved Oxygen (mg/l)	8.4	8.4	8.3	8.3	8.3	8.3	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.78	7.92	8.00	8.00	8.02	7.99	
	Dissolved Oxygen (mg/l)	9.3	9.3	9.2	9.1	9.1	9.2	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 Old	pH	8.07	8.33	8.48	8.65	8.76	8.62	
	Dissolved Oxygen (mg/l)	8.1	8.0	8.0	8.0	8.0	7.9	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	7.83	8.03	8.12	8.15	8.17	8.09	
	Dissolved Oxygen (mg/l)	9.1	9.1	9.0	8.7	8.4	8.2	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	8.10	8.35	8.43	8.63	8.70	8.64	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.1	8.2	
Date: 11/1/10	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kort [signature]

Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10. 234
Test Type: Chronic. Partridge R/ SD026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration						Remarks
		0	12.5	25	50	75	100	
Day: 5 NEW	pH	7.87	8.00	8.06	8.10	8.09	8.15	
	Dissolved Oxygen (mg/l)	8.9	8.9	8.9	8.8	8.8	8.4	
Date: 11 / 01 / 10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 OLD	pH	8.11	8.37	8.51	8.69	8.77	8.65	
	Dissolved Oxygen (mg/l)	8.9	8.8	8.5	8.5	8.5	8.5	
Date: 11 / 2 /10	Temperature (°C)	25.3	25.5	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	7.81	8.10	8.16	8.19	8.18	8.14	
	Dissolved Oxygen (mg/l)	9.2	9.2	9.1	8.9	8.8	8.7	
Date: 11 / 2 / 10	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 FINAL	pH	8.13	8.39	8.57	8.70	8.74	8.62	
	Dissolved Oxygen (mg/l)	7.9	7.9	7.9	7.9	7.8	8.0	
Date: 11 / 3 /10	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Date: 11/6/10

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet Project No.: 10-234
Test Dates/Time ● Initiation: 1455 10/27/10 Termination: 1110 11/3/10

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	3	4	3	3	4	4	4	4	4	
	5	5	7	5	7	4	8	7	6	6	6	
	6	0	12	6	8	10	0	0	0	0	10	
	7	10	0	0	0	0	9	6	8	8	0	
Total		17	22	15	18	17	21	17	18	18	20	$\bar{x}$ = 18.3
PM 12.1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	0	0	0	0	3	0	0	0	0	
	4	0	4	4	4	4	0	4	1	2	0	
	5	7	6	8	5	8	7	7	7	6	8	
	6	11	12	10	4	0	8	0	8	9	10	
	7	0	0	0	0	10	0	10	0	0	12	
total		22	22	22	13	22	18	21	16	17	30	$\bar{x}$ = 20.3
PM 17	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	2	2	0	0	0	2	0	0	0	
	4	0	0	0	3	4	2	0	3	3	1	
	5	7	8	8	7	7	6	8	6	7	6	
	6	11	12	10	11	12	12	12	0	11	12	
	7	0	0	0	0	0	0	0	10	0	0	
total		20	22	20	21	23	20	22	19	21	19	$\bar{x}$ = 20.7

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: Km Reviewed By: [signature]

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	PM 12.1	PM 17	Remarks
Day: 0	pH	8.05	8.07	8.09	
	Dissolved Oxygen (mg/l)	8.0	8.4	8.3	
Date: 10/27/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)	286	876	1116	
Analyst: Km	Total Alkalinity (mg/l)	88	180	354	
	Total Hardness (mg/l)	92	408	632	
	Total Ammonia (mg/l)				
Day: 1 old	pH	8.00	8.48	8.71	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.3	
Date: 10/28/10	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 1 New	pH	7.95	8.14	8.24	
	Dissolved Oxygen (mg/l)	8.2	8.4	8.4	
Date: 10/28/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 old	pH	7.98	8.44	8.70	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.4	
Date: 10/29/10	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 New	pH	8.02	8.08	8.18	
	Dissolved Oxygen (mg/l)	8.5	9.0	9.2	
Date: 10/29/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Koenst   Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 10-234
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	PM 12.1	PM 17	Remarks
Day: 3 old	pH	8.06	8.44	8.68	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.4	
Date: 10/30/10	Temperature (°C)	25.2	25.2	25.2	
	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 3 New	pH	8.01	8.14	8.20	
	Dissolved Oxygen (mg/l)	8.4	9.0	9.0	
Date: 10/30/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 OLD	pH	8.06	8.53	8.68	
	Dissolved Oxygen (mg/l)	8.1	8.0	8.1	
Date: 10/31/10	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 New	pH	8.12	8.09	8.20	
	Dissolved Oxygen (mg/l)	8.1	9.0	9.1	
Date: 10/31/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: Km	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 5 OLD	pH	8.13	8.46	8.69	
	Dissolved Oxygen (mg/l)	8.4	8.0	8.0	
Date: 11/1/10	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: WK.	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kreed Date: 11/6/10

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 10-234
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	PM 12.1	PM 17	Remarks
Day: 5 NEW	pH	8.20	8.07	8.13	
	Dissolved Oxygen (mg/l)	8.2	8.6	8.6	
Date: 11/01/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 6 old	pH	8.09	8.50	8.74	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.5	
Date: 11/2/10	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 6 New	pH	8.12	7.86	7.87	
	Dissolved Oxygen (mg/l)	8.5	9.3	9.3	
Date: 11/2/10	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 7 FINAL	pH	8.09	8.50	8.71	
	Dissolved Oxygen (mg/l)	8.1	8.0	8.0	
Date: 11/3/10	Temperature (°C)	25.1	25.1	25.1	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date: / /	Temperature (°C)				
	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kord Date: 11/6/10

Appendix 5-F3

WET Test Results, June 2011, Report 11-145

TOXICITY TEST RESULTS

POLYMET MINING

Report Date: June 16, 2011

Project No. 11-145

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.637 g/l NaCl	05/27/11

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

Table 1. Survival and Reproduction of *Ceriodaphnia dubia*.

Test: Reconstituted Water/SD033		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	19.2
12.5%	100	13.6
25%	100	15.4
50%	100	14.4
75%	100	12.0
100%	100	8.0
IC25		50.0%
NOEC	100%	<12.5%
TUc		2.0

Test: Reconstituted Water/SD026		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	19.2
12.5%	100	18.8
25%	100	17.6
50%	100	16.2
75%	100	15.0
100%	100	11.4
IC25		79.2%
NOEC	100%	50%
TUc		1.26

Table 1(Continued). Survival and Reproduction of *Ceriodaphnia dubia*.

Test: Reconstituted Water/Bear Creek		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	19.2
12.5%	100	18.4
25%	100	19.3
50%	100	20.1
75%	100	20.5
100%	100	22.6
IC25		>100%
NOEC	100%	100%
TUc		<1.0

Test: Embarrass River/SD033		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	19.1
12.5%	100	20.3
25%	100	17.7
50%	90	18.6
75%	100	17.8
100%	100	8.0
IC25		82.7%
NOEC	100%	75%
TUc		1.21

Table 1(Continued). Survival and Reproduction of *Ceriodaphnia dubia*.

Test: Partridge River/SD026		
Concentration (%)	**% Survival**	**Mean # of Young Produced**
Control	100	18.0
12.5%	100	16.8
25%	100	18.3
50%	100	21.5
75%	100	18.5
100%	100	11.4
IC25		90.9%
NOEC	100%	75%
TUc		1.10

Screen Test: Spring Mine Creek, PM 17		
Sample ID	**% Survival**	**Mean # of Young Produced**
Control	100	19.2
Spring Mine Creek	100	13.7
PM 17	100	13.3

Table 2. **Summary of Chemical and Physical Data of Toxicity Tests**

Test: Reconstituted Water/SD033						
% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.97 - 8.50	8.0 - 8.4	25	88	60	306
12.5	8.08 - 8.31	7.9 - 8.4	25			
25	8.11 - 8.43	8.0 - 8.6	25			
50	8.10 - 8.56	7.9 - 8.9	25			
75	8.08 - 8.64	7.8 - 9.2	25			
100	8.03 - 8.73	7.8 - 10.0	25	1176	352	2210

Test: Reconstituted Water/SD026						
% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.97 - 8.50	8.0 - 8.4	25	88	60	306
12.5	8.07 - 8.39	8.0 - 8.5	25			
25	8.04 - 8.51	7.8 - 8.5	25			
50	8.00 - 8.66	7.8 - 9.0	25			
75	7.99 - 8.75	7.9 - 9.2	25			
100	7.92 - 8.69	7.9 - 9.9	25	572	448	1059

Test: Reconstituted Water/Bear Creek						
% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.97 - 8.50	8.0 - 8.4	25	88	60	306
12.5	7.96 - 8.18	7.9 - 8.5	25			
25	7.75 - 8.09	7.9 - 8.6	25			
50	7.41 - 8.02	7.8 - 8.8	25			
75	7.25 - 7.96	7.8 - 8.9	25			
100	6.96 - 7.89	7.8 - 9.6	25	44	40	82

Table 2 (Continued). **Summary of Chemical and Physical Data of Toxicity Tests**

Test: Embarrass River/SD033

% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	6.69 - 7.81	7.8 - 9.3	25	48	44	71
12.5	7.19 - 8.01	7.8 - 9.3	25			
25	7.48 - 8.30	7.8 - 9.3	25			
50	7.87 - 8.53	7.8 - 9.4	25			
75	8.03 - 8.64	7.8 - 9.4	25			
100	8.03 - 8.73	7.8 - 10.0	25	1176	352	2210

Test: Partridge River/SD026

% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.41 - 7.93	8.0 - 9.5	25	76	44	144
12.5	7.78 - 8.22	8.0 - 9.4	25			
25	7.92 - 8.38	7.9 - 9.5	25			
50	7.99 - 8.66	7.8 - 9.5	25			
75	8.02 - 8.75	7.8 - 9.5	25			
100	7.92 - 8.69	7.9 - 9.9	25	572	448	1059

Screen Test: Spring Mine Creek, PM 17

% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.97 - 8.50	8.0 - 8.4	25	88	60	306
Spring Mine Cr.	7.60 - 8.37	7.9 - 9.8	25	312	128	684
PM 17	7.98 - 8.62	7.8 - 9.8	25	888	280	1459

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon | SD033 Project No.: 11-145

Test Dates/Time ● Initiation: 1115 6/3/11 Termination: 0900 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	3	3	2	3	3	2	2	4	
	4	6	6	6	0	6	0	0	6	6	0	
	5	10	9	0	6	0	7	7	0	0	6	
	6	0	0	12	9	12	14	10	13	12	7	
Total		16	15	21	18	20	24	20	21	20	17	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	0	0	1	0	0	3	0	0	2	
	4	0	3	4	6	4	6	0	6	4	6	
	5	5	7	0	0	6	6	6	4	7	0	
	6	10	0	7	8	0	0	13	0	0	10	
Total		17	10	11	15	10	12	22	10	11	18	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	3	0	4	3	3	0	0	3	0	
	4	0	0	6	6	0	0	1	3	0	5	
	5	7	0	9	0	6	7	3	5	5	8	
	6	9	10	0	9	11	6	8	0	10	0	
Total		20	13	15	19	20	16	12	8	18	13	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM / WK Reviewed By: WK

Bio.105

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon / SD033 Project No.: 11-145

Test Dates/Time • Initiation: 1115 6/3/11 Termination: 0900 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	0	0	2	2	0	3	2	0	3	
	4	0	4	5	0	5	7	0	4	4	6	
	5	6	8	5	4	0	10	5	0	6	0	
	6	8	0	0	6	7	0	8	11	0	9	
Total		18	12	10	12	14	17	16	17	10	18	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	2	2	4	2	0	0	3	0	0	
	4	0	4	6	0	4	4	4	0	5	7	
	5	3	0	0	5X	0	6	6	4	6	0	
	6	7	9	6		7	0	0	9	0	5	
Total		10	15	14	9	13	10	10	16	11	12	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	1	0	0	0	0	0	0	0	2	0	
	4	0	0	3	2	0	3	2	4	0	2	
	5	4	3	5	5	3	4	3	4	4	3	
	6	9	8	0	0	4	0	0	0	2	0	
Total		14	11	8	7	7	7	5	8	8	5	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM / WK Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	16	17	20	18	10	14
Response 2	15	10	13	12	15	11
Response 3	21	11	15	10	14	8
Response 4	18	15	19	12	9	7
Response 5	20	10	20	14	13	7
Response 6	24	12	16	17	10	7
Response 7	20	22	12	16	10	5
Response 8	21	10	8	17	16	8
Response 9	20	11	18	10	11	8
Response 10	17	18	13	18	12	5

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Recon/SDO33
Test Start Date: 6/3/11 Test Ending Date: 6/9/11
Test Species: Ceriodaphnia dubia
Test Duration: 6 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	19.200	2.700	19.200
2	10	12.500	13.600	4.195	14.500
3	10	25.000	15.400	3.950	14.500
4	10	50.000	14.400	3.204	14.400
5	10	75.000	12.000	2.404	12.000
6	10	100.000	8.000	2.708	8.000

The Linear Interpolation Estimate: 50.0000 Entered P Value: 25

Number of Resamplings: 80
The Bootstrap Estimates Mean: 30.2622 Standard Deviation: 20.1528
Original Confidence Limits: Lower: 9.8763 Upper: 59.1994
Resampling time in Seconds: 0.06 Random_Seed: 42286686

Ceriodaphnia reproduction
File: RECON SD033 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	689.933	137.987	12.964
Within (Error)	54	574.800	10.644	
Total	59	1264.733		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: RECON SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	19.200	19.200		
2	12.5	13.600	13.600	3.838	*
3	25	15.400	15.400	2.604	*
4	50	14.400	14.400	3.290	*
5	75	12.000	12.000	4.935	*
6	100	8.000	8.000	7.676	*

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: RECON SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.370	17.6	5.600
3	25	10	3.370	17.6	3.800
4	50	10	3.370	17.6	4.800
5	75	10	3.370	17.6	7.200
6	100	10	3.370	17.6	11.200

Ceriodaphnia reproduction
File: RECON SD033 Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	2	20	19	15	4

Calculated Chi-Square goodness of fit test statistic = 3.7696
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: RECON SD033 Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 4.43
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Recon / SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.03	8.08	8.11	8.10	8.08	8.03	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.5	8.7	9.0	9.9	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)	306					2210	
Analyst: KM	Total Alkalinity (mg/l)	60					352	
	Total Hardness (mg/l)	88					1176	
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.14	8.28	8.39	8.51	8.59	8.64	
	Dissolved Oxygen (mg/l)	8.3	8.1	8.1	8.1	8.1	8.1	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	8.16	8.15	8.14	8.11	8.11	8.04	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.4	8.5	8.8	9.5	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	8.19	8.31	8.43	8.56	8.64	8.73	
	Dissolved Oxygen (mg/l)	8.0	7.9	8.0	7.9	7.8	7.8	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.22	8.23	8.22	8.18	8.15	8.10	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.3	8.6	8.9	9.8	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Ford   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic-Recon/SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 Old	pH	8.04	8.19	8.30	8.43	8.53	8.64	
	Dissolved Oxygen (mg/l)	8.3	8.1	8.0	8.0	7.9	7.9	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.19	8.21	8.22	8.20	8.17	8.13	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.3	8.4	8.6	9.1	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.97	8.09	8.27	8.44	8.53	8.60	
	Dissolved Oxygen (mg/l)	8.3	8.1	8.1	8.0	8.0	8.0	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.14	8.24	8.20	8.20	8.17	8.14	
	Dissolved Oxygen (mg/l)	8.4	8.4	8.6	8.9	9.2	10.0	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	7.97	8.13	8.23	8.43	8.53	8.62	
	Dissolved Oxygen (mg/l)	8.2	8.0	8.0	8.0	8.1	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Ferrant Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Recon | SD033	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration						Remarks
		0	12.5	25	50	75	100	
Day: 5 New	pH	8.22	8.25	8.20	8.15	8.12	8.09	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.5	8.6	9.0	9.4	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 final	pH	8.50	8.21	8.35	8.43	8.57	8.67	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.1	8.0	8.0	8.1	
Date: 6/~~8~~9/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kount   Date: 6/13/11

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon | SD026 Project No.: 11-145
Test Dates/Time ● Initiation: 1125 6/3/11 Termination: 0915 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	3	3	2	3	3	2	2	4	
	4	6	6	6	0	6	0	0	6	6	0	
	5	10	9	0	6	0	7	7	0	0	6	
	6	0	0	12	9	12	14	10	13	12	7	
Total		16	15	21	18	20	24	20	21	20	17	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	2	2	3	1	0	0	3	4	4	
	4	0	6	6	5	4	5	4	6	0	6	
	5	7	0	0	0	0	9	8	0	3	0	
	6	12	10	12	14	12	1	0	12	12	12	
Total		22	18	20	22	17	15	12	21	19	22	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	~~8~~ 1 WK	2	4	0	4	0	3	0	3	
	4	0	3	0	6	4	4	6	0	7	6	
	5	6	0	2	0	8	0	6	5	0	0	
	6	8	14	15	14	0	11	0	11	9	12	
Total		16	18	19	24	12	19	12	19	16	21	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM/WK Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon | SD026 Project No.: 11-145
Test Dates/Time • Initiation: 1125 6/3/11 Termination: 0915 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	3	2	0	2	4	0	2	3	
	4	0	5	5	4	4	5	0	5	7	6	
	5	7	0	0	0	7	0	6	6	6	0	
	6	9	7	12	3	0	13	12	0	0	9	
Total		20	16	20	9	11	20	22	11	15	18	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	2	4	0	3	4	4	3	2	
	4	0	5	0	0	4	0	0	0	2	0	
	5	6	8	5	7	5	7	4	5	0	6	
	6	10	0	2	10	0	9	10	7	10	3	
Total		19	13	9	21	9	19	18	16	15	11	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	3	0	0	2	0	3	2	0	
	4	4	2	0	4	2	0	3	0	0	4	
	5	8	0	6	5	3	6	3	6	4	6	
	6	0	7	7	0	0	9	0	7	4	0	
Total		12	13	16	9	5	17	6	16	10	10	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: Km / WK Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	16	22	16	20	19	12
Response 2	15	18	18	16	13	13
Response 3	21	20	19	20	9	16
Response 4	18	22	24	9	21	9
Response 5	20	17	12	11	9	5
Response 6	24	15	19	20	19	17
Response 7	20	12	12	22	18	6
Response 8	21	21	19	11	16	16
Response 9	20	19	16	15	15	10
Response 10	17	22	21	18	11	10

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Recon/SD026
Test Start Date: 6/3/11 Test Ending Date: 6/9/11
Test Species: Ceriodaphnia dubia
Test Duration: 6 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	19.200	2.700	19.200
2	10	12.500	18.800	3.360	18.800
3	10	25.000	17.600	3.748	17.600
4	10	50.000	16.200	4.566	16.200
5	10	75.000	15.000	4.346	15.000
6	10	100.000	11.400	4.169	11.400

The Linear Interpolation Estimate: 79.1667 Entered P Value: 25

Number of Resamplings: 80
The Bootstrap Estimates Mean: 76.0246 Standard Deviation: 10.1619
Original Confidence Limits: Lower: 50.4808 Upper: 89.8077
Resampling time in Seconds: 0.06 Random_Seed: 349432308

Ceriodaphnia reproduction
File: RECON SD026 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	420.333	84.067	5.621
Within (Error)	54	807.600	14.956	
Total	59	1227.933		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: RECON SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	19.200	19.200		
2	12.5	18.800	18.800	0.231	
3	25	17.600	17.600	0.925	
4	50	16.200	16.200	1.735	
5	75	15.000	15.000	2.428	*
6	100	11.400	11.400	4.510	*

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: RECON SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.995	20.8	0.400
3	25	10	3.995	20.8	1.600
4	50	10	3.995	20.8	3.000
5	75	10	3.995	20.8	4.200
6	100	10	3.995	20.8	7.800

Ceriodaphnia reproduction
File: RECON SD026 Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	4	13	23	18	2

Calculated Chi-Square goodness of fit test statistic = 2.0086
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: RECON SD026 Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 3.00
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 11-145
Test Type: Chronic- Recon / SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.03	8.07	8.04	8.00	7.99	7.92	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.2	8.3	8.4	8.5	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	306					1059	
Analyst: KM	Total Alkalinity (mg/l)	60					448	
	Total Hardness (mg/l)	88					572	
	Total Ammonia (mg/l)							
Day: 1 Old	pH	8.14	8.34	8.43	8.57	8.63	8.64	
	Dissolved Oxygen (mg/l)	8.3	8.0	8.1	8.1	8.1	8.1	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	8.16	8.15	8.08	8.04	8.01	7.92	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.2	8.4	8.5	9.0	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 Old	pH	8.19	8.39	8.51	8.66	8.75	8.69	
	Dissolved Oxygen (mg/l)	8.0	8.1	8.0	8.0	7.9	7.9	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.22	8.24	8.18	8.10	8.06	8.00	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.2	8.4	8.5	9.1	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kount Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Recon 15D026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	0	12.5	25	50	75	100	Remarks
		Concentration						
Day: 3 Old	pH	8.04	8.31	8.39	8.56	8.65	8.64	
	Dissolved Oxygen (mg/l)	8.3	8.0	7.8	7.8	7.9	7.9	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.19	8.25	8.20	8.16	8.12	8.06	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	8.3	8.4	8.8	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 Old	pH	7.97	8.25	8.36	8.54	8.64	8.61	
	Dissolved Oxygen (mg/l)	8.3	8.5	8.5	8.4	8.3	8.0	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.14	8.19	8.17	8.14	8.12	8.07	
	Dissolved Oxygen (mg/l)	8.4	8.5	8.5	9.0	9.2	9.9	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	7.97	8.20	8.33	8.50	8.59	8.54	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	8.1	8.1	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kourt

Date: 6/15/11

Toxicity Test
Daily Chemistries

Client:	Polymet	Project Number:	11-145
Test Type:	Chronic - Recon / SP026	Species:	C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	8.22	8.18	8.13	8.09	8.07	8.02	
	Dissolved Oxygen (mg/l)	8.3	8.4	8.4	8.5	8.6	8.7	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	8.50	8.34	8.42	8.58	8.68	8.63	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.1	8.1	8.0	8.0	
Date: 6/9/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kraut   Date: 6/15/11

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Recon | Bear Creek Project No.: 11-145
Test Dates/~~Time~~ ● Initiation: 1135 6/3/11 Termination: 0930 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	3	3	3	3	3	3	3	4	
	4	6	6	6	0	6	0	0	6	6	0	
	5	10	9	0	6	0	7	7	0	0	6	
	6	0	0	12	9	12	14	10	13	12	7	
Total		16	15	21	18	20	24	20	21	20	17	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	4	3	2	4	4	0	4	2	
	4	6	7	0	6	6	0	0	4	4	6	
	5	10	0	7	0	8	8	6	4	0	0	
	6	0	11	8	14	0	8	13	0	13	8	
Total		16	22	19	23	16	20	23	8	21	16	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	4	3	4	3	3	4	2	0	
	4	4	7	7	9	6	7	0	5	8	5	
	5	7	0	0	0	0	0	7	0	0	10	
	6	0	13	12	11	3	12	10	13	10	0	
Total		11	24	23	23	13	22	20	22	20	15	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM / WK Reviewed By: WK

Bio.105

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Recon/Bear Creek Project No.: 11-145
Test Dates/Time ● Initiation: 1135 6/3/11 Termination: 0930 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	3	4	4	3	3	0	2	5	
	4	8	4	0	8	0	0	0	6	4	0	
	5	0	10	10	0	5	9	8	9	0	11	
	6	12	0	1	9	4	16	10	0	12	16	
Total		23	14	14	21	13	28	21	15	20	32	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	2	0	3	4	4	5	1	2	1	
	4	0	7	5	7	8	0	0	7	8	6	
	5	7	0	8	0	0	6	9	0	0	0	
	6	14	11	0	14	13	3	13	12	10	12	
Total		24	20	13	24	25	13	27	20	20	19	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	3	4	4	2	4	2	4	3	
	4	0	7	7	0	5	6	8	6	3	6	
	5	6	0	0	9	0	0	0	0	0	0	
	6	13	14	14	13	12	12	12	14	12	14	
Total		22	25	24	26	21	20	24	22	19	23	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: km/WK Reviewed By: WK

Ceriodaphnia reproduction
File: RECON BEAR CREEK Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	107.083	21.417	1.091
Within (Error)	54	1059.900	19.628	
Total	59	1166.983		

Critical F value = 2.45 (0.05,5,40)
Since F < Critical F FAIL TO REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: RECON BEAR CREEK Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	19.200	19.200		
2	12.5	18.400	18.400	0.404	
3	25	19.300	19.300	-0.050	
4	50	20.100	20.100	-0.454	
5	75	20.500	20.500	-0.656	
6	100	22.600	22.600	-1.716	

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: RECON BEAR CREEK Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	4.577	23.8	0.800
3	25	10	4.577	23.8	-0.100
4	50	10	4.577	23.8	-0.900
5	75	10	4.577	23.8	-1.300
6	100	10	4.577	23.8	-3.400

Ceriodaphnia reproduction
File: RECON BEAR CREEK   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	6	13	19	19	3

Calculated Chi-Square goodness of fit test statistic = 3.4458
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: RECON BEAR CREEK   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 11.65
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 11-145
Test Type: Chronic - Recon / Bear Creek	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 0	pH	8.03	8.05	7.75	7.41	7.25	6.96	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.1	8.0	7.9	7.9	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	306					82	
Analyst: Km	Total Alkalinity (mg/l)	60					40	
	Total Hardness (mg/l)	88					44	
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.14	8.12	8.04	7.96	7.88	7.68	
	Dissolved Oxygen (mg/l)	8.3	8.1	8.0	8.1	8.1	8.0	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	8.16	8.03	7.81	7.49	7.26	6.97	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.1	8.2	8.2	8.2	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	8.19	8.18	8.09	8.02	7.96	7.89	
	Dissolved Oxygen (mg/l)	8.0	7.9	8.0	8.0	8.0	8.0	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.22	8.16	7.87	7.57	7.35	7.10	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.1	8.2	8.3	8.4	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kowalski [signature]   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Recon/Bear Creek	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	8.04	7.96	7.82	7.69	7.81	7.77	
	Dissolved Oxygen (mg/l)	8.3	7.9	7.9	7.8	7.8	7.8	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.19	8.17	7.95	7.76	7.63	7.25	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	8.3	8.4	8.5	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.97	7.98	7.90	7.90	7.86	7.72	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.3	8.2	8.3	8.2	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.14	8.07	7.80	7.66	7.51	7.20	
	Dissolved Oxygen (mg/l)	8.4	8.5	8.6	8.7	8.9	9.6	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	7.97	8.00	7.90	7.93	7.80	7.70	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.2	8.1	8.1	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kunt Date: 6/15/11

Toxicity Test
Daily Chemistries

Client:	Polymet	Project Number:	11-145
Test Type:	Chronic- Recon / Bear Creek	Species:	C-dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	8.22	8.00	7.90	7.74	7.60	7.40	
	Dissolved Oxygen (mg/l)	8.3	8.5	8.6	8.8	8.9	9.1	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	8.50	8.09	7.99	7.92	7.87	7.83	
	Dissolved Oxygen (mg/l)	8.2	8.1	8.1	8.1	8.2	8.1	
Date: 6/9/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (μmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kovat

Date: 6/15/11

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet - Embarrass River / SD033 Project No.: 11-145
Test Dates/~~Time~~ • Initiation: 1145 6/3/11 Termination: 0945 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	3	2	4	3	1	3	4	2	3	
	4	4	7	5	8	7	5	7	7	6	7	
	5	4	0	0	0	0	0	0	0	0	0	
	6	0	14	4	13	13	9	11	12	10	13	
Total		8	24	11	25	23	15	21	23	18	23	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	3	3	2	4	4	2	2	2	2	
	4	6	9	5	6	0	6	7	6	5	6	
	5	0	0	0	0	6	0	10	8	0	12	
	6	16	13	11	11	5	14	0	1	13	0	
Total		25	25	19	19	15	24	19	17	20	20	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	0	0	3	2	0	0	2	2	
	4	6	6	4	4	6	5	6	7	8	6	
	5	0	9	0	12	0	0	0	0	0	0	
	6	13	0	10	0	12	11	11	10	6	9	
Total		22	19	14	16	21	18	17	17	16	17	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM | WK Reviewed By: WK

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Embarrass River / SD033 Project No.: 11-145
Test Dates/Time ● Initiation: 1145 6/3/11 Termination: 0945 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	4	0	2	2	3	3	0	2	
	4	6	8	4	3	6	3	4	0	4	6	
	5	0	0	0	11	0	0	0	7	9	0	
	6	12	15	11	0	11	11	9	11	0	12	
Total		21	27	19	14	19	16	16	21	13	20	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	2	2	3	2	4	0	0	3	4	
	4	4	6	0	0	0	2	2	0	6	0	
	5	0	10	5	7	6	0	9	4	0	8	
	6	8	0	7	10	13	14	12	7	7	8	
Total		15	18	14	20	21	20	23	11	16	20	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	1	0	0	0	0	0	0	0	2	0	
	4	0	0	3	2	0	3	2	4	0	2	
	5	4	3	5	5	3	4	3	4	4	3	
	6	9	8	0	0	4	0	0	0	2	0	
Total		14	11	8	7	7	7	5	8	8	5	

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: KM / WK Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	8	25	22	21	15	14
Response 2	24	25	19	27	18	11
Response 3	11	19	14	19	14	8
Response 4	25	19	16	14	20	7
Response 5	23	15	21	19	21	7
Response 6	15	24	18	16	20	7
Response 7	21	19	17	16	23	5
Response 8	23	17	17	21	11	8
Response 9	18	20	16	13	16	8
Response 10	23	20	17	20	20	5

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Embarrass River/SD033
Test Start Date: 6/3/11   Test Ending Date: 6/9/11
Test Species: Ceriodaphnia dubia
Test Duration: 6 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	19.100	5.915	19.700
2	10	12.500	20.300	3.368	19.700
3	10	25.000	17.700	2.406	18.150
4	10	50.000	18.600	4.088	18.150
5	10	75.000	17.800	3.706	17.800
6	10	100.000	8.000	2.708	8.000

The Linear Interpolation Estimate: 82.7168   Entered P Value: 25

Number of Resamplings: 80
The Bootstrap Estimates Mean: 79.9222 Standard Deviation: 9.1263
Original Confidence Limits: Lower: 63.9423 Upper: 87.3018
Resampling time in Seconds: 0.06 Random_Seed: 11075006

Ceriodaphnia reproduction
File: EMBARRASS RIVER SD033 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	999.483	199.897	13.342
Within (Error)	54	809.100	14.983	
Total	59	1808.583		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: EMBARRASS RIVER SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	19.100	19.100		
2	12.5	20.300	20.300	-0.693	
3	25	17.700	17.700	0.809	
4	50	18.600	18.600	0.289	
5	75	17.800	17.800	0.751	
6	100	8.000	8.000	6.412	*

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: EMBARRASS RIVER SD033 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	3.999	20.9	-1.200
3	25	10	3.999	20.9	1.400
4	50	10	3.999	20.9	0.500
5	75	10	3.999	20.9	1.300
6	100	10	3.999	20.9	11.100

Ceriodaphnia reproduction
File: EMBARRASS RIVER SD033 Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	4	13	22	18	3

Calculated Chi-Square goodness of fit test statistic = 1.2890
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: EMBARRASS RIVER SD033 Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 9.26
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 11-145
Test Type: Chronic- Embarrass River / SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	0	12.5	25	50	75	100	Remarks
Day: 0	pH	6.73	6.7.23	7.48	7.87	8.05	8.03	
	Dissolved Oxygen (mg/l)	7.8	7.8	8.0	8.4	8.6	9.9	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	71					2210	
Analyst: KM	Total Alkalinity (mg/l)	44					352	
	Total Hardness (mg/l)	48					1176	
	Total Ammonia (mg/l)							
Day: 1 Old	pH	7.76	7.99	8.23	8.48	8.55	8.64	
	Dissolved Oxygen (mg/l)	8.4	8.1	8.1	8.1	8.1	8.1	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	6.69	7.19	7.56	7.92	8.03	8.04	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.4	8.6	8.8	9.5	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 Old	pH	7.67	8.01	8.30	8.53	8.64	8.73	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.1	8.1	8.1	7.8	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	6.85	7.25	7.64	7.94	8.12	8.10	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.5	8.6	8.9	9.8	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Ronds

Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Embarass River / SD033	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	7.74	7.92	8.14	8.36	8.50	8.64	
	Dissolved Oxygen (mg/l)	7.8	7.9	7.8	7.8	7.8	7.9	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	6.98	7.46	7.83	8.10	8.18	8.13	
	Dissolved Oxygen (mg/l)	8.3	8.3	8.4	8.5	8.5	9.1	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.72	7.89	8.11	8.38	8.51	8.60	
	Dissolved Oxygen (mg/l)	8.4	8.3	8.1	8.2	8.0	8.0	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	7.00	7.37	7.80	8.09	8.18	8.14	
	Dissolved Oxygen (mg/l)	9.3	9.3	9.3	9.4	9.4	10.0	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	7.64	7.83	8.10	8.37	8.51	8.62	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.1	8.1	8.1	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kamb   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic- embarrass River / SD033	Species: C-dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	7.22	7.60	7.91	8.09	8.14	8.09	
	Dissolved Oxygen (mg/l)	9.0	9.0	9.0	8.9	9.0	9.4	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	7.81	7.95	8.22	8.47	8.59	8.67	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.3	8.4	8.4	8.1	
Date: 6/9/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kound Date: 6/15/11

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Partridge River | SD026 Project No.: 11-145
Test Dates/~~Time~~ ● Initiation: 1155 6/3/11 Termination: 1015 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	2	2	2	2	4	2	2	3	
	4	6	0	7	5	7	5	7	7	0	0	
	5	0	7	11	0	0	0	0	0	3	7	
	6	12	3	0	11	11	13	10	2	10	10	
Total		21	14	20	18	20	20	21	11	15	20	
12.5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	2	4	3	3	2	4	2	2	2	
	4	4	0	6	7	6	6	7	6	5	5	
	5	0	6	0	0	0	0	0	0	0	0	
	6	12	6	3	10	11	2	11	9	10	10	
Total		18	14	13	20	20	10	22	17	17	17	
25	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	3	0	4	3	4	2	4	1	4	
	4	6	0	3	6	7	7	6	4	6	8	
	5	0	7	7	0	0	0	0	0	0	0	
	6	12	8	0	9	10	9	10	11	9	9	
Total		22	18	10	19	20	20	18	19	16	21	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: KM | WK Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Polymet - Partridge River / SD026 Project No.: 11-145

Test Dates/Time ● Initiation: 1155 6/3/11 Termination: 1015 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
50	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	0	4	3	4	4	4	3	5	4	
	4	6	5	5	0	6	4	5	0	0	8	
	5	0	11	0	10	0	0	0	6	9	0	
	6	10	0	10	12	11	9	15	11	14	12	
Total		19	16	19	25	21	17	24	20	30	24	
75	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	2	4	4	2	2	0	4	4	4	3	
	4	4	0	0	5	0	4	0	6	7	0	
	5	0	9	7	0	4	8	5	0	0	6	
	6	8	13	11	9	9	0	11	13	10	7	
Total		14	26	22	16	15	12	20	23	21	16	
100	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	4	3	0	0	3	0	3	2	0	
	4	4	2	0	4	2	0	3	0	0	4	
	5	8	0	6	5	3	6	3	6	4	6	
	6	0	7	7	0	0	9	0	7	4	0	
Total		12	13	16	9	5	17	6	~~18~~ 16 km	10	10	

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing

(-#) = No. of Dead Young

Analyst: km / WK Reviewed By: WK

Conc. ID	1	2	3	4	5	6
Conc. Tested	0	12.5	25	50	75	100
Response 1	21	18	22	19	14	12
Response 2	14	14	18	16	26	13
Response 3	20	13	10	19	22	16
Response 4	18	20	19	25	16	9
Response 5	20	20	20	21	15	5
Response 6	20	10	20	17	12	17
Response 7	21	22	18	24	20	6
Response 8	11	17	19	20	23	16
Response 9	15	17	16	30	21	10
Response 10	20	17	21	24	16	10

*** Inhibition Concentration Percentage Estimate ***
Toxicant/Effluent: Partridge River/SD026
Test Start Date: 6/3/11 Test Ending Date: 6/9/11
Test Species: Ceriodaphnia dubia
Test Duration: 6 days
DATA FILE:

Conc. ID	Number Replicates	Concentration %	Response Means	Std. Dev.	Pooled Response Means
1	10	0.000	18.000	3.464	18.650
2	10	12.500	16.800	3.615	18.650
3	10	25.000	18.300	3.368	18.650
4	10	50.000	21.500	4.249	18.650
5	10	75.000	18.500	4.528	18.500
6	10	100.000	11.400	4.169	11.400

The Linear Interpolation Estimate: 90.8891 Entered P Value: 25

Number of Resamplings: 80Those resamples not used had estimates above the highest concentration/ %Effluent.

The Bootstrap Estimates Mean: 90.1171 Standard Deviation: 3.0369

No Confidence Limits can be produced since the number of resamples generated is not a multiple of 40.
Resampling time in Seconds: 0.06 Random_Seed: -295203832

Ceriodaphnia reproduction
File: PARTRIDGE RIVER SD026 Transform: NO TRANSFORMATION

ANOVA TABLE

SOURCE	DF	SS	MS	F
Between	5	555.483	111.097	7.218
Within (Error)	54	831.100	15.391	
Total	59	1386.583		

Critical F value = 2.45 (0.05,5,40)
Since F > Critical F REJECT Ho:All groups equal

Ceriodaphnia reproduction
File: PARTRIDGE RIVER SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 1 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	TRANSFORMED MEAN	MEAN CALCULATED IN ORIGINAL UNITS	T STAT	SIG
1	0	18.000	18.000		
2	12.5	16.800	16.800	0.684	
3	25	18.300	18.300	-0.171	
4	50	21.500	21.500	-1.995	
5	75	18.500	18.500	-0.285	
6	100	11.400	11.400	3.762	*

Dunnett table value = 2.31 (1 Tailed Value, P=0.05, df=40,5)

Ceriodaphnia reproduction
File: PARTRIDGE RIVER SD026 Transform: NO TRANSFORMATION

DUNNETTS TEST - TABLE 2 OF 2 Ho:Control<Treatment

GROUP	IDENTIFICATION	NUM OF REPS	Minimum Sig Diff (IN ORIG. UNITS)	% of CONTROL	DIFFERENCE FROM CONTROL
1	0	10			
2	12.5	10	4.053	22.5	1.200
3	25	10	4.053	22.5	-0.300
4	50	10	4.053	22.5	-3.500
5	75	10	4.053	22.5	-0.500
6	100	10	4.053	22.5	6.600

Ceriodaphnia reproduction
File: PARTRIDGE RIVER SD026   Transform: NO TRANSFORMATION

Chi-square test for normality: actual and expected frequencies

INTERVAL	<-1.5	-1.5 to <-0.5	-0.5 to 0.5	>0.5 to 1.5	>1.5
EXPECTED	4.020	14.520	22.920	14.520	4.020
OBSERVED	4	16	16	22	2

Calculated Chi-Square goodness of fit test statistic = 7.1086
Table Chi-Square value (alpha = 0.01) = 13.277

Data PASS normality test. Continue analysis.

Ceriodaphnia reproduction
File: PARTRIDGE RIVER SD026   Transform: NO TRANSFORMATION

Bartletts test for homogeneity of variance

Calculated B statistic = 1.29
Table Chi-square value = 15.09 (alpha = 0.01)
Table Chi-square value = 11.07 (alpha = 0.05)

Average df used in calculation ==> df (avg n - 1) = 9.00
Used for Chi-square table value ==> df (#groups-1) = 5

Data PASS homogeneity test at 0.01 level. Continue analysis.

NOTE: If groups have unequal replicate sizes the average replicate size is used to calculate the B statistic (see above).

Toxicity Test
Daily Chemistries

Client: PolyMet	Project Number: 11-145
Test Type: Chronic- Partridge River / SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	0	12.5	25	50	75	100	Remarks
		Concentration						
Day: 0	pH	7.43	7.78	7.92	7.99	8.02	7.92	
	Dissolved Oxygen (mg/l)	8.5	8.4	8.5	8.4	8.4	8.5	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)	144					1059	
Analyst: WK	Total Alkalinity (mg/l)	44					448	
	Total Hardness (mg/l)	76					572	
	Total Ammonia (mg/l)							
Day: 1 old	pH	7.79	8.18	8.36	8.57	8.66	8.64	
	Dissolved Oxygen (mg/l)	8.2	8.0	8.1	8.1	8.1	8.1	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.41	7.83	7.93	8.03	8.06	7.92	
	Dissolved Oxygen (mg/l)	8.7	8.7	8.7	8.6	8.6	9.0	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	7.85	8.22	8.37	8.66	8.75	8.69	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.0	8.0	8.0	7.9	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	7.64	8.01	8.08	8.15	8.14	8.00	
	Dissolved Oxygen (mg/l)	8.7	8.7	8.8	8.8	8.7	9.1	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kount   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic- Partridge River / SD026	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 3 OLD	pH	7.82	8.13	8.25	8.50	8.61	8.61	
	Dissolved Oxygen (mg/l)	8.0	8.0	7.9	7.8	7.8	7.9	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	25.4	25.4	25.4	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.63	8.05	8.13	8.19	8.17	8.06	
	Dissolved Oxygen (mg/l)	8.6	8.5	8.4	8.4	8.5	8.8	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 OLD	pH	7.77	8.07	8.26	8.52	8.63	8.61	
	Dissolved Oxygen (mg/l)	8.2	8.2	8.1	8.1	8.0	8.0	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	7.63	7.99	8.07	8.13	8.14	8.07	
	Dissolved Oxygen (mg/l)	9.5	9.4	9.5	9.5	9.5	9.9	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 OLD	pH	7.75	8.00	8.21	8.46	8.56	8.54	
	Dissolved Oxygen (mg/l)	8.4	8.1	8.0	8.0	8.0	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (μmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Kound   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic - Partridge River / SD026	Species: C. dubia

Day/Date/Analyst	Parameter	Concentration 0	12.5	25	50	75	100	Remarks
Day: 5 New	pH	7.93	8.13	8.13	8.15	8.13	8.02	
	Dissolved Oxygen (mg/l)	9.0	8.9	8.9	8.8	8.7	8.7	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: WK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	7.88	8.17	8.38	8.60	8.73	8.63	
	Dissolved Oxygen (mg/l)	8.3	8.2	8.2	8.2	8.3	8.0	
Date: 6/9/11	Temperature (°C)	24.9	24.9	24.9	24.9	24.9	24.9	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Krant　　Date: 6/15/11

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: PolyMet Project No.: 11-145

Test Dates/Time ● Initiation: 1200 6/3/11 Termination: 1025 6/9/11

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
Recon.	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	3	3	2	3	3	2	2	4	
	4	6	6	6	0	6	0	0	6	6	0	
	5	10	9	0	6	0	7	7	0	0	6	
	6	0	0	12	9	12	14	10	13	12	7	
Total		16	15	21	18	20	24	20	21	20	17	$\bar{x} = 19.2$
Lower	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Spring	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Mine	3	M	0	2	3	0	2	0	4	2	2	
Creek	4		5	0	6	3	5	0	0	0	4	
	5		8	6	0	5	0	5	6	9	0	
	6		0	6	8	0	8	9	11	0	4	
Total			13	14	17	8	15	14	21	11	10	$\bar{x} = 13.7$
PM17	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	4	3	0	2	3	2	0	0	2	
	4	4	4	6	2	6	5	5	5	4	5	
	5	0	0	0	7	0	0	0	6	8	0	
	6	7	9	8	0	0	7	8	0	0	8	
Total		14	17	17	9	8	15	15	11	12	15	$\bar{x} = 13.3$

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing

(-#) = No. of Dead Young

Analyst: km/WK Reviewed By: WK

Toxicity Test
Daily Chemistries

Client: Paymet	Project Number: 11-145
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration Recon	Lower Spring Mine Creek	PM17	Remarks
Day: 0	pH	8.03	7.65	8.05	
	Dissolved Oxygen (mg/l)	8.3	8.9	8.8	
Date: 6/3/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)	306	684	1459	
Analyst: KM	Total Alkalinity (mg/l)	60	128	280	
	Total Hardness (mg/l)	88	312	888	
	Total Ammonia (mg/l)				
Day: 1 old	pH	8.14	8.35	8.60	
	Dissolved Oxygen (mg/l)	8.3	8.4	8.4	
Date: 6/4/11	Temperature (°C)	25.4	25.4	25.4	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 1 New	pH	8.16	7.65	8.06	
	Dissolved Oxygen (mg/l)	8.2	9.5	9.7	
Date: 6/4/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 old	pH	8.19	8.37	8.62	
	Dissolved Oxygen (mg/l)	8.0	7.9	7.8	
Date: 6/5/11	Temperature (°C)	25.3	25.3	25.3	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 2 New	pH	8.22	7.60	7.98	
	Dissolved Oxygen (mg/l)	8.2	8.9	9.3	
Date: 6/5/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kowal [signature] Date: 6/15/11

Toxicity Test
Daily Chemistries

Client: Polymet	Project Number: 11-145
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Concentration: Recon	Concentration: Lower Spring Mine Creek	Concentration: PM17	Remarks
Day: 3 OLD	pH	8.04	8.25	8.53	
	Dissolved Oxygen (mg/l)	8.3	7.9	7.9	
Date: 6/6/11	Temperature (°C)	25.4	25.4	25.4	
	Conductivity (µmhos)				
Analyst: WK.	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 3 New	pH	8.19	7.95	8.21	
	Dissolved Oxygen (mg/l)	8.2	8.7	8.6	
Date: 6/6/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: SW	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 OLD	pH	7.97	8.24	8.56	
	Dissolved Oxygen (mg/l)	8.3	7.9	8.0	
Date: 6/7/11	Temperature (°C)	25.2	25.2	25.2	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 4 New	pH	8.14	7.95	8.14	
	Dissolved Oxygen (mg/l)	8.4	9.8	9.8	
Date: 6/7/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day: 5 OLD	pH	7.97	8.18	8.51	
	Dissolved Oxygen (mg/l)	8.2	7.9	8.1	
Date: 6/8/11	Temperature (°C)	24.9	24.9	24.9	
	Conductivity (µmhos)				
Analyst: WK.	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kornd   Date: 6/15/11

Toxicity Test
Daily Chemistries

Client:	Polymet	Project Number:	11-145
Test Type:	Chronic	Species:	C. dubia

Day/Date/Analyst	Parameter	Concentration			Remarks
		Recon	Lower Spring Mine Creek	PM17	
Day: 5 New	pH	8.23	8.06	8.21	
	Dissolved Oxygen (mg/l)	8.3	8.9	9.0	
Date: 6/8/11	Temperature (°C)	25.0	25.0	25.0	
	Conductivity (µmhos)				
Analyst: WK	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
	Total Ammonia (mg/l)				
Day: 6 Final	pH	8.50	8.36	8.57	
	Dissolved Oxygen (mg/l)	8.2	8.3	8.1	
Date: 6/9/11	Temperature (°C)	24.9	24.9	24.9	
	Conductivity (µmhos)				
Analyst: KM	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date: / /	Temperature (°C)				
	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date: / /	Temperature (°C)				
	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				
Day:	pH				
	Dissolved Oxygen (mg/l)				
Date: / /	Temperature (°C)				
	Conductivity (µmhos)				
Analyst:	Total Alkalinity (mg/l)				
	Total Hardness (mg/l)				

Reviewed by: Walter Kount   Date: 6/15/11