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APPENDICES

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Appendix 2  Site 23/D 2010 As-built and Cross Sections
Appendix 3  Data Graphs
Appendix 4  Site Photographs
1.0 Executive Summary

This annual report has been prepared by Greens Creek Mining Company in accordance with Alaska Waste Disposal Permit 0211-BA001 and the mine’s General Plan of Operations Appendices 3 and 11. The following itemized list summarizes key information and indicates where in this report the information outlined in Section 6.2 of Permit 0211-BA001 is presented:

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<th>Report Section</th>
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</thead>
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<td>6.2.1 Closure plan summary</td>
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<td>Precipitation</td>
<td>2.4, 3.4</td>
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<td>Mill Site 59.4” Tailings 36.4”</td>
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<tr>
<td>Summary of internal monitoring and fresh water monitoring plans</td>
<td>2.5, 3.5</td>
</tr>
<tr>
<td>FWMP annual report separate for water year 2010 as per the ADEC request for full data presentation.</td>
<td></td>
</tr>
<tr>
<td>Internal monitoring water compositions at both sites dominated by Ca, Mg, SO₄, neutral pH, high alkalinity, high zinc, low to moderate concentrations of other metals. Data are consistent with sulfide oxidation and carbonate mineral buffering. Sulfate reduction in saturated zone of tailings pile yields low concentrations of all metals. Concentration of As continues higher in some tailings wells due to migration of redox boundary. Seasonal compositional fluctuations continue evident in most wells/drains.</td>
<td></td>
</tr>
<tr>
<td>Stability</td>
<td>2.3, 3.3</td>
</tr>
<tr>
<td>Stability monitoring at the Tailings facility and Site 23 indicate that that sites meet design specifications. Foundation heads are consistently low at both sites except for short-lived spikes in one piezometer (north end of West Buttress).</td>
<td></td>
</tr>
<tr>
<td>Cover performance</td>
<td>3.8</td>
</tr>
<tr>
<td>&gt;85% saturation maintained, barrier layer not subject to freeze/thaw cycles. Net measured “percolation” up to 19%. Oregon State University studies are ongoing to help better understand cover water characteristics. Lateral flows are being analyzed within cover.</td>
<td></td>
</tr>
<tr>
<td>Pond D flow and composition</td>
<td>3.4, 3.5</td>
</tr>
<tr>
<td>Average flow pumped from Pond D is about 60 gpm, similar composition to dilute Site 23 finger drains (e.g. 23FD-3 and 23FD-6).</td>
<td></td>
</tr>
<tr>
<td>Summary of inspections</td>
<td>2.3, 3.3</td>
</tr>
<tr>
<td>Inspections confirm compliance with WMP and GPO guidelines at both sites.</td>
<td></td>
</tr>
<tr>
<td>6.2.2 Summary of inspections</td>
<td>2.3, 3.3</td>
</tr>
<tr>
<td>Summarized above</td>
<td></td>
</tr>
<tr>
<td>Monitoring results</td>
<td>2.3, 3.3</td>
</tr>
<tr>
<td>Summarized above</td>
<td></td>
</tr>
<tr>
<td>6.2.3 Changes to GPO in 2010</td>
<td>2.5, 3.5</td>
</tr>
<tr>
<td>GPO’s are currently being updated as part of the ADEC Waste Management Permit renewal</td>
<td></td>
</tr>
<tr>
<td>6.2.5 Location and volume of materials</td>
<td>2.2, 3.2</td>
</tr>
<tr>
<td>Northwest Tailings area 402,855 total tons in 2010 (tailings 266,983 and other materials 135,872 tons)</td>
<td></td>
</tr>
<tr>
<td>Site 23 20,430 total tons placed in 2010</td>
<td></td>
</tr>
</tbody>
</table>
Compaction
  Target compaction densities achieved in nuclear density tests.
Acid Base Accounting
  Potentially acid generating Class 3 production rock
  Neutralization potential values continue to demonstrate long lag time
  (buffering capacity)
  Class 1 production rock is significantly acid neutralizing (about 36% carbonate)
Possible water releases
  No new signs of possible release were identified in 2010
6.2.4 Information regarding validity, variations and trends
  various
  Full FWMP data assessment in separate report
  Internal Monitoring Plan variations are seasonal, no deleterious trends identified

The report is separated such that all aspects of the Tailings Facility are discussed first in Section 2 followed by discussion of Site 23/D in Section 3. Information that is pertinent to both sections is generally not repeated but is discussed in the most relevant section and identified by reference in the other section.
2.0 Tailings Area

2.1 Introduction

Hecla Greens Creek Mining Company (HGCMC) has prepared this section of the Annual Report in accordance with the mine’s General Plan of Operations (Appendix 3) and Alaska Waste Management Permit 0211-BA001. Permit 0211-BA001 expired in November of 2008 and is in the process of renewal. HGCMC is operating under a permit extension from ADEC (letter dated October 6, 2008) until a new permit is finalized. This report provides a summary of all operational and monitoring activities performed in 2010. Refer to GPO Appendix 3 and permit 0211-BA001 for a detailed description of the Tailings Facility and associated monitoring requirements.

HGCMC operated its Tailings Facility continuously in 2010. Primary placement of tailings was in the Northwest Excavation area (see Tailings Facility as-built in Appendix 1). HGCMC added 222,363 cubic yards of material to the Tailings Facility in 2010, bringing the total facility volume to approximately 3,301,020 cubic yards. These yardages convert to approximately 266,983 tons of tailings placed at the Tailings Facility with placement of all materials at the tailings facility totaling approximately 402,855 tons during this report period as calculated from HGCMC surveyed volumes and material densities.
2.2 Placement Records

Table 2.1 contains the monthly placement records for tailings, production rock and other materials at the Tailings Facility for 2010. Surveyed volumes (cubic yards) were converted to tons using a tonnage factor of 1.8 tons per cubic yard (134.2 pcf for tailings). Production rock from Site 23 used for road access and erosion control contributed approximately 30,796 tons to the facility. An additional 105,076 tons of other material (including production rock from Site E) were also placed at the facility in 2010. The calculated tonnage of tailings was derived by subtracting the tons of production rock and other material from the surveyed total. The full pile currently contains approximately 6.0 million tons of material. Based on the survey data presented in Table 2.1 there is a remaining capacity of approximately 3.6 million tons of the 9.6 million tons permitted for placement at the facility. Estimates of other miscellaneous materials disposed in the facility are shown in Table 2.2.

<table>
<thead>
<tr>
<th>Date</th>
<th>All Materials Monthly Total by Survey (CY)</th>
<th>All Materials Cumulative by Survey (CY)</th>
<th>All Materials Monthly Total Tonnage (Calculated tons)</th>
<th>All Materials Cumulative Total Tonnage (Calculated tons)</th>
<th>Prod Rock from Site 23 by truck count (tons)</th>
<th>All Other Materials (Ditch Seds and Construction) by truck count (tons)</th>
<th>Tailings Tonnage (Calculated tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/31/2010</td>
<td>6,901</td>
<td>3,085,558</td>
<td>12,503</td>
<td>5,590,105</td>
<td>1309</td>
<td>627</td>
<td>10,567</td>
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<tr>
<td>2/28/2010</td>
<td>13,181</td>
<td>3,098,739</td>
<td>23,880</td>
<td>5,613,985</td>
<td>672</td>
<td>200</td>
<td>23,008</td>
</tr>
<tr>
<td>4/30/2010</td>
<td>16,814</td>
<td>3,128,513</td>
<td>30,462</td>
<td>5,667,927</td>
<td>4263</td>
<td>15,205</td>
<td>23,394</td>
</tr>
<tr>
<td>5/31/2010</td>
<td>16,256</td>
<td>3,144,769</td>
<td>29,451</td>
<td>5,697,378</td>
<td>6258</td>
<td>800</td>
<td>15,193</td>
</tr>
<tr>
<td>6/30/2010</td>
<td>34,381</td>
<td>3,179,150</td>
<td>62,288</td>
<td>5,759,666</td>
<td>6693</td>
<td>28485</td>
<td>27,110</td>
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<tr>
<td>7/30/2010</td>
<td>30,285</td>
<td>3,209,435</td>
<td>54,867</td>
<td>5,814,533</td>
<td>2562</td>
<td>32034</td>
<td>20,271</td>
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<tr>
<td>8/31/2010</td>
<td>29,221</td>
<td>3,238,656</td>
<td>52,940</td>
<td>5,867,473</td>
<td>1806</td>
<td>22045</td>
<td>29,089</td>
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<tr>
<td>9/30/2010</td>
<td>14,304</td>
<td>3,252,960</td>
<td>25,915</td>
<td>5,893,387</td>
<td>2073</td>
<td>2216</td>
<td>21,626</td>
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<tr>
<td>10/30/2010</td>
<td>12,891</td>
<td>3,265,851</td>
<td>23,355</td>
<td>5,916,742</td>
<td>3539</td>
<td>5418</td>
<td>14,398</td>
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<tr>
<td>11/30/2010</td>
<td>18,324</td>
<td>3,284,175</td>
<td>33,198</td>
<td>5,949,940</td>
<td>656</td>
<td>1170</td>
<td>31,372</td>
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<tr>
<td>12/31/2010</td>
<td>16,845</td>
<td>3,301,020</td>
<td>30,518</td>
<td>5,980,458</td>
<td>0</td>
<td>1185</td>
<td>29,333</td>
</tr>
<tr>
<td>Totals</td>
<td><strong>222,363</strong></td>
<td><strong>3,301,020</strong></td>
<td><strong>402,855</strong></td>
<td><strong>5,980,458</strong></td>
<td><strong>30,796</strong></td>
<td><strong>105,076</strong></td>
<td><strong>266,983</strong></td>
</tr>
</tbody>
</table>

Tons calculated at 134.2 pounds per cubic foot for tailings

Table 2.2 Miscellaneous 2010 Materials Disposal Estimates

<table>
<thead>
<tr>
<th>Surface Tailings</th>
<th>CY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressed Sewage Sludge</td>
<td>50</td>
</tr>
<tr>
<td>Pressed Water Treatment Plant Sludge</td>
<td>500</td>
</tr>
<tr>
<td>Incinerator Ash</td>
<td>16</td>
</tr>
<tr>
<td>Site E</td>
<td>40,000</td>
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</table>

<table>
<thead>
<tr>
<th>Underground</th>
<th>CY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tires</td>
<td>550 ea</td>
</tr>
<tr>
<td>Sump Sediments</td>
<td>3640</td>
</tr>
<tr>
<td>Shop Refuse</td>
<td>730</td>
</tr>
<tr>
<td>Mill Refuse</td>
<td>310</td>
</tr>
<tr>
<td>Electrical Refuse</td>
<td>120</td>
</tr>
</tbody>
</table>
2.3 Stability

Tailings placement compaction is tested to monitor the performance goal of achieving 90 percent or greater compaction relative to a standard Proctor density. HGCMC staff utilizes a Troxler Model 3430 nuclear moisture-density gauge to measure wet density and percent moisture content of placed tailings. Dry densities are calculated and compared to laboratory measured standard Proctors.

Compaction

Summary results for 2010 are shown in Table 2.3. Standard Proctor values were measured on samples taken from the tailings-loadout facility at the 920 and submitted to an outside materials testing lab, which performed the test within the ASTM guidelines for method #D698. The standard Proctor value was 146 pcf (pounds per cubic foot). HGCMC instituted a program at its on-site lab to determine 1-point proctors at the end of 2005. The mean dry density for 25 samples taken throughout the year in 2010 was 144 pcf, and the average percent moisture was 11.8%. Results to date confirm proctor and moisture data received from the outside materials testing lab.

Field measurement results show a high degree of achieving greater than 90% compaction (with respect to an average Standard Proctor value of 146). Testing done in prior years has confirmed that density results obtained using the Troxler procedure average approximately 2 percent higher than the densities obtained via other methods.

With the codisposal of Site E materials into the tailings facility beginning in 2009, field measurements were not as frequent. It is unlikely that the Troxler (or other methods) would provide useful information on the codisposed material. Unlike run-of-mill tailings, which have a relatively consistent standard Proctor value to compare field densities to, the mixture of rock and tailings will not. The Proctor density of the mixture would vary with the proportion of rock added and the density of the rock fraction. As with waste rock, measuring Proctor densities of materials containing a coarse fraction is not recommended. For codisposal HGCMC will use the same method of compaction necessary to achieve the target density for straight tailings. This is typically at least two back and forth passes with the dozer and at least one back and forth pass with the roller. Visual observations of the codisposed material placed to date indicate that the mixed material compacts very well. HGCMC will continue to evaluate the placement procedures and may continue to use the Troxler in areas that receive just tailings.

<table>
<thead>
<tr>
<th>Compaction Variable</th>
<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>Std. Dev.</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std. Proctor [ASTM #D698] (pcf)</td>
<td>146</td>
<td>149</td>
<td>143</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Opt. Moisture (%)</td>
<td>11.8%</td>
<td>12.3%</td>
<td>11.2%</td>
<td>0.9%</td>
<td></td>
</tr>
<tr>
<td>1-pt Proctor (pcf)</td>
<td>144</td>
<td>154</td>
<td>134</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>As Received Moisture (%)</td>
<td>11.8%</td>
<td>13.5%</td>
<td>9.7%</td>
<td>1.0%</td>
<td></td>
</tr>
</tbody>
</table>

* Percent compaction calculated with respect to corresponding monthly proctor.

Inspections

Several independent inspections are carried out at the tailings area throughout the year. Operators working at the site carry out daily visual work place inspections. The Surface Civil Engineer and/or Surface Operations Manager carry out weekly visual inspections of the Tailings Facility area,
as well as a checklist inspection of Pond 7. The environmental department carries out a monthly checklist inspection of the Tailings Facility.

ADEC representatives inspected the site six times in 2010 (February 1, February 24, April 29, June 1, June 9, and September 9). During 2010 the USFS conducted 16 routine inspections (Site inspections #310-#325) to monitor for best management practices effectiveness and compliance to the General Plan of Operations. No issues of non-compliance or poor operations practices of the surface Tailings Facility were noted during the routine inspections. The USFS typically noted that the facility is being developed and operated to required operations and maintenance specifications of GPO Appendix 3.

Well and Piezometer Water Level Data

Water level data for the Tailings Facility are presented in Figures 2.1 to 2.18. A variety of methods are used to determine water levels including:

- Measuring the depth to water by tape or sonic indicator in PVC monitoring wells (also called standpipe piezometers)
- Measuring air pressure in pneumatic piezometers where water pressure against the transducer diaphragm increases air pressure between the diaphragm and the monitoring gauge
- Measuring the frequency of vibration of a vibrating wire piezometer where water pressure creates tension on the transducer wire changing its vibration frequency

Pneumatic and vibrating wire piezometers are typically installed in locations where standpipes are impractical, such as under a liner or in active placement areas. Installation of vibrating wire piezometers allows “real time” data logging and measurement of negative pressures (matric suction). Vibrating wire piezometers can also be installed in existing PVC well casing to allow covering during liner installation and if real time data logging and water sampling is desired (e.g. MW-T-00-05A and PZ-T-00-02). A drawback of pneumatic and vibrating wire piezometers is that they do not provide a means for water sampling or aquifer testing (unless they are installed in an existing well).

Well and piezometer locations and water level cross sections are shown on the tailing facility as-built (Appendix 1). The maximum saturated thickness (approximately 35 feet) occurs near the center of the main portion of the pile. However, this elevated water table level does not extend close to the down-slope toe of the pile. The foundations of the West Buttress and southern portion of the pile are well drained, as indicated by typically consistent unsaturated conditions in the blanket drains (MW-T-00-05A, Figure 2.14) and at the base of the West Buttress (piezometers 74 and PZ-T-05-08 in Figures 2.8 and 2.9). Low head elevations near the pile toe maximize the pile’s geotechnical stability. Intermittent head increases in the foundation drains are localized and of short duration and should not have an adverse effect on pile stability.

The data from standpipe and pneumatic piezometers completed above the blanket drain (Piezometer 76, PZ-T-00-01, PZ-T-00-02, PZ-T-00-03 in Figures 2.10, 2.11, 2.12, 2.13) indicate that saturated conditions can develop above the unsaturated underdrains to a thickness of approximately 12 feet. This is consistent with the low permeability of the tailings and the uncapped condition of the pile. Covering the pile will help minimize the saturated zone in the pile. This was demonstrated by the over 10 foot decrease in the water table that occurred from 1995 to 1997 when the pile was covered (see Figures 2.1 to 2.7). Water levels have rebounded to, and in some cases above, 1994 elevations in most areas. Areas where water levels exceed their
1994 values are areas where the pile is considerably thicker than it was in 1994. The increase in water levels observed in PZ-T-00-01 (and to a lesser extent in instruments nearby) from 2005 to 2007 is likely a result of new tailings placement in the area and staged decommissioning of Wet Well 2.

Periodic spikes in water levels in the wells and piezometers are due to a variety of factors including extreme weather events (e.g. Fall/Winter 2005-2006), changes to water management infrastructure (e.g. decommissioning of Wet Well 2 from 2005-2008), damage to instrumentation (Piezometer 76 in 2004), and measurement errors (e.g. MW-T-00-05A in 2002-2003 and 2007).

Water levels in four wells completed east and west of the pile are shown for comparison in Figures 2.15 to 2.18. The eastern wells, MW-T-00-03A (Figure 2.15) and MW-T-00-03B (Figure 2.16), are completed in the shallow sands 12 and 17 feet, respectively, below ground surface. The figures for these wells show that the water elevation in shallow completions in native materials can be readily influenced by abnormal weather conditions. Wells MW-T-01-03A and MW-T-01-03B are installed west of the pile. Their water levels are shown in Figures 2.17 and 2.18, respectively. MW-T-01-03A is completed in bedrock to a depth of 20 feet and MW-T-01-03B is completed in clayey silt to a depth of 12 feet. These wells show similar water level fluctuations with weather conditions as the two eastern wells. However, the water level in MW-T-01-03B shows a larger differential than MW-T-01-03A because silts and clays hold more water in tension, so a small increase in water content causes a large change in head. The ground surface elevation is 134 feet in the proximity of these two wells. Both MW-T-01-03A and MW-T-01-03B were damaged by bears in 2006 and attempts to recover them were not successful until 2010.

2.4 Hydrology

A detailed review of the hydrology of the Tailings Facility was performed by Environmental Design Engineering (EDE) in 2001 (EDE 2002a) with an update in 2006 (EDE 2007). Those reports describe the hydrogeology of the site and present calculations of anticipated post-closure hydrologic conditions. Water management at the facility consists of a complex network of drains under the pile, bentonite slurry walls around the perimeter of the site, and ditches to divert up-slope water and collect surface runoff. See the Tailings Facility as-built for locations of the site’s water management components. The site is underlain by a low permeability silt/clay till and other glacial/marine deposits or an engineered HDPE liner. These features minimize the potential for the downward migration of contact waters. An upward hydrologic gradient under the site further improves contact water collection. EDE initiated work on the update to the hydrology analysis in 2006, and the final report was completed in 2007 (EDE 2007). That update made the following conclusions and recommendations:

- Bedrock exposures protruding under the northwest corner of the tailing pile may be a pathway for contact water to mix with groundwater. It is therefore practical to have the liner for the new Northwest Expansion also extend over bedrock that currently protrudes beneath the existing pile. Excavation of the northwest corner of the tailings pile will be required to expose the bedrock and tie the liner into the low permeability silt/clay glacio-marine sedimentary unit that surrounds the bedrock.
- Excavation of the northwest corner of the tailing pile will also allow installation of an underdrain to convey surface water and contact water from the northern part of the facility to the southwest. This will facilitate post-closure gravity drainage to the west.
Excavation and lining of the northwest area is expected to lower bedrock heads, but bedrock groundwater levels may equilibrate to a level close to or slightly below the top of the fractured bedrock.

Available data indicate that the existing placement areas are underlain either by synthetic liners or by glacio-marine sediments which act as a competent natural liner.

Historical piezometric data were used to determine a conservative maximum tailings phreatic surface for stability analyses. Two dimensional, cross sectional flow modeling is recommended.

The 2003 Environmental Impact Statement (USFS 2003) process analyzed the incremental expansion of the Tailings Facility storage capacity, a continuation of which is in progress to accommodate the projected tailings storage requirements for the mine. As part of the expansion work, Pond 6 and Pit 5 areas are being constructed for tailings disposal. To accommodate these expansion plans and a change in the regulatory requirements for storm water retention, HGCMC constructed a 30 acre-foot storm water pond (Pond 7) in 2005, and rerouted collection and distribution facilities to include the new Pond 7. For background and design information for Pond 7, see Klohn Crippen’s 2005 report, and EDE’s 2005 Pond 7 Hydrology Report.

Precipitation and temperature data are presented in Table 2.4. The Hawk Inlet precipitation bucket was malfunctioning in March and December 2010. This bucket has been repaired. July and August were the warmest months while December exhibited the coolest temperatures. It was a warmer than normal year with below normal precipitation and well below normal snowfall, with the Juneau annual climate summary stating for 2010:

“Total precipitation lagged below normal from mid May through mid November. Snowfall was particularly dismal with…32.5 percent below normal snowfall.”

Flow data from Wet Wells 2 and 3 are presented with the precipitation data for 2005 – 2010 in Figure 2.19. The wet well flows respond relatively quickly to precipitation events, demonstrating a significant contribution of surface water. The use of the wet well flow meters has been discontinued since 2005 as part of the tailings expansion activities.

Table 2.4 Monthly Summaries of Tailings Area Climate Data

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg Temp (°C)</th>
<th>Precipitation (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.58</td>
<td>2.6</td>
</tr>
<tr>
<td>February</td>
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<tr>
<td>March</td>
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<tr>
<td>April</td>
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<td>2.01</td>
</tr>
<tr>
<td>May</td>
<td>8.99</td>
<td>1.08</td>
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<tr>
<td>June</td>
<td>10.92</td>
<td>3.49</td>
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<tr>
<td>July</td>
<td>12.03</td>
<td>2.56</td>
</tr>
<tr>
<td>August</td>
<td>13.04</td>
<td>3.26</td>
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<tr>
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<td>10.54</td>
<td>5.34</td>
</tr>
<tr>
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<td>6.46</td>
<td>6.34</td>
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<tr>
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<td>4.94</td>
</tr>
<tr>
<td>December</td>
<td>-2.18</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>2010</strong></td>
<td><strong>6.06</strong></td>
<td><strong>36.35</strong></td>
</tr>
</tbody>
</table>
2.5 Water Quality

Compliance Monitoring

Sites around the surface tailings storage facility have been monitored continuously since 1988. This sampling pre-dates the placement of tailings at this facility. The FWMP Annual Report for water year 2010 is being prepared separately and will be submitted to the Forest Service and ADEC upon completion.

Internal Monitoring

As described in Waste Management Permit Number 0211-BA001 Section 2.8.3.1, the internal plan addressed monitoring at both the surface Tailings Facility and the surface production rock storage areas covered by the permit. The Internal Monitoring Plan describes monitoring within the pile areas, in contrast to the compliance monitoring (under the Fresh Water Monitoring Plan) at peripheral facility boundary sites. As such, data generated by the Internal Monitoring Plan effort are “…not for compliance purposes…” as noted in the above referenced permit Section 2.8.3.1, but provide a continuing perspective on in-pile geochemical processes.

The analytical results of HGCMC’s internal site monitoring plan are summarized in Figures 2.20 to 2.31. Sites were distinguished between foundation wet wells (Wet Well 2 and Wet Well 3), wells completed in tailings (PZ-T-00-01, PZ-T-00-02, PZ-T-00-03, MW-T-02-5 and MW-T-02-6) and suction lysimeters (SL-T-02-4, SL-T-02-5, SL-T-02-6, and SL-T-02-7). These lysimeters are installed at various depths within the pile’s vadose zone. These groups are separated on Figures 2.20 through 2.31 with the suffix a, b or c, respectively. For example, a figure number such as 2.20a would show the data for the wet wells group, 2.20b would show the data for the tailings completion wells, and 2.20c would show the data for the suction lysimeters.

An in-depth evaluation of the hydrology and geochemistry of the Tailings Facility was performed by Environmental Design Engineering (EDE) and KGCMC in late 2001 and 2007 (EDE 2002a, EDE 2002b, EDE 2007, KGCMC 2002a) and during the Tailings Expansion EIS (USFS 2003). The observations made under the 2010 internal monitoring plan are consistent with the findings of the EDE, KGCMC/HGCMC and USFS reports.

All internal monitoring waters are captured and treated prior to discharge to the ocean floor under HGCMC’s National Pollutant Discharge Elimination System Permit (AK 004320-6) from EPA. Authority over the federal permitting, compliance and enforcement NPDES program transferred to the State (ADEC) in November of 2010 for the mining industry.

Most values of pH remained between 6.0 and 8.5 for all internal monitoring site samples in 2010 (Figures 2.20a, b and c). PZ-T-00-01, PZ-T-00-2 and PZ-T-00-3, which screen the lower ten feet of the tailings pile, have the highest pH on average of the internal monitoring sites. This is likely a result of microbial sulfate reduction and equilibration with carbonate in the saturated zone of the pile. The wet wells produce water with slightly lower pH (generally between 6.5 and 7.0), reflecting minor influences from groundwater (organic acids) and oxidized surface waters (acidity from thiosalt, sulfide and iron oxidation). The suction lysimeters all have pH values between 6.87 and 8.03 with the exception of SL-T-02-06 which has shown pHs above 8.5 since 2006, likely a result of sulfate reduction.

Alkalinity data are presented in Figures 2.21a, b and c. Alkalinity generally ranges between 150 and 600 mg/L CaCO$_3$ within the tailings pile waters, consistent with buffering from carbonate
minerals and the products of microbial sulfate reduction. The fact that these internal waters are near-neutral to alkaline and continue to show substantial alkalinity indicates that the buffering capacity of the tailings is sufficient to prevent acidification of site drainage in the near-term (at least tens of years) even though portions of this material have now been in place at this site for approximately 20 years.

The conductivity results from internal monitoring site waters are presented in Figures 2.22a, b, and c. Conductivity measurements in 2010 ranged between 2,900 (wet wells), 4,190 (wells completed in tailings) and 4,740 (suction lysimeters) μS/cm. The higher conductivity of the site contact waters reflects a larger dissolved load caused by weathering of the tailings. Pyrite oxidation and carbonate dissolution contribute dissolved ions such as sulfate, bicarbonate, calcium and magnesium to the contact waters, increasing their conductivity. Wet Well 3 has a different capture area than Wet Well 2 and shows a different pattern with respect to conductivity. The changes in conductivity observed in Wet Well 3 suggest changes in the relative contributions from runoff, addition of the Northwest Diversion Ditch flow, infiltration and groundwater as the West Buttress was constructed. The increase in conductivity seen in Wet Well 2 over the past several years likely reflects an increasing contribution from contact water in the drain system and an increase in the dissolved load from migration/remobilization of oxidation products in the pile. In 2008 Wet Well 2 was routed to Wet Well A, a new wet well located in the newly modified Pond 6 area. Suction lysimeter samples are drawn from the smallest pore spaces of the unsaturated zone. Water held in these pores is often isolated from flow paths and thus usually has higher dissolved constituent concentrations than water from the saturated zone and foundation drains.

Hardness and sulfate concentrations remain consistent with the conductivity results. Calcium and magnesium are the primary contributors to hardness (Figures 2.23a and b) and reflect dissolution of carbonate minerals, such as calcite and dolomite. Carbonate dissolution neutralizes acidity formed by sulfide oxidation, which is also the source of sulfate shown in Figures 2.24a, b, and c. Sulfate concentrations typically range between 500 and 5,000 mg/L in the tailings pile waters. The increase in sulfate and other constituents seen in PZ-T-00-03 likely reflects the replacement of interstitial process water with infiltrating surface water, which carries a higher dissolved load.

Arsenic data are presented in Figures 2.25a, b and c. The variability in arsenic concentrations observed in Wet Well 2, MW-T-02-06, and some suction lysimeters is related to evolving redox conditions in the pile. As arsenic-bearing minerals such as tetrahedrite/tennantite (and to a lesser extent pyrite) weather, the arsenic that is released is typically co-precipitated with iron oxyhydroxides. As the pile grows, reducing conditions overtake areas that were once oxidizing. This was particularly true as the water table rose following removal of the temporary PVC cover that was placed on the pile in 1995 (removal began in 1997). Dissolution of oxyhydroxides (and possibly sulfates) is expected as the waters respond to the changing redox conditions. This will contribute arsenic and iron (Figures 2.30a, b and c) to the drainage water. Arsenic concentrations in the pile drainage will therefore decrease when redox conditions in the pile stabilize (e.g. with closure and capping of the pile). Sulfate reduction may also lower arsenic concentrations. This is apparent in the composition of waters from the saturated zone and in some of the SRMP test cells, which are discussed in more detail below.

Figures 2.26a, b and c show the concentration of zinc from the monitoring sites. Zinc levels from the saturated zone of the pile continue to remain low (Figure 2.26b), a result of sulfate reduction and/or thiosulfate disproportionation, which promote zinc sulfide precipitation. A zinc concentration of 328 ppb was reported in PZ-T-00-02 in 2009. The cause for this value was not immediately apparent, but in 2010, the zinc in PZ-T-00-02 returned to within historical levels.
The zinc concentration in MW-T-02-06 in 2003 and 2004, along with the lower alkalinity, suggest that sulfate reduction may not yet have been occurring in this portion of the West Buttress. However, the April 2005 data showed a significant decrease in the concentration of zinc (from an average of 1,000 ug/L to less than 10 ug/L), and the zinc has continued to remain below 50 ug/L. Placement of argillite on the outer slopes of the West Buttress has also led to higher zinc concentrations in Wet Well 3 from surface runoff flushing of this material when it was initially placed. In 2003, the zinc concentration in this wet well returned to within historical limits, and has remained between 500 – 3,500 ug/L, except for a result of 6030 ug/L in the first sample of 2009. The second sample in 2009 was 1830 ug/L. The two 20 foot suction lysimeters showed zinc concentrations between 730 – 2,410 ug/L (SL-02-05, SL-02-07), and the two 40 foot lysimeters (SL-02-04, SL-02-06) had zinc concentrations less that 150 ug/L (Figure 2.26c).

The concentrations of copper and lead are considerably lower than that of zinc. Both of these metals' concentrations are generally less than 5 ug/L in water from each site (Figures 2.27a, b and c and 2.28a, b and c). Previous observations have shown that copper and lead mobility are greatest when the tailings are first placed, then decrease with time.

Cadmium data are shown in Figures 2.29a, b and c. With the exception of Wet Well 2 and 3, cadmium concentrations are very low (less than 2 ug/L). Cadmium in Wet Well 3 had a maximum value of 27 ug/L in 2002 and showed seasonal fluctuation similar that of zinc, albeit at significantly lower concentrations. In the first 2007 sample, Wet Well 2 showed an elevated cadmium level, but the second sample was less than the detection limit, and has remained below the detection limit in 2009. Well MW-T-02-06 showed a cadmium concentration of 4.5 ug/L in June 2003; however, samples since then have all been 0.6 ug/L or less.

Iron and manganese data are presented in Figures 2.30 a, b and c and 2.31 a, b and c, respectively. Concentrations of iron and manganese are high in the wet wells, groundwater and most of the suction lysimeters due to oxidation/reduction and buffering reactions. Lower concentrations of iron and other metals in PZ-T-00-01, PZ-T-00-02 and PZ-T-00-03 likely indicate sulfide precipitation resulting from sulfate reduction and/or thiosulfate disproportionation in these waters.

In previous years, Wet Well 3 reflected surface effects while Wet Well 2 was influenced more by internal-pile contact water and foundation groundwater. However, in recent years, the compositions of Wet Well 2 and Wet Well 3 waters have become similar, reflecting a decrease in surface effects. Before it was decommissioned in 2007, MW-T-02-06 water had evolved toward compositions indicative of sulfate reduction, similar to those seen in PZ-T-00-01, PZ-T-00-02 and PZ-T-00-03.

Acid Base Accounting Analyses

ABA analyses of monthly composite samples were taken of tailings at the Mill filter press. Figure 2.32 shows the monthly composite sample ABA results for 2001 through 2010. The average net neutralization potential (NNP) results are shown in Table 2.5. The variability from year to year is primarily due to fluctuations in acid potential (AP), which is an indication of the pyrite content of the ore. Neutralization potential (NP) values, which primarily reflect carbonate content, are generally more constant.
Table 2.5 Average Tailings NNP - Mill Filter Press

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
</table>

The results of ABA analyses on grid samples taken from the Tailing Facility from 2002 to 2008 are presented in Figures 2.33 and 2.34. The grid included portions of the pile that had exposures of tailings, argillite slope armorine, road rock, and ditch sediment. Figure 2.33 shows the acid generation potential (AP) versus neutralization potential (NP) of all grid samples. The pure tailings samples plot in the upper half of this figure, indicating that they are potentially acid generating. However, the high carbonate content of the tailings (NP >100 CaCO$_3$/1000t) indicates there is substantial buffering capacity remaining in the tailings. These results remain consistent with previous studies of the mine’s tailings. Samples of weathered tailings (after approximately 12 years of exposure) have been shown to still retain a considerable amount of neutralization potential, equivalent to approximately 20% calcium carbonate (KGCMC 2002b). This suggests that the potential lag time to acid generation of exposed tailings is on the order of decades. This long lag time allows time for construction and adequate closure of the site (including covering the pile with a composite soil cover designed to minimize oxygen ingress).

Figure 2.34 shows the relationship of pH to net neutralization potential for the same suite of samples shown in Figure 2.33. Rinse pH is a measure of the pH of a one-to-one mixture of “as received” fines and water. The rinse pH of all of the samples of pure tailings are above 6.0, indicating that the exposed surfaces of the tailings pile remain well buffered. Grid samples with positive NNP values are not representative of tailings and may include argillite and ditch sediments. Samples containing peat can produce a lower pH because of acids formed from the natural decomposition of organic matter.

**Sulfate Reduction Monitoring Program (SRMP)**

Following the USFS 2003 EIS Record of Decision for expansion of the tailings pile, HGCMC began a mandated 30 month study to determine the feasibility of promoting long term sulfate reduction at the facility. HGCMC assembled a team comprised of personnel from the University of Waterloo, HGCMC and independent consultants to develop and implement the investigation. The primary objective of the sulfate reduction monitoring program (SRMP) is to determine the feasibility of meeting closure objectives related to water quality by promoting in-situ microbial processes that increase alkalinity and reduce the concentration of constituents of concern.

A summary report of the 2006 data was distributed to regulatory agencies in 2007. The report and submittal explained the need to extend the study beyond the originally envisioned 30 month time period. A summary report from University of Waterloo including data from the 2007 and 2008 field seasons is expected during the 1st quarter of 2011. A second phase of the Waterloo investigation commenced in 2009 and will continue in 2010. Findings from this second phase will be presented in a follow-up report in 2011. HGCMC will forward both reports to the regulatory agencies for their review. By the end of 2011, HGCMC anticipates having enough information about the merits and liabilities of carbon amendment to decide if full-scale application is advisable.
Field test program
Seven field test cells were constructed and instrumented in the fall of 2004 to monitor the effects of adding different carbon sources to an unsaturated portion of the pile. Cell treatments are summarized in Table 2.6. The cells are 10 feet square and 13 feet deep. A synthetic liner was installed around the vertical sides of the excavations (Cells 2-7) to isolate the cells from lateral flow while allowing vertical flow through the cells. Pore water and core samples are taken annually from multiple depths through each cell and soil suction, moisture content and temperature profiles are also collected.

Table 2.6 SRMP Cell Treatments

<table>
<thead>
<tr>
<th></th>
<th>Tailings (volume %)</th>
<th>Peat (volume %)</th>
<th>Spent Brewing Grain (volume %)</th>
<th>Municipal Biosolids (volume %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell 1</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>1.25</td>
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<tr>
<td>Cell 7</td>
<td>90</td>
<td>5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The field test program results as reported in the performance report for 2006 (University of Waterloo, 2007) and follow-up communications are summarized as follows:

Addition of organic carbon has initiated microbially mediated sulfate reduction in Cells 4 through 7. Cells containing spent brewing grain (SBG) supported more diverse bacterial populations and outperformed cells that did not contain SBG. Decreases in dissolved sulfate concentrations in the SBG amended cells generally correspond to hydrogen sulfide formation, precipitation of metal-sulfide minerals, increases in alkalinity, depletion of $^{13}$C in dissolved inorganic carbon, enrichment of $^{34}$S in pore water sulfate, and under saturation with respect to gypsum. Activity of sulfate reducing bacteria in mixtures containing SBG was likely sustained by fermentative bacteria producing simple forms of organic carbon.

Evidence for effective sulfate reduction was not observed in the control cells or the cell amended only with peat. This was likely a result of the inability for the peat to independently contribute dissolved organic carbon in a form usable to sulfate reducing bacteria.

Precipitation of metal-sulfide minerals is likely contributing to decreases in sulfate and metals concentrations (Fe, Zn, Pb, Ni, Mn, Sb, Tl) in cells exhibiting sulfate reduction. Mineralogical investigation determined that precipitation of Fe- and Zn-sulfide phases is occurring in cells containing SBG. Carbonate precipitation may also decrease the concentration of lead, zinc, iron and manganese in some test cells. Arsenic concentrations remained elevated in carbon amended cells, however decreases in average arsenic concentrations between 2005 and 2008 were observed for cells with SBG. Barium concentrations are controlled by barite solubility and have increased in cells exhibiting sulfate reduction.

Sulfide oxidation produced elevated sulfate concentrations in the upper 50 cm of all cells, but carbonate mineral dissolution has maintained pore water pH between 6.5 and 7.5 in this zone. Near the tailings surface gypsum is a less effective control on sulfate concentrations because of
the two-to-one ratio of sulfate generated by pyrite oxidation to calcium generated by dolomite dissolution.

At depth, alkalinity production from sulfate reduction promotes precipitation of calcium carbonate. Calcium carbonate precipitation decreases aqueous calcium concentrations and limits the effectiveness of gypsum as a control on aqueous sulfate concentrations. Decreases in calcium concentrations caused by calcium carbonate and gypsum precipitation will promote increased sulfate concentrations in the absence of sulfate reduction.

Carbon amendment also resulted in increased iron reducing bacteria populations. Reductive dissolution of iron oxyhydroxides and mobilization of associated oxyanions led to corresponding increases in iron, chromium, and molybdenum concentrations. Mobilization of these elements was observed in all test cells, however higher concentrations generally correspond to cells with larger iron reducing bacteria populations. Pore water concentrations of iron generally decreased in cells containing SBG in 2007 and 2008, likely a result of iron-sulfide precipitation. Amendments containing municipal biosolids supported rapid increases in iron and arsenic concentrations and increases in the amount of organic carbon amendment also resulted in increased iron and arsenic mobilization.

Geochemical and microbial data suggest that ingress of oxygen is limited to the upper two feet of the test cells. Elevated populations of sulfate reducing bacteria (obligate anaerobes) and the presence of ferrous iron within 1.6 feet of the surface indicate that oxygen consumption is occurring. Sulfide oxidation is likely the dominant oxygen consuming mechanism.

Sulfate reduction and calcite and metal-sulfide precipitation appear to control the chemical composition of pore waters in Cells 4 through 7, while sulfate oxidation, dissolution of dolomite and gypsum precipitation/dissolution control the compositions of pore waters in Cell 1 through 3.

The presence of thiosulfate in the tailings pore water was attributed to the flotation reagent sodium isopropyl xanthate in residual process water or adhered to mineral surfaces. Reduction and/or disproportionation of thiosulfate contributes to metalloid attenuation by generating hydrogen sulfide and promoting metal-sulfide precipitation. Enhanced rates of thiosulfate removal were observed in organic carbon amended versus non-amended tailings. Disproportionation or reduction of thiosulfate in non-amended tailings may have contributed to the previously observed increases in hydrogen sulfide concentrations coupled with metal and trace metal attenuation.

Data from field and laboratory batch tests indicates that the rate of sulfate reduction has declined in tailings amended with only biosolids. This suggests that organic carbon contributed by biosolids is rapidly consumed and may not sustain long-term sulfate reduction. In contrast, evidence for sulfate reduction was observed in Cell 4 in 2007 and this was not the case in 2006. The availability of reactive organic carbon may have been limited at the onset of the testing but increased over time due to fermentation. Addition of mixed sources of organic carbon (Cells 6 and 7) can rapidly promote and sustain active microbial sulfate reduction. However rapid increases in dissolved organic carbon led to increased mobility of iron and arsenic caused by iron reduction.

Evidence of methanogenesis was observed in pore water samples with low sulfate concentrations. This could indicate competition for organic carbon or other nutrients; however, methane concentrations were low and sulfate reduction appears to be the dominant of these two microbially mediated processes.
Thiosulfate was a significant component of pore water in recently placed tailings and appears to be a by-product of decomposition of the flotation reagent, sodium isopropyl xanthate. Reduction and disproportionation of thiosulfate produces hydrogen sulfide, which contributes to attenuation of metals and metalloids via sulfide mineral precipitation. Addition of organic carbon increased the rate of thiosulfate removal.

**Laboratory test program**

A number of laboratory batch tests have been conducted on samples of amended tailings. The most recent batch tests in 2008 included the carbon sources used in the field tests plus fish/wood compost and phosphate amended peat and brewery waste. Batch tests conducted in 2005 and 2007 suggested that municipal biosolids supported the highest sulfate reducing bacteria (SRB) populations and rates of sulfate reduction. Measurable sulfate reduction was observed with an amendment containing only peat, which contrasts somewhat with results from the field tests. A decrease in pH associated with addition of 50 wt % dried brewery waste may have limited SRB activity. The batch test dose was more than an order of magnitude higher than that applied in the field tests.

A series of supplementary laboratory batch experiments was conducted between March and August, 2008. The supplementary experiments utilized a lower amendment rate than the initial set of experiments and evaluated composted fish waste as a potential organic carbon source. These experiments utilized pore water which contained similar elevated thiosulfate and sulfate concentrations. After approximately 18 weeks, batches were spiked with metals and metalloids, including Sb, As, Fe, Ni, Se, Mo, Tl and Zn, at concentrations higher than those typically observed in tailings pore water at the Greens Creek Mine.

Organic carbon amended tailings supported pH conditions ranging from 6.2 to 7.8. Concomitant increases in alkalinity and dissolved iron and arsenic were observed in the first ten weeks of these experiments. Decreases in aqueous concentrations of thiosulfate were initially observed in mixtures containing SBG, whereas sulfate concentrations remained relatively constant. Further removal of thiosulfate occurred following spiking with elevated concentrations of metals and metalloids, and sulfate concentrations declined over this period. Greater removal of thiosulfate and sulfate following the addition of iron and zinc suggests that sulfate reduction was limited in the absence of metal-sulfide precipitation. Rapid declines in Sb, As, Cu, Mo, Se and Tl, following spiking, were also observed in SBG amended tailings. These results indicate that (co)precipitation or sorption reactions can effectively promote the removal of these trace elements under sulfate-reducing conditions. Results of these experiments demonstrate that SBG is effective in supporting sulfate reduction. Furthermore, a stoichiometric excess of sulfur relative to metals and metalloids can limit metal-sulfide precipitation and therefore sulfate removal.

Column experiments commenced in August 2007 and were monitored through 2008. These experiments focused on three mixtures of tailings and organic carbon in 30 cm long by 7.5 cm diameter acrylic columns. Simulated tailings pore water was pumped through three columns containing 0 (GC1), 2 (GC2) and 5 (GC3) vol % organic carbon. The chemical composition of the input solution was varied to simulate pore water at three distinct time periods: (1) immediately following tailings placement, (2) at the onset of sulfide oxidation and (3) following an extended period of sulfide oxidation where carbonate dissolution maintains near-neutral pH conditions. To accelerate the assessment of treatment potential, these experiments utilized a higher flow rate than that observed for the field trial experiments. Greater than 30 pore-volumes passed through each column during the test period. This higher flow rate simulates long-term treatment and places limits on kinetically controlled reaction rates.
Effluent pH remained between 6.5 and 7.5, and redox conditions were similar among columns. Alkalinity increased in GC2 and GC3, relative to the control; however, alkalinity production declined with time in both organic carbon amended cells. This suggests that carbon oxidation by SRB may be declining due to a decrease in bioavailable carbon. The data also suggest that sulfate removal is limited when pore water exhibits a stoichiometric excess of sulfur relative to metals (e.g., Fe, Zn, Ni, etc.). The lack of a sink for hydrogen sulfide may also limit the removal of thiosulfate. Reductive dissolution of iron (hydr)oxides caused an initial increase in iron in the effluent of both amended columns and the control. Subsequent removal of iron and zinc occurred in all columns, with the greatest removal occurring in GC3. Removal of arsenic occurred in all cells after an initial period of mobilization. Removal of antimony and thallium was most effective in GC3, while attenuation of molybdenum and selenium was similar among columns.

These laboratory batch tests indicated that composted fish waste supported sulfate reduction but was a less effective source of organic carbon than SBG.

**Pile characterization**

Five sites beyond the SRMP field test cell monitoring area were sampled to characterize the tailings pile geochemistry and microbiology in 2005. The results of the sampling indicate that the pile is generally uniform in composition and has a diverse microbial population that shows no distinct vertical or horizontal trends in distribution. Microbial enumerations give an indication of the presence of various microbial groups but do not necessarily show how active the microbes are or their influence on pore water compositions. Despite the lack of apparent zoning of microbial groups, water compositions suggest that three geochemical zones exist in the pile. Oxidizing conditions are present close to the surface and decrease rapidly with depth. A thick reduced zone that does not appear to promote robust sulfate reduction is present above the water table. The bulk of the unsaturated zone lacks oxygen but may not have redox values low enough to support a large population of sulfate reducing bacteria. Below the water table where redox conditions are even lower, hydrogen sulfide, high alkalinity and low metals concentrations are evidence of significant sulfate (and thiosulfate) reduction. The distribution of organic carbon is also relatively uniform and may not be the limiting factor for promoting sulfate reduction. Pore water compositions suggest that competition for nutrients by other microbial groups such as iron reducers may also limit the rate of sulfate reduction in unamended tailings.

Results of acid base accounting are consistent with previous studies, indicating that the tailings are potentially acid generating. The primary mineral assemblage is quartz, dolomite and pyrite.

**Hydrology**

A component of the SRMP is to define how pore water passes through the tailings pile. This is necessary to determine retention times and if there is the potential for pore water to bypass zones of effective sulfate reduction.

Measurements of moisture content, pore water pressure, and soil suction indicate that a dynamic flow regime exists in the tailings pile. The main saturated zone in the pile exhibits a mounded shape that is thickest (about 35 feet) in the north/central part of the pile, where foundation drains do not appear to effectively dissipate buildup of pore pressures between the foundation and the pile. The mound thins to 15 feet or less toward the edges of the pile and over areas with more robust foundation drains. Tensiometer and vibrating wire piezometer data show that suction gradients fluctuate between upward during dry periods and downward during wet periods in the top 15 feet of the pile and that saturation fronts appear to migrate through the pile profile.
data suggest that though the bulk of the tailings are not 100% saturated, they are nearly so, due to their fine grain size and their relatively high moisture content.

The calculated residence time in the field column experiments was four to five years.

**Technical considerations for full-scale application**

Despite limitations highlighted by the field and laboratory experiments, addition of a small amount of dispersed organic carbon containing spent brewing grain (SBG) shows promise for improving pore water in the tailings pile. The following list of technical aspects should be considered if full-scale application of organic carbon is employed.

- Adding organic carbon at a rate of 5% by volume should support sulfate reduction and improvement of water quality. Higher application rates are not recommended because of the potential for iron, arsenic, and barium mobilization. (Thio)sulfate reduction and metal removal may be limited at lower amendment rates.
- Organic materials that produce concentrated, highly available dissolved organic carbon (DOC), e.g. municipal biosolids, and ones that produce very little DOC (peat) should not be applied alone. They may be used sparingly in conjunction with sources that produce moderate amounts of bio-available DOC (e.g. SPG).
- Organic carbon sources should be well mixed with tailings. Layers and large zones of organic carbon should be avoided because they can produce high concentrations of DOC which can lead to iron and arsenic mobilization and may compromise geotechnical stability.
- Addition of organic carbon to (or above) weathered tailings should be avoided because of the potential for iron reduction and increased mobility of iron, arsenic, and other metal(loids). Areas receiving codisposal of waste rock (e.g. Site E material) and tailings may not be suitable for application of organic carbon.
- The stoichiometry of sulfur to divalent metals in the tailings pore water may limit the potential for pore-water treatment. The ratio of sulfur to metals will determine the extent of removal that can be achieved via metal-sulfide precipitation under sulfate reducing conditions. An excess of either sulfur or divalent metals will result in a limited removal once aqueous concentrations of either reactant becomes limited.
- Indefinite support of sulfate reduction cannot be achieved without an infinite supply of organic carbon. However, a one-time application of organic carbon during tailings placement followed by reclamation of the site with an oxygen limiting cover is a promising approach to minimizing post-closure metal loading from the site.

**Ongoing work**

- Determine logistics of adding organic carbon to the tailings at production-scale.
- Refine the hydrologic model for the site, including analysis of current conditions and predicted post-closure behavior.
- Analyses to determine the geotechnical effects of carbon amendment on the tailings are planned, pending successful field and laboratory geochemical testing of the various amendments.
- Continue second phase of field data collection and perform laboratory study on enzymes related to cellulose degradation.
2.6 General Site Management

Tailings Operation and Management

The General Plan of Operations (GPO) Appendix 3 includes the general operating and management goals to achieve site stability and satisfy regulatory requirements for the HGCMC tailings facility. In Appendix 3, Section 2.1.4, HGCMC operations place tailings in the impoundment using specific criteria established by Klohn Crippen Engineering in 1999 for the placement of tailings in cellular configurations with compaction standards. HGCMC continued to place tailings in this manner through 2010.

HGCMC continues the use of off-highway lidded trailered trucks to transport the tailings to the surface placement area. The material is end dumped, spread and compacted using a bulldozer, followed by a smooth-drum vibratory compactor. Compaction checks using a Troxler density and moisture gauge confirm the resultant performance in the placement area, as per the GPO Appendix 3. See Section 2.3 for a discussion of compaction results.

HGCMC does not expect any changes to the placement methodology in 2011 and will continue placement according to the established criteria. Continued development of placement areas for the remaining mine life are a part of the Stage 2 Expansion Project, approved in January 2004. The 2003 Stage II Tailings Expansion Environmental Impact Statement (EIS) is summarized in HGCMC Tailing and Production Rock Site 2004 Annual Report (KGCMC 2005). In 2010 the majority of tailings were placed in the Northwest Expansion area and the former Pond 6 area.

Construction activities for 2010 included:

- Cleaned sediment from the lined degrit basins that were installed in 2009.
- Replaced the geomembrane at the inlet area to Pond 7 with concrete to create a permanent inlet channel.
- Expanded the 1.4 mile A Road sand pit in support of the planned 2011 East Ridge tailings expansion.
- Performed geotechnical investigation in the East Ridge area to support foundation design work.

HGCMC submitted an updated West Tailings Facility Monitoring Action Plan on December 15, 2009 (HGCMC 2009). The plan described processes affecting water quality in the area and presented an updated monitoring plan. Key aspects of the plan and a summary of 2010 findings are as follows:

- A complex history of disturbance in the area poses challenges to identifying potential leakage from the facility; however, leakage would likely produce a chemical signature similar to Wet Well 3.
- Zinc in the drainage was an order of magnitude or more lower than contact water suggesting that effects from seepage, if any, from the tailings pile are minimal.
- Further Seep zinc concentrations remained relatively unchanged since 2000.
- Zinc in the upper portion of the Further Creek drainage (Site 610) increased with construction and tailings placement activity (likely dust) in the area.
- Zinc in the southern portion of the Further Creek drainage (Site 611) increased from 2004 to 2009, but the absence of manganese suggests that the source of the loading is not tailings leachate. The maximum zinc concentration at Site 611 decreased to 166 ug/L in
2010 from a high in 2009 of 214 ug/L. Sulfate also decreased to 111 mg/L in 2010 from a high of 451 mg/L in 2009.

- Site 609 is an appropriate monitoring site for tracking all facility related influences to Further Creek. Figures 2.40 and 2.41 show the concentrations of zinc and lead at Site 609. The values for both metals were well below the Alaska Water Quality Standard in 2010.

- The composition of waters in the Further Creek drainage is expected to improve as effects from previous disturbance, rock fill, dust and other sources decrease. Some element concentrations may temporarily increase as the drainage pH approaches its naturally acidic, dilute condition. The expected reduction in hardness would lower the Alaska Water Quality Standard (AWQS) for hardness dependent elements and may cause exceedances despite the improvement in water quality.

- Quarrying and construction of Pond 7 in 2004/2005 caused an increase in conductivity, sulfate, pH, hardness, and trace and major elements. Following installation of a pump to collect drainage from the pond foundation the Althea Creek drainage (Site 60) started to return to pre-construction conditions.

- Zinc and lead concentrations at Site 60 area shown in Figures 2.42 and 2.43. Zinc concentrations are very low (< 11 ug/L) and the small increase observed in 2010 does not appear to reflect a change in drainage containment from Pond 7. Zinc concentrations in the underdrain collection from Pond 7 (Site 396) were 18 ug/L in 2010, which is slightly lower than the 2006 to 2010 average of 22 ug/L. Sulfate concentrations at Site 396 also decreased in 2010 to 285 mg/L, relative to the 2006 to 2010 average of 339 mg/L. As the hardness at Site 60 decreases toward background conditions, the AWQS for lead, which is hardness dependent, is approaching the lead levels at Site 60.

- The nearly two orders of magnitude difference in zinc concentration above and below the liner indicates that the liner is intact and functioning as designed.

- As efforts to reduce the sources of sulfate and metals loading to Althea Creek and Further Creek continue, HGCMC expects these drainages to approach pre-disturbance compositions. Background conditions typical of these muskeg drainages preclude compliance with AWQS for pH, alkalinity, aluminum and iron at sites 60 and 609. The concentrations of some metals and trace elements (e.g. lead, zinc, cadmium, mercury and manganese) are expected to exceed background levels and may not meet AWQS as the pH and hardness in the drainages decrease to background levels. The magnitude of the exceedance is expected to be small and temporary.

**Codisposal Studies**

HGCMC compared the relative costs of recontouring and covering the existing Site E production rock pile versus consolidating it with another surface facility, and found that relocating the material to the surface Tailings Facility is the most economical and environmentally protective solution. The geotechnical feasibility of blending production rock with tailings was studied in 2005 (Klohn Crippen, 2005). Laboratory tests conducted in a large scale permeameter cell measured the hydraulic and strength properties of tailings only, production rock only, and various blends of production rock and tailings. Based on the results, the following main conclusions were drawn:

- The difference in permeability between compacted production rock and compacted saturated tailings is at least 33 times. Blend ratios of 2:3 (production rock to tailings by volume) and 3:2 resulted in lower values of permeability as compared to the tailings-only sample. The 2:3 blend exhibited the lowest value of permeability. This behavior is
mainly attributed to the elongated length of the seepage path (and reduced seepage flow area) through the tailings dominated soil matrix and around the larger rock fragments.

- Friction angle of the 2:3 blend was similar to that of the tailings-only sample showing that the tailings were dominant in the blend. As expected, the friction angle improved with the addition of more production rock in the 3:2 blend. Addition of production rock generally increased the overall strength of the compacted tailings with all blend ratios.
- Relatively uniform mixing of the tailings and production rock was very easily obtained in the laboratory in all cases.

A production rock to tailings ratio of 3:2 (60% production rock by volume) with a permeability of $5 \times 10^{-6}$ cm/s and a friction angle of 43° is recommended by Klohn Crippen as the limiting blend for blended codisposal of production rock and filter pressed tailings at Greens Creek. Field trials confirmed that the waste rock and tailings mixed well when pushed with a bulldozer. This is consistent with the findings of the laboratory mixing experiments.

In 2006 HGCMC initiated a geochemical assessment of the blend ratio recommended by Klohn Crippen. Column testing continued in 2008 and also showed positive results. Key findings of the geochemical assessment are as follows:

- Drainage quality at Site E will improve significantly following relocation of the waste rock.
- Reduced oxidation of the waste rock by blending with tailings will extend the duration over which the rock is able to neutralize acidity (extended lag period).
- The codisposal material will have a lower acid generation potential (higher NNP) than tailings alone.
- Characterization of Site E waste rock indicated roughly equal proportions of Class 1, Class 2 and Class 3 type materials and that Class 4 type rock is only a minor component (approximately 5%). The site was constructed prior to implementation of the classification system. Since no segregation by type occurred, the four types are likely distributed relatively evenly throughout the pile. It is unlikely that large areas of oxidized/acidic rock or any one type, particularly Class 4, are present in the pile.
- Comparison of metals and trace element contents between samples of Site E and tailings show that the codisposal blend will have a lower metal content than the tailings.
- Codisposal of waste rock with tailings exhibited improved pore water chemistry relative to that of tailings and waste rock disposed of separately (Figure 2.36).
- Analysis of the Mill site till indicates that it is not acid generating and that metals of concern do not appear to have accumulated in this material beneath the waste rock. Infiltration water percolates through the waste rock then likely flows laterally along the till interface to the toe rather than flowing through it to the base of the pile (Figure 2.37).
- Dissolution of oxidation products, including reductive dissolution of iron and manganese oxides/oxyhydroxides will occur in response to the change in redox environment with codisposal. Consequently, increases in iron, manganese, arsenic and co-precipitated or sorbed metals are expected. However, pore water compositions are not expected to be significantly different than those that develop when oxidized tailings surfaces are buried as the pile expands. Microbial sulfate reduction observed below the water table in the tailing pile and in carbon amended, unsaturated test cells produces alkalinity and sulfide. This has the potential to remove much of the dissolved load caused by reductive dissolution.
- Codisposal of unamended, acidic rock with tailings significantly reduced metals leaching relative to the acidic rock control and demonstrates that the tailings are capable of
neutralizing the acidity present in the acidic rock. This positive result also suggests that addition of lime, though protective, is not an essential component of the codisposal process.

Geochemical results, as well as a geotechnical summary and a site excavation plan, are presented in the Site E Removal: Waste Rock and Tailings Codisposal Plan (HGCMC 2009). This plan was approved by the agencies on June 16, 2009. The plan outlined the removal activities and associated best management practices (BMPs) to be used during active removal (summer construction season) and inactive periods (fall rainy season and winter). Between June and September 2009 and 2010, HGCMC removed approximately 40,000 cubic yards of waste rock and reclamation material from Site E each year. On December 30, 2010 HGCMC requested a modification to the Plan to allow for year round codisposal operations with additional BMPs being implemented. Figure 2.38 is a photograph taken during the removal activities at Site E.

Dust Monitoring and Abatement

Monitoring performed under the Freshwater Monitoring Program has identified lead levels in three shallow peat wells south (Site 27) and west (Site 29 and Site 32) of the tailings pile that approach or exceed freshwater quality standards (KGCMC 2007). The formation water in these wells is generally very dilute (low conductivity and hardness) and acidic (due to organic acids), which is ideal for promoting lead mobility. Dust from the tailings pile may contribute to the lead levels observed in these wells.

Visual observations and operational experience indicate that dust loss from the tailings pile occurs when dry, windy conditions persist at the site. These conditions typically occur for short periods between mid December and late February when high pressure systems produce cold, dry weather and strong northerly winds. The north-south orientation of Hawk Inlet and the Tributary Creek valley exposes the tailing pile to these winds.

Warm, dry conditions occur periodically during the spring and summer months, but wind direction and velocity are not typically as favorable for dust entrainment during these periods. Salt formation on tailings surfaces and application of water to access roads further reduces the potential for dust formation during warmer months.

Snow samples were collected just prior to the loss of snow cover each spring. Sample locations are shown on Figure 2.35a. Additional sites were added in 2009 to provide data around the entire pile. The objective of the sampling was to quantify the amount of tailings dust that had accumulated on the snow pack when conditions for dust loss were greatest (typically December through February). The samples were analyzed for total lead concentrations, and a lead load per square meter was calculated (Table 2.7).
The data indicate that the loading is observable up to 1600 feet from the pile and that the loading has decreased each year since 2007 (Figure 2.35b). Several factors, including fewer dust-producing weather events, a shorter snow accumulation period and improved abatement measures, likely contributed to the reduction in calculated loading values.

Lead levels in water from the three wells do not correlate directly with lead loading values. In fact, the well with the highest lead concentration (Site 32, ~ 6.5µg/l) actually has one of the lowest lead loading values determined from the snow survey. Site 32 is downwind of the Wet Well 1 building, Outfall Shack and a stand of pine trees, which may collectively act as a dust trap, preventing accumulation of dust in the immediate vicinity of the Site 32 well. Tailings dust that settles on the peat up-gradient from Site 32 may be the source of the lead observed in the well. The chemical composition of the water at Site 32 suggests that its completion zone is better suited for lead mobility than the completion zones at Site 27 and Site 29. It is the most dilute of the three waters and there is very little in the water that would cause the lead to precipitate. Complexing with organic ligands may also promote lead mobility in these peat waters.

### Table 2.7 Tails Snow Dust Loading Table

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Date</th>
<th>Lead Load mg/m²</th>
<th>Zinc Load mg/m²</th>
<th>Feet from Pile Center</th>
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<td>2</td>
<td></td>
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<td>3</td>
<td>2</td>
<td>980</td>
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<td>1</td>
<td></td>
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<tr>
<td></td>
<td>4/16/09</td>
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<td>1</td>
<td></td>
</tr>
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<td>79</td>
<td>860</td>
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<tr>
<td></td>
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<td></td>
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<td>3</td>
<td></td>
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<td>5</td>
<td>710</td>
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</tbody>
</table>
A direct link between dust accumulation and lead concentrations in the wells has not yet been established. However the lead loading determined from snow surveys suggests that the amount of lead accumulating on the peat in the vicinity of the wells is sufficient to account for the lead values observed in the wells. This is based on the simplifying assumption that all of the lead is leached from the dust and that it is distributed evenly in a two-meter column of water (saturated peat).

HGCMC evaluated air sampling methods that may augment the lead loading analysis from snow sampling. This would allow year-round monitoring, which will help quantify the temporal distribution of loading at the site. Standard air sampler devices were determined to be an inefficient method for monitoring at this site. Maintenance issues with the air samplers and a lack of available power at most remote locations prevented the air samplers from operating effectively.

HGCMC researched additional methods for lead loading analysis and is evaluating a more passive monitoring system. This more passive system involves the use of a 10 liter microcosm chamber. This microcosm chamber requires less maintenance and is more portable than the current air samplers. The decreased maintenance and the increased portability of the microcosm chambers would allow for year-round monitoring of the area around the entire pile.

The following measures were taken to reduce dust loss from the tailings pile:

- Snow fence and concrete block wind breaks were installed on the crest of the tailings pile
- Snow removal was limited to only active placement areas
- Interim slopes were covered with rock
- Outer slopes were hydroseeded where appropriate

Visual observations and snow sample assays suggest that these mitigation measures have helped reduce the dispersion of dust at the Tailings Facility, however additional efforts are still warranted. Continued snow, water and air monitoring will determine the effectiveness of the control measures. Active placement in the northwest expansion area likely contributed to reduced dusting at the southern sites relative to previous years due to its topography and location.

2.7 Site as-built

As-built drawings for the Tailings Facility are presented in Appendix 1. The drawings depict the 2010 year-end topography, water management features, monitoring device locations and other significant features of the site. An additional tailings drawing includes cross sections that show the following information:

- existing topographic surface
- prepared ground upon which the pile was constructed
- water levels
- projected locations of piezometers from Figures 2.1 – 2.18

Photographs from 2010 are presented in Figures 2.39 to 2.40 (Appendix 4). Figure 2.39 shows the Northwest area of the Tailings Facility on April 22, 2010.
2.8 Reclamation/Closure Plan

Reclamation Plan

In November 2001, as part of the ADEC Waste Management Permit requirements, Greens Creek submitted a “Detail Reclamation Plan with Cost Estimates” as an attachment to the GPO Appendix 14. A Federal/State/Municipal inter-agency team approved this attachment to Appendix 14, as the basis of current site reclamation bonding levels. Bonding levels were set for $24,400,000 in conjunction with the approved site reclamation plan. The Detail Reclamation Plan includes all estimated costs (labor, materials, equipment, consumables, administration, monitoring, and long term maintenance) for task specific work associated with the final closure of the property under a default scenario. HGCMC detailed a scope of work to accommodate the physical reclamation projects and the reclamation monitoring and maintenance of all site facilities by segmenting the overall reclamation closure project work at the mine into 7 elements:

- Roads
- Production Rock Sites
- Tailings Area
- Site General
- Water Systems
- Maintenance and Monitoring
- Administration

Each of the above elements of the Detail Reclamation Plan include narrative and cost estimates to define the closure of the property by discipline (type of work) and area. The elements of the plan encompass the entire mine site, and also include reclamation performance monitoring and facility maintenance after final closure according to the Waste Disposal Permit standards.

The Stage 2 Tailings Expansion process included a National Environmental Policy Act (NEPA) review through an Environmental Impact Statement (2003 EIS) to analyze the potential environmental effects of the project. As part of the tailings expansion, a reclamation review was requested to update the current General Plan of Operations (GPO) Appendix 14 – Reclamation Plan (the Plan) and the costs associated with the tailings expansion area and to revise the Plan’s cost estimates to year 2003 values. The request was made in a joint letter dated October 16, 2003 from the Alaska Department of Natural Resources (ADNR), USFS, and ADEC. HGCMC submitted this cost estimate revision as Attachment A.1 to the Plan on October 22, 2003. The estimated reclamation cost detailed in this document, including the anticipated first, 5-year Tailings area expansion development phase, was approximately $26,200,000, a difference of approximately $1,800,000 from the 2001 estimate. As noted above, the regulatory agencies accepted this bond revision amount and the company deposited the necessary funds in the Forest Service administered Federal reserve account.

The value of the reclamation bonding fund was recalculated in 2005 for an internal Rio Tinto closure review. Based on this new estimate, HGCMC proposed an adjustment increase of $2,765,371 in the fund level from the then current $26,200,000 to $29,000,000 as discussed in the 2006 annual presentation meeting and then presented in a 17 August 2006 letter to the regulatory agencies. The regulatory agencies provided their review response to HGCMC on 19 January 2007, raising 21 points for consideration and further elaboration. HGCMC fully responded to these issues with a 25 February 2007 letter.
A fully updated Reclamation Plan was submitted to regulatory agencies in April 2008. The 2008 updated Reclamation Plan fulfills a portion of the ADEC requirements for the renewal of the Waste Management Permit. SRK Consultants, in their environmental audit of the mine in 2008, reviewed the updated reclamation plan and proposed bond amount, and provided comments in their audit report. The updated plan is currently pending review by the agencies. Upon approval, HGCMC will take the necessary steps to formally update the bond amount.

Reclamation Projects

HGCMC continued using past interim reclamation measures, such as hydroseeding and various erosion controls at the Tailings Facility, to improve and maintain established site controls. A growth medium (six inches to one foot) of native soils was placed on selected slopes of the tailings pile to promote the hydroseeded growth. HGCMC also continued the use of other sediment control measures including silt fencing, jute mat, rock check dams, solid and flexible runoff collection pipes, coarse-rock slope armoring and slope contouring throughout the site. HGCMC is committed to the continued use of site controls as the operation has consistently demonstrated the benefits of these interim reclamation programs to reduce impacts during the operational period.

The Waste Management Permit allows time to gather cover performance information for further analysis, prior to installing the covers en mass. Continued evaluation of the cover performance remains ongoing since its installation in 2000 to justify and improve closure cover technology. Extensive reviews in 2002 of the cap performance also took place during the HGCMC Stage 2 Tailings Expansion project work with the USFS (O’Kane 2001). HGCMC recognizes that the soil covers represent a significant part of the site reclamation plan. Therefore, HGCMC has continued to commit resources to develop and monitor the performance of the cover at Site 23. See Section 3.8 for more details on the Site 23 test cover performance.

In 2003, EDE performed mass loading calculations to test hypotheses about flow regimes at Site 23/D and to predict possible post-closure water compositions (EDE 2004). These results compare favorably with the TDS analysis, the hydrologic analysis as well as past and present flow and water compositional data. The model was used to compare 12 potential post-closure scenarios, including removal of Site D, a range of cover percolation values and a range of annual precipitation rates. The results showed flows at Pond D ranged from 70 gpm to 176 gpm while sulfate values ranged from 24 to 233 mg/L. Cadmium appears to be the metal of greatest concern for this site with respect to meeting water quality standards at Pond D after closure. Cover percolation rates of 20% or less may be required to meet the dissolved freshwater chronic zinc standard, and rates as low as 2% may be required to meet the recently lowered cadmium standard. These predictions do not consider natural attenuation processes, such as microbial or abiotic oxidation/reduction and sorption that could occur in the system following closure of the facility. These predictions will likely require refinement as more information about the site and its final configuration becomes available.

In 2009, improvements in the D pond area included installation of a larger pump system to increase pumping capacity. Also, approximately 4,500 cubic yards of waste rock and pyritic berm material were removed, and replaced with clean fill. The majority of the fill was sourced from the backslope of Site 23, with minor amounts of sand and gravel used for drains. Minor additional work was completed here in 2010 (9 cy of Pond D berm material was removed and replaced with clean fill) - see Figure 3.36 for a photograph of this work in progress.
Environmental Design Engineering (EDE) is assisting HGCMC with a study of the hydrology and geochemistry of the underground workings. Key aspects of the study include:

- Determining the current water table and hydrologic characteristics of the bedrock and backfill
- Consolidating information on the location of drill holes, headings, stopes and related mine features
- Characterizing the geochemistry of underground waters
- Developing a water balance for the mine system
- Estimating the stored soluble load in backfill and on rock surfaces
- Modeling natural and manual flooding scenarios
- Predicting post-closure flow rates and drainage compositions
- Evaluating potential active and passive treatment options for mine waters

HGCMC received an interim report (EDE, 2010), which included several key findings summarized below:

- Large scale dewatering has not occurred as a result of Greens Creek mining operations. Instead, it appears that mining operations have created a dewatered halo of limited extent around underground workings.
- The hydraulic conductivity of bedrock in the mine area is low ($10^{-6}$ cm/s to $10^{-8}$ cm/s), thus there is a limited water supply to re-saturate the dewatered halo to feed seeps and boreholes at depth.
- The quality of potential future deep groundwater inflows may be characterized by high concentrations of barium and elevated concentrations of arsenic and chromium. Precipitation of barite would attenuate high barium concentrations if the background water mixed with oxidized sulfate-rich contact water.
- Near-surface background water is expected to be of better quality and will have a greater effect on underground water chemistry because there is a greater contribution from near-surface sources.
- Measurements indicate approximately 4-8 gpm of inflow from boreholes and seeps below the 1350 level. The composition of this water is variable and dependent upon differences in source rocks, type of backfill the water may drain through, residence time, drainage rates, ventilation of source areas and proximity to the surface. Concentrations of some constituents can be locally high. Reclaim water and Greens Creek surface waters pumped into the mine can also influence seepage compositions.
- Borehole tests, flow measurements, and comparison of water compositions indicate that perennial flows from some boreholes and seeps appear to be related to fault zones or other near-surface structures that have greater connectivity with surface recharge sources. The near-surface sources tend to produce dilute water containing relatively low concentrations of constituents of concern.
- The water balance indicates that the greatest source of water to the underground workings (excluding operations-related inflows) is inflow that accumulates in the 1350 level. Of the estimated total inflow from natural sources (30 gpm), approximately 80% is drainage...
collected at the 1350 portal. The water is a result of better connectivity to surface recharge areas, is fairly dilute and has major ion compositions similar to near-surface background water types. Metal and sulfate concentrations are relatively low compared to other underground waters.

- Water collected from a cemented paste backfill zone contained thiosulfate and had elevated DOC and very high alkalinity and pH. Concentrations of antimony, arsenic, barium, lead and molybdenum were very high and selenium and zinc were elevated. It is estimated that nearly 80% of the workings will be filled at closure and approximately half of the fill will be cemented paste backfill.

- Water from the 33 Decline probably represents the upper end of the range of concentrations of constituents to be expected in flooded workings. The water resulted from flooding old, oxidized, mineralized, backfilled workings with contact water. It is characterized by near-neutral pH and elevated acidity. Concentrations of cadmium, manganese, nickel, zinc, sulfate and chloride are particularly high compared to other underground waters. High concentrations of calcium and magnesium and near-neutral pH attest to the buffering capacity of the wall rock and backfill materials.

- Possible closure scenarios include, but are not limited to, submergence of the mine workings via natural or controlled flooding to minimize oxidation of potentially acid-generating material. Results of a preliminary numerical model indicate that natural flooding of the void volume may require approximately 50 years. Simple rate/volume calculations indicate that voids that are not backfilled could be flooded in approximately 2 years (assuming a constant inflow of 700 gpm). Preliminary calculations suggest that saturation of all cemented paste backfill could theoretically occur in less than 5 years.

- It is likely that maintaining flooded conditions above the 920 level may not be possible. When the workings become flooded to an elevation of the Greens Creek base level the head gradients would favor leakage from the underground mine to the creek or to land surface. If structural features or boreholes create preferential flow paths from mine workings that cannot be completely sealed, release of contact water is possible. Alternatives to flooding the entire mine void, such as flooding the lower workings below the Greens Creek valley base elevation or flooding only selected mine areas above that elevation that can be sealed via bulkheads, should be considered.

- Calculated mass loads based on wall rinse tests represent a portion of the stored soluble load because of incomplete capture and dissolution of oxidation products and additional load present in less soluble forms and in fractures further from wall surfaces. The estimated concentration of constituents based on wall rinse testing represent the low end of the range of concentrations that might be expected in flooded workings. At this low range, concentrations of cadmium and potentially copper, iron, nickel, lead, manganese and zinc may exceed water quality standards.

- Results of biostimulation testing indicate that sulfate reduction may be a viable option for in situ treatment of mine water. Continued testing is recommended.

- Further characterization of mine backfill materials, stored soluble load, buffering capacity and acid generation potential of wall rocks, locations of critical fracture zones and drill holes, and flooding options is recommended.
3.0 Site 23/D

3.1 Introduction

Hecla Greens Creek Mining Company (HGCMC) has prepared this report in accordance with the mine’s General Plan of Operations (Appendix 11) and Alaska Department of Environmental Conservation Waste Management Permit 0211-BA001. A summary of all operational and monitoring activities performed in 2010 is provided. Refer to GPO Appendix 11 and Permit 0211-BA001 for a detailed description of Site 23, Site D and associated monitoring requirements.

Operation of Site 23 (HGCMC’s only active production rock disposal facility) continued in 2010. See the Site 23 as-built in Appendix 2 for facility layout. Approximately 12,069 cubic yards of production rock were placed at Site 23 during this report period. HGCMC estimates the projected remaining capacity at Site 23 at approximately 546,481 cubic yards, based on the current design.
3.2 Placement Records

Site 23 survey data and truck count haulage information are presented in Table 3.1. Site 23 received approximately 20,430 tons of production rock in 2010 as calculated from HGCMC surveyed volumes. A tonnage factor of 1.7 tons/yd$^3$ was used to convert surveyed volume to tonnage. The difference between truck count totals and calculated totals based on survey data reflects variations in tonnage factors, small differences in load capacities and double handling of materials. The surveyed volume reported in cubic yards has the least uncertainty relative to other quantities reported in Table 3.1. The acid base accounting data presented in Section 3.5 indicate that HGCMC continues to conservatively classify its production rock. Some of the phyllite that is visually classified as Class 3 is actually chemically Class 2 (i.e. laboratory testing demonstrates a NNP between 100 and −100 tons CaCO$_3$/1000t).

<table>
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<tr>
<th>Date</th>
<th>Monthly Surveyed (cy)</th>
<th>Cumulative Surveyed (tons)</th>
<th>Hauled To Tails from Site 23 (tons)</th>
<th>From UG Truck Counts (tons)</th>
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<th>Class 2</th>
<th>Class 3</th>
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<td>5,190</td>
<td>12,450</td>
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</tr>
</tbody>
</table>

* No survey taken due to equipment failure or excessive snow

3.3 Stability

Klohn Crippen conducted a stability assessment of Site 23 and Site D in 2003. The stratigraphy and geology were reassessed using the results from drilling programs by HGCMC and Klohn Crippen, historical drill hole data, seismic refraction data, geological mapping and piezometer data. This assessment enabled the previous stratigraphic interpretations to be revised as follows (from top to bottom): a layer of colluvium and blocky rubble about 80 feet thick; a layer of glacial till and sediment about 120 feet thick; a comparatively thin layer of weathered bedrock about 10 to 20 feet thick; and unweathered bedrock (Klohn Crippen, 2004). The blocky colluvium is interpreted to be historical (likely ancient) landslide debris.

Limit-equilibrium stability analyses and the liquefaction potential of the foundation materials were evaluated for Site 23 and Site D, using the reinterpretated geological model. Site 23 has calculated static Factors of Safety greater than 1.6 for the existing configuration, and 1.7 for the
proposed final build-out geometry at 1,120 feet with 3H:1V exterior slopes. The static calculated Factor of Safety of the backslope above Site 23 ranges from 1.0 for shallow surficial slips to 1.3 for deeper surfaces.

The excavation of the soil from the slope behind Site 23 (temporary construction condition) reduces the calculated Factor of Safety for those sections of the backslope, but this temporary reduction is not expected to cause serious backslope instability. Placement of rock fill within the excavation and construction of the final build-out geometry for the production rock site increases the calculated Factor of Safety to slightly above those for the pre-excavation condition.

Approximately 20 feet of saturated fill material identified at the base of drill holes DH-00-03 (north-central) and DH-02-14 (east end) at Site D was found to be potentially liquefiable under design basis earthquake (DBE) and maximum design earthquake (MDE) loading. Liquefaction of this fill material will impact the stability of Site D, but will not reduce the stability of Site 23 to unacceptable levels.

Site D is projected to fail under a significant earthquake. In its current configuration, Site D is expected to fail under the 1/475-year magnitude design earthquake. This represents an approximate probability of failure of about 0.21% annually, or about 2% during the mine’s current projected remaining operational period of about 10 years.

Inspections

Several independent inspections are carried out at Site 23 throughout the year. Operators working at the site carry out daily visual work place inspections. The Surface Civil Engineer and or Surface Operations Manager carry out weekly visual inspections. The environmental department carries out a monthly checklist inspection. No visible signs of physical instability were observed at Site 23 during this report period.

ADEC representatives inspected the site six times in 2010 (February 1, February 24, April 29, June 1, June 9, and September 9). During 2010 the USFS conducted 16 routine inspections (Site inspections #310-#325) to monitor for best management practices effectiveness and compliance to the General Plan of Operations. No issues of non-compliance at Site 23/D were noted during the routine inspections. The USFS typically noted that the facility is being developed and operated to required operations and maintenance specifications of GPO Appendix 11.

Slope Monitoring

Slope monitoring at Site 23/D consisted of GPS monitoring of 10 survey hubs distributed across the sites. The resolution was felt sufficient to identify large potential movement and no such movements were identified. An additional three permanent GPS sites were installed in 2010 alongside the inclinometer sites to collect full time surface movement data. These new inclinometers will be online in 2011.

Inclinometers are used to measure potential subsurface displacement and aid in characterizing slope stability. A total of seven inclinometers have been installed at various locations including Site 23/D, the Tailings Facility, the Mill Backslope, and along the 1350 access road. One inclinometer was installed in 2005; the other six were installed in 2010. A summary of the inclinometer installations by location is shown below.
The digital inclinometer probe used for 2010 instrumentation monitoring was recalibrated in October 2010. Data taken in September (prior to instrument calibration) and November 2010 (after instrument calibration) indicate no documentable shift in data accuracy with the use of this instrument post-calibration. However, for the inclinometers installed in 2010, the November 2010 data will be used as the baseline for future monitoring. The inclinometer installations and associated intended monitoring objectives are summarized by site location in the following paragraphs.

Inclinometer IN-23-05-01 was installed at Site 23 at the end of 2005 to aid with stability monitoring at Site 23/D. This inclinometer, located at the central area of the site, has been monitored on nine occasions from 2006 through 2010, with the baseline reading taken in October 2006. The measurements are presented in two forms, absolute position and incremental displacement. The view of absolute position (Figure 3.31) shows the orientation of the inclinometer casing. A positive deviation on the A axis and a negative deviation on the B axis indicate southerly (downslope) and easterly (up valley) deviations, respectively. The deviation from vertical in this view likely represents deflection of the bore hole that occurred during drilling. The displacements measured since the initial readings are too small to show up in this view and the curves plot on top of each other. The incremental displacement chart (Figure 3.30) shows the location and magnitude of displacement since the initial 2006 reading. Displacements at the top of the hole are attributed to frost heaving, grout settling, and damage from bear activity. The incremental displacement view shows the amount of movement has been 13 mm (since 2006) and is confined to a surface approximately 80 feet below ground level (85 feet was previously reported in 2009; however, that value did not consider 4.65 feet of above ground casing). This depth roughly corresponds to the base of the slide/colluvium unit and the top of the dense till in the foundation.

Three additional inclinometers were installed at Site 23 during the summer of 2010 and baseline readings were taken September and November (after instrument calibration). Inclinometers will be monitored quarterly during 2011 to assess whether seasonal fluctuation in water levels has an influence on displacement (if occurring). An updated evaluation of the stability of this site is planned for 2011. HGCMC will continue to take measurements to determine if there is a seasonal influence on the movement. Given the very small rate of movement there is not an immediate cause for concern, but HGCMC will continue to monitor the situation closely.
One inclinometer was installed in the southwest slope of the existing tailings pile in 2010 to monitor the stability of that slope area. Quarterly readings will be taken in 2011 and reading frequency adjusted as appropriate based on site data.

One inclinometer was installed in the central area of the Mill Backslope in 2010. This inclinometer was installed to monitor the slope above the main mill site. The original slope was cut between 1987 and 1989 to create the bench for the mill site area infrastructure. Shortly after excavation, slope movement was identified and drains were installed to lower water levels and improve slope stability. Water levels are monitored and maintained to minimize the potential for slope failure. Quarterly inclinometer readings will be taken in 2011 and reading frequency adjusted as appropriate based on site data.

One inclinometer was installed along the 1350 Area access road in 2010. This inclinometer was installed to evaluate whether the landslide materials observed during installation of groundwater monitoring instruments are associated with an inactive or active slide zone. Quarterly readings will be taken in 2011 and reading frequency adjusted as appropriate based on site data.

**Well and Piezometer Water Level Data**

Well and piezometer water level data are provided in Figures 3.1 to 3.12. The lack of significant pressure in piezometers installed close to the base of Site 23 (piezometers 52-55, Figures 3.1 to 3.4) demonstrates that the pile remains free draining. This is consistent with the construction of a network of finger drains under the pile and a blanket drain at the pile toe. Comparison of historic versus modeled flow from the finger drains and the curtain drain indicated they are performing as designed and as necessary (EDE 2004). See Appendix 2 for piezometer and finger drain locations. The lack of pore pressure at the toe indicates that pile stability has been maximized. Water levels from several monitoring locations are shown in Appendix 2. The inferred water table is 30 to 60 feet below the base of the production rock pile material up-slope of the Site 23 active placement area and 5 to 20 feet below the base of material placed in Site D and the toe of Site 23, respectively (see also Figures 3.5 to 3.12). MW-23-00-03 data showed an atypical drop in water elevation in August 2007. However, data collected before and after that date are within the historical data range. Observations from wells completed in the colluvium below the sites indicate that perched water tables and braided flow paths exist beneath the site (e.g. compare Figure 3.6 and 3.7). This unit also shows large (up to 10 feet) fluctuations in head levels, which are consistent with perched, confined conditions and channel-like flow. There is a distinct seasonal pattern to the water level fluctuations beneath Site 23/D, particularly in the alluvial sands (Figures 3.9 and 3.11).

The silty/clay till that underlies the colluvial unit impedes downward flow and has an upward hydrologic gradient caused by its confining the more permeable bedrock below it. MW-23-98-01 (Figure 3.8) is completed in the till unit and indicates a water table near the top of the till, which is approximately 100 feet below the existing topographic surface. Alluvial sands occur between the colluvial unit and the silt/clay till near the toe of Site 23 and under Site D. Data from MW-23-A4 and MW-D-94-D3 (Figures 3.9 and 3.11) indicate that the sands are saturated. A curtain drain installed in between Site D and Site 23 in 1994 collects water that flows at the base of the colluvial unit and the top of the alluvial sands (see as-built and sections). This drain helps reduce pore pressures in the foundation of Site D, as well as capturing infiltration waters from Site 23.
3.4 Hydrology

Surface and groundwater are managed using a network of drains, ditches and sediment ponds at both Site D and Site 23. See the Site 23 as-built for locations of these features. Water that is collected in the finger drains beneath Site 23 is routed to Pond 23 along with Site 23 runoff via a lined ditch. Pond 23 also periodically receives stormwater via pipeline from the 920 area. A curtain drain below the toe of Site 23 captures groundwater from the colluvial unit beneath the site and reports to the Pond D wet well via pipelines. Pond D also captures surface water and drainage from seeps near the toe of Site D. Pond D water is returned to the Pond 23 pump station where it is either sent to the Mill or down to the Pond 7 water treatment facility. An 18” HDPE pipeline was installed in 2008 to carry stormwater from Pond 23 (which receives water from Pond D) to the Pond 7 water treatment facility. This pipeline, along with the installation of new pumps, increased the stormwater handling capacity of Site 23/D to a 25-year 24-hour storm.

Flow data for Pond D are shown with precipitation in Figure 3.13. The Pond D flow meter was not operating from July 2008 through 2010 due to changes in pumping/piping as noted above. Once all equipment is in place and operating, flow measurements will resume.

Monthly temperature and precipitation data are provided in Table 3.2. December was the driest month with 0.98 inches. July and August were the warmest months while December exhibited the coolest temperatures.

The production rock and colluvium units respond rapidly to hydrologic events such as snowmelt and rainfall, indicating very local recharge and discharge (EDE 2004).

<table>
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<th>Month</th>
<th>Avg Temp (°C)</th>
<th>Precipitation (in)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
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3.5 Water Quality

An in-depth re-evaluation of the geochemistry and hydrology of Site 23 and Site D was performed in 2003 by Environmental Design Engineering (EDE) and HGCMC in accordance with the ADEC Waste Management Permit Section 4.1.1. In general, metal concentrations in the production rock are above crustal averages and are higher than those of the underlying till, colluvium, and alluvium units. Site contact water, therefore, has a generally higher dissolved load than background surface water and groundwater. Bruin Creek and Greens Creek have specific conductivities that range seasonally from 50 to 225 \( \mu \text{S/cm} \). The lack of significant differences between upgradient and downgradient sites on these two creeks demonstrates that effects from Site 23/D are negligible.

Groundwater upgradient and downgradient of Site 23/D also varies between sites and seasonally, with specific conductivity ranging from 200 to 800 \( \mu \text{S/cm} \). Compositional differences between upgradient and downgradient wells demonstrate that the slide unit hosts a series of disconnected, perched water tables of varying water qualities.

Monitoring data from surface water and groundwater sites indicate that the combination of finger drains, curtain drain, ditches and ponds is effectively collecting contact waters and that downgradient effects from Site 23/D are negligible.

Data collected from basal drains, the curtain drain and Pond D show a progressive, down-slope increase in the groundwater component of the flow. This is consistent with the hydrologic interpretation that water infiltrates through the slide material and daylights as springs near the toe of this unit. As Site 23 expands, the proportion of contact water in the flow increases, as demonstrated by the increase in the curtain drain dissolved load since 1995. While the volume of contact water has increased, the dissolved load of the contact water has not increased over time. This is a positive result because it demonstrates that acid generation is not imminent.

A dissolved load analysis based on calculated TDS was performed to determine the relative proportions of various source waters in downgradient waters. Based on this analysis, Pond D contains 12\% contact water, and approximately 80\% of the Pond D flow is contributed by the curtain drain.

Representative water quality analyses for the major water types are consistent with the conductivity and TDS results and help to further define the geochemical processes occurring at the site. Alkalinity and pH values from all site waters support the conclusion that carbonate minerals are effectively neutralizing acids formed by oxidation of pyrite in the production rock. Zinc, cadmium, manganese, nickel and arsenic are more mobile than other metals of interest in the drainage. Precipitation of iron oxy-hydroxides and manganese oxides controls the concentrations of iron, manganese, and arsenic. Zinc, cadmium and nickel are controlled by mixing and sorption mechanisms. Gypsum is controlling the concentration of calcium in the drainage and will slowly be removed from the system after the pile is covered.

Compliance Monitoring

Water sampling sites around the Site 23/D production rock storage area have been monitored for various periods. Sites have been added and deleted over time as rock storage area development required. The full FWMP Annual Report for water year 2010 is being prepared separately and will be submitted to the Forest Service and ADEC upon completion.
Internal Monitoring

In May 2001 Greens Creek submitted an Internal Monitoring Plan to the Alaska Department of Environmental Conservation – Solid Waste Management Program. This submittal satisfied Section 2.8.3.1 of the HGCMC Waste Disposal Permit Number 0111-BA001. The provision was retained in Waste Management Permit 0211-BA001 with its issuance in November 2003, and reissuance in 2008.

As described in Section 2.8.3.1 of both permits, the internal plan addressed monitoring at both the surface Tailings Facility and the surface production rock storage areas covered by the permit. The Internal Monitoring Plan describes monitoring of the pile areas, in contrast to the compliance monitoring (under the Fresh Water Monitoring Plan) at peripheral facility boundary sites. As such, data generated by the Internal Monitoring Plan effort are “… not for compliance purposes…” as noted in the above referenced permit Section 2.8.3.1.

Waters represented by the internal monitoring sites are captured, routed to the Mill or Tailings Facility and treated prior to discharge to the ocean floor under HGCMC’s National Pollutant Discharge Elimination System Permit (AK 004320-6) from EPA. Authority over the federal permitting, compliance and enforcement NPDES program transferred to the State (ADEC) in November of 2010 for the mining industry.

Operationally for HGCMC, the production rock Site 23 and the adjacent production rock Site D are treated as a single entity, primarily due to their conterminous positions making isolation from one another impractical. Consequently, they are operated and referred to as Site 23/D in this report.

The results of HGCMC’s Site 23/D internal site monitoring plan are summarized in Figures 3.14 to 3.26. Personnel issues and EIS field activities contributed to a reduction in monitoring of these internal sites in 2010. Review of the prior years’ data suggests that changes in chemical composition were not imminent, and HGCMC will ensure that these sites or replacements are monitored in 2011. Sites were distinguished between finger drains and groundwater. These groups are separated on the Figures 3.14 through 3.26 with the suffix a or b, respectively. For example, a figure number such as 3.14a would show the pH data for the finger drains, and 3.14b would show the pH data for the groundwater sites. Sample collection from the Site 23 finger drains is dependent upon their flow. Flow from several of these finger drains is very irregular, responding directly to precipitation-induced infiltration and groundwater fluctuations (Figure 3.27). Monthly sampling of the flowing drains has identified the typical range of concentrations of constituents in the drain waters. HGCMC reduced the frequency of sampling to quarterly for all internal monitoring sites starting in 2003.

Figure 3.14a shows the pH of waters collected from Site 23 Finger Drains 2 through 8, and Figure 3.14b shows the pH of monitoring wells MW-23-A2D, MW-23-A4, MW-D3 and Pond D (see as-built in Appendix 2 for locations). Values of pH were between 6 and 8.5 for all internal monitoring site samples in 2010. The lower pH values (generally pH 6.0 to 7.0) were recorded in MW-23-A4 and MW-D3, both of which are completed in alluvial sands beneath Site 23 and Site D, respectively. MW-23-A2D, which screens colluvium upgradient of Site 23, typically has the highest pH (generally pH 7.0 to 8.5). The Site 23 finger drains fluctuate at values between those of the monitoring wells. Figures 3.14a and b suggest that waters from different foundation units have different pH values and that Site 23 and Site D contact waters and the materials with which they are in contact exhibit sufficient buffering capacity to prevent acidification of site drainage in
the near term. Seasonal fluctuations are apparent in the finger drains with highest pH values occurring in winter months and lower pH in mid to late summer.

As with pH, high alkalinity values (Figures 3.15a and b) indicate that the waters are well buffered. Fluctuations in alkalinity correlate with those of other parameters, such as hardness (Figures 3.16a and b) and conductivity (Figures 3.17a and b), and also appear to be seasonal. Carbonate minerals in the production rock contribute to the high alkalinity of the drainage from the finger drains. Alkalinity is lowest in samples with the highest groundwater component (e.g. the monitoring wells, Pond D, 23FD-5 and 23FD-7). Calcium and magnesium are the primary contributors to hardness (Figure 3.16a) and reflect dissolution of carbonate minerals, such as calcite and dolomite. Carbonate dissolution neutralizes acidity formed by sulfide oxidation, which is also the source of sulfate shown in Figure 3.18a.

Conductivity results from internal monitoring site waters are presented in Figures 3.17a and b. The 2010 conductivity measurements continue to range up to 4,420 uS/cm. MW-23-A2D and MW-D3 have the lowest conductivity. MW-D3 is completed in alluvial sands below the fill placed at Site D. The finger drains with the highest flow (e.g. 23FD-5, which directly drains an excavated spring) generally have lower conductivities than the drains with lower flow. This reflects a larger contribution from groundwater to the high-flow drains relative to a higher proportion of site contact water in the other finger drains. The significant decrease in conductivity in 23FD-7 that occurred in 2000 is probably the result of incorporation of groundwater collected in the upper portion of the drain above the active placement area. The presence of contact water in the alluvial sand below Site 23 (as seen in MW-23-A4) is not surprising given the permeable nature of the colluvium that lies immediately beneath the site. A clay till layer underlies the colluvium and alluvial sands beneath the site. The clay till serves as a barrier to downward flow; however, as discussed earlier, it occurs well below the base of both piles. The fact that MW-D3 does not show signs of a contribution from contact water suggests that an upward hydrologic gradient may exist beneath Site D.

Finger Drain 23FD-2 has the highest conductivity but consistently low flow, suggesting no significant influence from groundwater. This drain may also be influenced by runoff that infiltrates along the access ramp to the site. The higher conductivity of the site contact waters reflects a larger dissolved load caused by weathering of the production rock. As with tailings, pyrite oxidation and carbonate dissolution contribute dissolved ions such as sulfate, bicarbonate, calcium and magnesium to the contact waters, increasing their conductivity. Sulfate concentrations for the finger drains and groundwater wells are plotted in Figures 3.18a and 3.18b and match closely the relative value patterns of conductivity. The drier than average spring and summer in 2009 and 2010 likely contributed to a greater buildup of oxidation products and reduced groundwater contribution to the water balance. This may result in higher conductivity and sulfate values for some sample sites.

Arsenic data are presented in Figures 3.19a and b and are generally quite low. All finger drains and MW-23-A4 experienced increases in their arsenic concentrations in September 2003, with subsequent decreases back down to historical levels in October. The flows in the finger drains positively correlate with these changes. Fluctuations in arsenic values in 23FD-2 can be attributed to changes in redox conditions. Low arsenic and iron (Figures 3.25a and b) concentrations indicate that these metals are precipitating as oxyhydroxides on rock surfaces in the pile.

Figures 3.20a and b show the concentration of zinc in the internal monitoring locations at Site 23/D. Zinc levels appear to be controlled by seasonal conditions. The changes in zinc concentrations mimic those for conductivity and sulfate. 23FD-2 had a zinc concentration of
approximately 70 mg/L in June 2002. Although, zinc averages have fluctuated since 2002, there has been an overall decreasing trend. In 2010 zinc levels were near 20 mg/L. Zinc concentrations in the range of 20 to 70 mg/L are consistent with laboratory kinetic weathering tests performed on samples of argillite and serpentinite (Vos, 1993). The zinc concentrations recorded for Pond D are generally below 0.9 mg/L and reflect contributions from several source waters. Pond D receives water from Site D surface runoff, seeps on the slope and at the toe of the site and the effluent from the curtain drain that HGCMC installed between Site D and Site 23. MW-D3 showed elevated zinc concentrations in both 2005 samples: zinc levels rose from an average of 10 ug/L in 1998-2004 to an average of 177 ug/L in 2005. Average sulfate also increased by approximately 30 mg/L in 2005 compared to average values from 2002-2004. The zinc and sulfate returned to within historical limits in 2006. The cause for the increases in 2005 is not immediately apparent; however, if it was the arrival of a contact water front, a significant increase in conductivity, sulfate, calcium and magnesium should have preceded an increase in metals such as lead and zinc.

Cadmium concentrations (Figures 3.21a and b) correlate well with those of zinc for the internal monitoring sites although at much lower values (0 to 35 ug/L).

The concentrations of copper and lead (Figures 3.22a and b and 3.23a and b) are considerably lower than that of zinc in the Site 23/D internal monitoring sites. Both of these metals show the same general trends as zinc with the exception of one anomalous lead result in a sample from 23FD-2 in 1999. The nickel concentrations presented in Figures 3.24a and b support the observation that the drainage from 23FD-2 is different than that of other drainages. It is possible that the material that supplies water to this drain has a greater proportion of serpentinite, which was shown to produce higher zinc and nickel concentrations than other rock types such as argillite and phyllite (Vos, 1993). What appeared to be a linear increase in nickel concentrations in 23FD-2 prior to 2002 now appears to be decreasing or at least cyclical. The December 2005 sample from MW-23-A2D was an order of magnitude higher than historical values and was likely an analytical error as it did not correspond with the conductivity and TDS of that sample. Also, the more recent metal concentrations for this site have returned within historical data values. Monitoring will continue to determine trends.

An overall increase in arsenic cadmium, copper and zinc concentrations was apparent in the majority of finger drain samples between 2005 and 2006, though the elevated levels remained within historical limits. This may be the result of capturing the flow from a spring along the site’s backslope.

Manganese concentrations (Figures 3.26a and b) are generally less than 50 ug/L for MW23-A2D, MW23-A4, and three of the finger drains (23FD-3, 23FD-5 and 23FD-8). The other three finger drains (23FD-2, 23FD-6 and 23FD-7) and MW-D3 and Pond D have elevated manganese concentrations, indicative of the different redox conditions. Precipitation/dissolution of iron oxyhydroxides and manganese oxides controls the concentrations of iron and manganese in these waters. Increases in iron concentrations from 2009 to 2010 samples appear to be due to analytical error rather than actual field geochemistry changes. If the iron increase was a real change in chemistry, manganese and arsenic would have also increased, and this did not occur.

Acid Base Accounting Data

Acid base accounting (ABA) results from 65 underground rib composites collected in 2010 are presented in Table 3.3 and Figure 3.28. Class 1 rib samples had an average neutralization potential (NP) of 333 tons CaCO₃/1000t, which is equivalent to about 35% carbonate. The Class
1 samples had an average acid potential (AP) of 103 tons CaCO$_3$/1000t, which produced an average net neutralization potential (NNP) of 230 tons CaCO$_3$/1000t. Class 1 production rock does not have the potential to generate acid rock drainage; however, HGCMC recognizes the potential for metal mobility (primarily zinc) from this argillite rock. HGCMC has long-recognized this characteristic of Class 1 production rock and handles the material accordingly by placing it in controlled facilities, such as Site 23 and the tailings area.

Class 2 production rock rib samples had a moderate average NP value of 155 tons CaCO$_3$/1000t and an average AP of 166 tons CaCO$_3$/1000t. The resulting average NNP for the Class 2 rib samples was -11 tons CaCO$_3$/1000t. Class 3 rib samples had an average NP, AP and NNP of 127, 298 and, -171 tonsCaCO$_3$/1000t, respectively. Negative values for NNP indicate that the materials are potentially acid generating, thus requiring appropriate ARD control measures. Carbonate in the Class 2 and Class 3 production rock prevents ARD formation in the short term, allowing time for placement of a composite soil cover to be constructed during reclamation. The soil cover is designed to inhibit ARD formation by minimizing oxygen and water infiltration into the underlying production rock. Class 4 rib samples produced an average NNP of -597 tons CaCO$_3$/1000t. Class 4 material is retained underground.

Figure 3.28 compares actual class designation based on ABA analyses to the results of visual designation use underground to classify the production rock. Of the 65 composites, visual classification assigned 8 samples (12%) to a lower, less conservative class. Forty-seven (72%) of the composites were assigned to the appropriate class and 10 (16%) to a higher, more conservative class. These data represent an 88% success rate for the visual classification program.

Table 3.3 Acid Base Accounting Data Summary for Underground Rib Samples and Site 23

<table>
<thead>
<tr>
<th>2010</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 23</td>
<td>Rib Sample #1</td>
<td>Site 23</td>
<td>Rib Sample #2</td>
</tr>
<tr>
<td>NP</td>
<td>448</td>
<td>333</td>
<td>41</td>
<td>155</td>
</tr>
<tr>
<td>AP</td>
<td>67</td>
<td>103</td>
<td>162</td>
<td>166</td>
</tr>
<tr>
<td>NNP</td>
<td>382</td>
<td>230</td>
<td>-120</td>
<td>-11</td>
</tr>
</tbody>
</table>

Notes: Values are averages from 65 samples for rib samples and 8 samples for Site 23
ABA units are tons CaCO$_3$/1000t
NP determined by modified Sobek method
AP determined from total sulfur assay (converted to pyrite equivalent)

2010 ABA results from the Site 23 active placement areas are shown also in Table 3.3 and Figure 3.29. Active placement area ABA results from previous years as well as the 2006-2008 grid data are also shown on Figure 3.29. The AP to NP distribution in the Site 23 samples differs from that of the underground rib samples. The Class 2 and Class 3 stockpiles areas are frequently empty except for a safety berm, which is constructed of Class 1 rock in the absence of other material. It is probable that several of the samples included this berm material. The grid sampling is also skewed toward higher NNP values because most of the outer surface of the pile is covered with Class 1 rock.
3.6 General Site Management

The construction method used at Site 23 (bottom-up construction) limits the site’s complexity. Designated placement zones are marked on the active lift of the site and production rock is placed according to class. No activities other than routine monitoring occurred at Site 23 in 2010.

In 2005 HGCMC modified placement methods to minimize the formation of permeable areas, or chimneys, between placement zones. The homogenous, planar placement surface that resulted from the new method created surface drainage challenges. HGCMC experimented with a ridge and swale pattern that appeared to improve drainage during the rainy season but was susceptible to drifting snow in the winter months. Fine tuning of methods to improve drainage and accessibility continued in 2010.

In 2008, HGCMC received approval from ADEC to construct an interim storage area for waste rock to be backfilled underground (see photo Figure 3.35). This 25,000 cubic yard capacity area was constructed to aid in concurrent reclamation efforts and can potentially be utilized on a continual 12-month schedule. This is a large increase over the previous 920 remuck bay which had a seasonal 700 cubic yard capacity. The area is layered with 6” of sand; a 36 mil reinforced polypropylene liner, another 6” layer of sand, 3’ of class 3 production rock, and finally a geofabric layer. An HDPE pipe collects water from the area which is sloped to a central collection point. The water collected in this area drains to Pond 23. Material placed in this area is treated with up to 1 wt% lime. Waste rock from the B and D Pond berms, the 1350 and segments of the pipeline excavation were placed at the Site 23 temporary storage area. These materials are backfilled underground as space and resources become available.

Approximately 5,000 cubic yards of material was excavated from the backslope of Site 23 during the 2005 construction season. The material was used as fill in the 960 road base and the Mill Backslope road. Additional material that was removed is stored at 4.9 on the B Road for future site reclamation activities. In 2007, approximately 8,000 cubic yards were removed from this area for site development and other various projects. In 2008, 360 cubic yards were excavated for the B Pond berm project. In 2009, improvements in the D pond area included installation of a larger pump system to increase pumping capacity. Also, approximately 4,500 cubic yards of waste rock and pyritic berm material were removed, and replaced with clean fill. The majority of the fill was sourced from the backslope of Site 23, with minor amounts of sand and gravel used for drains. In 2010, approximately 9 cy of Pond D berm material was removed and replaced with clean fill. Also, the construction of the 860 pad was completed adjacent to Site 23.

3.7 Site as-built

As-built drawings for Site 23/D are presented in Appendix 2. Three drawings from the Site 23/D Hydrogeology and Geochemistry Analysis Report (EDE 2004) (Site 23/D conceptual model, Site 23/D colluvium potentiometric surface and Site 23/D cross section) are also included in Appendix 2. The drawings show the year-end topography, water management features, monitoring device locations, and other significant features of the site. The as-built also includes cross sections that show the following information:

- existing topographic surface
- prepared ground upon which the pile was constructed
- original unprepared ground
- fill design level
Figure 3.34 shows an aerial photo of Site 23 in August 2010. The interim storage area at Site 23 is shown in Figure 3.35. Figure 3.36 shows the D Pond berm removal work in progress.

3.8 Reclamation

HGCMC has monitored the performance of a one-acre composite soil cover plot on Site 23 since September 2000 (see Site 23 as-built in Appendix 2 for plot location). Key performance aspects of the cover system through 2010 include:

- Damage to the Site 23 station necessitated the use of total precipitation data from the Mill site station. The 59.38 inches recorded during the 2010 monitoring period was significantly less than the 68.2 inch average for the 2000-2010 period.
- Snow depth measurements indicated that there was approximately 39 inches of snow (~6 inches of snow water equivalent) at the site just prior to snowmelt.
- Calculated potential evaporation (PE) for 2010 was 16.4 inches (long term average, 16.2 inches) and estimated actual evapotranspiration was 12.6 inches.
- Time domain resonance (TDR) probe neutron moisture probe readings collected in 2010 are consistent with neutron moisture probe measurements from previous years, showing little variation in volumetric water content at depth in the soil profiles.
- The degree of saturation in the barrier layer was greater than 85% for the entire monitoring period. In fact, saturation appears to have stabilized at about 95 percent. The very low matric suction values (<10 kPa) observed in 2010 suggest that there has been no reduction in the degree of saturation in 2010. This is a positive cover performance aspect and implies that the oxygen diffusion coefficient of the barrier material was minimized, thus minimizing the ingress of atmospheric oxygen with respect to diffusion through the pore-air space. The 2010 measured percolation rate of 17% is similar to the long term average of 15 to 20 percent of annual precipitation.
- The recorded temperatures within the growth medium layer and the compacted barrier layers have been similar for the nine years of monitoring. The data show that freezing conditions have not been encountered in the compacted barrier layer, suggesting that freeze/thaw cycling is not occurring.
- Vegetative cover continues to be dominated by the hydroseeded grass and clover plant species. However natural invasion, primarily by spruce seedlings, is evident, particularly on the western-most portion of the cover area.

In December 2006 HGCMC began collaborating with Oregon State University (OSU) and M.A. O’Kane Consultants Inc. to further characterize the hydrology of the cover plot and evaluate how evolution of native forest vegetation (spruce-hemlock forest) may affect cover system performance. Key findings from OSU’s 2010 final report (Hopp et al., 2010) include:

- Approximately 50% of the rainfall during the monitoring period was captured at the collection trench. Tipping bucket malfunctions contributed to an underestimation of subsurface “runoff” coefficient relative to previous years. Between 20-30% of subsurface flow are collected from the growth medium and 70-80% are contributed by the upper capillary break (drainage layer) of the cover system.
- The subsurface flow responds quickly to precipitation events. Short-lived transient water tables develop at the interface between the upper capillary break and the barrier layer preceeding subsurface flow.
The hydrological model HYDRUS-2D was used to evaluate cover performance and compare the effects of potential design modifications including removal of one or both of the capillary breaks, a thicker growth medium, and a less permeable barrier layer. The upper capillary break significantly increases lateral subsurface flow and prevents surface runoff and development of positive pressure heads in the growth medium and barrier layer. Positive pressure heads occur in the growth medium in scenarios without the upper capillary break and in some cases persist for extended periods.

A growth medium (> 1 m) in the absence of an upper capillary break cannot prevent surface runoff during the modeled fall rain events.

A lower hydraulic conductivity of the barrier layer (1 x 10^{-7} cm/s vs 1 x 10^{-6} cm/s) dramatically decreases vertical percolation through the base of the cover (from ~10% to ~0.1% of incident precipitation).

The current design, especially in combination with a barrier layer with even lower hydraulic conductivity, still seems to be the most effective design with respect to generation of lateral subsurface flow, minimizing percolation through the barrier layer and preventing the build-up of shallow water tables in the growth medium and surface runoff. However, the simplified cover design without the lower capillary break and with the lower hydraulic conductivity barrier layer shows very similar results.

Increasing the growth medium thickness to 1 meter, as recommended in the vegetation study to sufficiently protect the underlying capillary break and barrier layer from exposure by windthrow, shows very similar results to the current design. This has the added benefit of allowing mature forest to develop without affecting cover performance.

In the absence of continual intervention, the site will be forested. Allowing the development of a forest on the site is the best means of protecting the barrier layer. With a slight increase in the depth of the growth medium to 100 cm or more there is a high confidence that neither windthrow (uprooting) nor erosion/mass wasting will expose and compromise the function of the barrier layer.

Natural processes (reforestation with alder, Sitka spruce, and western hemlock, soil evolution, and windthrow (uprooting)) are the best strategy for protecting the barrier layer.

The resulting stand would likely be uneven-aged Sitka spruce and western hemlock in a hummocky topography with micro-relief of about 1 m. Soils would be subject to periodic mixing via uprooting, which is the dominant process through which SE Alaskan forests maintain productivity and avoid stagnation and paludification (bog formation).

Windthrow helps break up the placic horizon (a product of podsolization), improving vertical percolation and minimizing soil erosion.

Rooting development depends on the distance to the soil water table and depth to bedrock, but the typical depth of rooting is 1 m. Roots cannot grow into soils with a bulk density > 1.6 g/cm. Roots are highly unlikely to penetrate the barrier layer.

Pit depths 1 year after uprooting are expected to be ~40 cm and mound heights ~70 cm. The deepest area of possible freezing is about 45 cm above the barrier layer. It appears highly unlikely that the barrier layer would be exposed or frozen due to uprooting (blow down).

Other than increasing the growth medium to a depth of at least 1 m, no other changes in the cover system appear necessary from the perspectives of vegetation cover and the function of the barrier layer.

In 2008 HGCMC began monitoring oxygen and carbon dioxide concentrations in the instrumentation trench building (the “Chalet”) to determine if conditions were unsafe for human entrance. Gas levels showed a slight season fluctuation, but did not approach unsafe levels.
Hecla Greens Creek Mining Company
Tailings and Production Rock Site 2010 Annual Report

Figures 3.32 and 3.33 show oxygen levels decreased slightly and carbon dioxide levels increased slightly in the summer months and were at atmospheric conditions in the winter months (20.9% oxygen and 0% carbon monoxide). These monitoring results are consistent with the conceptual model of pile gas transport. When the internal temperature of the pile is colder than the external air temperature, oxygen-deficient, carbon dioxide-rich air flows out the toe of the pile. When the pile temperature is warmer than external air temperature, oxygen rich air is drawn in at the base of the pile. HGCMC personnel will continue to monitor gas levels in the summer months prior to entering into the building.

Reclamation Plan

The HGCMC Reclamation Plan, as well as its implementation is discussed above in Section 2.8 Tailings of this report. Please refer to that discussion for aspects relevant to Site 23/D area reclamation.
4.0 References


Environmental Design Engineering (EDE), 2002a, Kennecott Greens Creek Mining Company Stage II Tailings Expansion Hydrologic Analysis, February 5, 2002.

Environmental Design Engineering (EDE), 2002b, Kennecott Greens Creek Mining Company Stage II Tailings Expansion Geochemistry Report, February 5, 2002.


Hecla Greens Creek Mining Company (HGCMC), 2011, Tailings and Production Rock Site 2010 Annual Report, April 2011.


Hecla Greens Creek Mining Company (HGCMC), 2009a, Tailings and Production Rock Site 2008 Annual Report, April 2009.


Hecla Greens Creek Mining Company (HGCMC), 2009c, West Tailings Facility Monitoring Action Plan, December 2009.


APPENDIX 1

Tailings Facility 2010 As-built and Cross Sections
APPENDIX 2

Site 23/D 2010 As-built and Cross Section
APPENDIX 3

Data Figures
Figure 2.1 Water Level Data for Piezometer 41

PIEZOMETER 41

Transducer Elevation 176.0'
Figure 2.2 Water Level Data for Piezometer 42

PIEZOMETER 42

Transducer Elevation 202.5'

Groundwater Elev. (FT-MSL)

DATE

Figure 2.3 Water Level Data for Piezometer 44

TAILINGS PIEZOMETER 44

Transducer Elevation 177.3’
Figure 2.4 Water Level Data for Piezometer 46

TAILINGS PIEZOMETER 46

Transducer Elevation 140.9'
Figure 2.5 Water Level Data for Piezometer 47

TAILINGS PIEZOMETER 47

Transducer Elevation 144.7'
Figure 2.6 Water Level Data for Piezometer 50

TAILINGS PIEZOMETER 50

Transducer Elevation 164.9'
Figure 2.7 Water Level Data for Piezometer 51

TAILINGS PIEZOMETER 51

Transducer Elevation 176.9'
Figure 2.8 Water Level Data for Piezometer 74

Transducer Elevation 141.1'
Figure 2.9 Water Level Data for Piezometer PZ-T-05-08 VW

PZ-T-05-08

Transducer Elevation 157.3
Figure 2.10 Water Level Data for Piezometer 76

Transducer Elevation 142.7"
Figure 2.11 Water Level Data for Standpipe Piezometer PZ-T-00-01

Bottom of well screen elevation 148.06
Figure 2.12 Water Level Data for Standpipe Piezometer PZ-T-00-02

PZ-T-00-02

WATER ELEVATION (FT-MSL)

DATE

01/01/07 01/01/08 01/01/09 01/01/10 01/02/11

GW Temp (°C)

VW Piezo Temp (°C)
Figure 2.13 Water Level Data for Standpipe Piezometer PZ-T-00-03

PZ-T-00-03

Bottom of well screen elevation 142.71
Figure 2.14 Water Level Data for Standpipe Piezometer MW-T-00-05A

NOTE: Water level reading taken with a sonic indicator caused these erratic data points in 2002 and 2003.

Bottom of well screen elevation 135.17

NOTE: Missing VW data between mid 2008 to late 2009 was due to instrumentation issues.
Figure 2.15 Water Level Data for Well MW-T-00-03A
Figure 2.16 Water Level Data for Well MW-T-00-03B
Figure 2.17 Water Level Data for Well MW-T-01-03A

MW-T-01-03A

WATER ELEVATION (FT-MSL)

DATE

Figure 2.18 Water Level Data for Well MW-T-01-03B

MW-T-01-03B

DATE

WATER ELEVATION (FT-MSL)
Figure 2.19 Tailings Area Wet Well Flow Data

FIGURE 2.19 TAILINGS AREA WET WELL FLOW

- Wet Well 2
- Wet Well 3
- Precipitation
Figure 2.20a  GREENS CREEK TAILINGS AREA INTERNAL MONITORING SITES:
WET WELLS - pH DATA

- WetWell 2
- WetWell 3
Figure 2.20b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - pH DATA
Figure 2.21a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - ALKALINITY
(Non-detectable analysis plotted as zero)
Figure 2.21b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - ALKALINITY DATA
(Non-detectable analysis plotted as zero)
Figure 2.21c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION lysimeters - FIELD ALKALINITY

mg/L CaCO3

0 100 200 300 400 500 600

1/1/02 1/1/03 1/2/04 1/1/05 1/2/06 1/2/07 1/3/08 1/2/09 1/3/10 1/3/11

SL-T-02-04
SL-T-02-05
SL-T-02-06
SL-T-02-07
Figure 2.22a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:  
WET WELLS - CONDUCTIVITY DATA
Figure 2.22b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES: TAILINGS COMPLETIONS - CONDUCTIVITY DATA
Figure 2.22c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - CONDUCTIVITY
Figure 2.23a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - HARDNESS DATA
(Non-detectable analysis plotted as zero)
Figure 2.23b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - HARDNESS DATA
(Non-detectable analysis plotted as zero)
Figure 2.24a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - SULFATE DATA
(Non-detectable analysis plotted as zero)
Figure 2.24b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:  
TAILINGS COMPLETIONS - SULFATE DATA  
(Non-detectable analyses plotted as zero)
Figure 2.24c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - SULFATE DATA
(Non-detectable analysis plotted as zero)
Figure 2.25a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - ARSENIC DATA
(Non-detectable analyses plotted as zero)
Figure 2.25b GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - ARSENIC DATA
(Non-detectable analyses plotted as zero)
Figure 2.25c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - ARSENIC DATA
(Non-detectable analyses plotted as zero)
Figure 2.26a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - ZINC DATA
(Non-detectable analyses plotted as zero)
Figure 2.26b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - ZINC DATA
(Non-detectable analyses plotted as zero)

(6/5/03, 2520)
Figure 2.26c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - ZINC DATA
(Primary and secondary y axis: Non-detectable analysis plotted as zero)
Figure 2.27a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES: WET WELLS - COPPER DATA
(Non-detectable analyses plotted as zero)
Figure 2.27b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - COPPER DATA
(Non-detectable analyses platted as zero)
Figure 2.27c GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - COPPER DATA
(Non-detectable analyses plotted as zero)
Figure 2.28a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - LEAD DATA
(Non-detectable analyses plotted as zero)
Figure 2.28b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - LEAD DATA
(Non-detectable analyses plotted as zero)
Figure 2.28c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - LEAD DATA
Non-detectable analyses plotted as zero)
Figure 2.29a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - CADMIUM DATA
(Non-detectable analyses plotted as zero)
Figure 2.29c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES: SUCTION LYSIMETERS - CADMIUM DATA
(Non-detectable analyses plotted as zero)
Figure 2.30a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - IRON DATA
(Non-detectable analyses plotted as zero)
Figure 2.30b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
TAILINGS COMPLETIONS - IRON DATA
(Non-detectable analyses plotted as zero)
Figure 2.30c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMETERS - IRON DATA
(Non-detectable analyses plotted as zero)
Figure 2.31a  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
WET WELLS - MANGANESE DATA
(Non-detectable analyses plotted as zero)
Figure 2.31b  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:  TAILINGS COMpletIONS - MAINANSE DATA  
(Non-detectable analyses plotted as zero)
Figure 2.31c  GREENS CREEK TAILINGS INTERNAL MONITORING SITES:
SUCTION LYSIMTERS - MANGANESE DATA
(Non-detectable analyses plotted as zero)
Figure 2.33 Tailings ABA Data
Figure 2.34 Tailings Grid ABA Data

Rinse or Paste pH (s.u) vs. Net Neutralization Potential (tCaCO_3/kt) for Tailings Grid 2002-2008.
Figure 2.35b  Tails Snow Dust Lead Load vs Distance

Snow Survey Analysis - Lead Loading

Dec-06  Dec-07  Dec-08  Dec-09  Dec-10

Lead Loading (mg/m²)

- 1015 MW-T-00-04A
- 1014 MW-T-02-07
- 1013 Main Embkmnt Toe
- 1012 Lease Line South
- 1009 Wet Well 1 75’ S
- 1007 MW 3S, Site 29
- 1010 MW 1S, Site 25
- 1011 MW 2S, Site 27
- 1008 MW 5, Site 32
Figure 2.36 Co-disposal Test Drainage Compositions (Site E waste rock)

Non-detection results are shown at the detection limit in a lighter shade.

Legend:
- Tailings
- 40:60 wr:tls
- 60:40 wr:tls
- Site E waste rock
Figure 2.37 Acid Base Accounting Data (Site E Co-Disposal Study)

Acid Generation Potential (tCaCO₃/kt) vs. Neutralization Potential (tCaCO₃/kt)

- Site E Rock
- Tailings
- Mill Site Till
- NNP 100
- NNP -100
- NNP -300
Figure 2.40 Site 609 Zinc Concentrations

Zinc (ug/L)

AWQS
Site 609 FCLR

Figure 2.41 Site 609 Lead Concentrations

Pb (ug/L)

AWQS

Site 609 FCLR
Figure 2.42 Site 60 Zinc Concentration
Figure 2.43 Site 60 Lead Concentration
Figure 3.1 Pressure Data for Piezometer 52
Figure 3.2 Pressure Data for Piezometer 53

PIEZOMETER 53

DATE

HEAD (ft)
Figure 3.3 Pressure Data for Piezometer 54

HEAD (ft)

DATE

Figure 3.4 Pressure Data for Piezometer 55

PIEZOMETER 55

(HEAD ft)
Figure 3.5 Water Level Data for Well MW-23/D-00-03
Figure 3.6 Water Level Data for Well MW-23-A2D
Figure 3.7 Water Level Data for Well MW-23-A2S
Figure 3.8 Water Level Data for Well MW-23-98-01

MW-23-98-01

WATER ELEVATION (FT - MSL)

DATE


Figure 3.9 Water Level Data for Well MW-23-A4

MW-23-A4

WATER ELEVATION (FT-MSL)

DATE

Figure 3.10 Water Level Data for MW-23/D-00-01

MW-D-00-01
Figure 3.11 Water Level Data for Well MW-D-94-D3
Figure 3.12 Water Level Data for Well MW-D-94-D4
Figure 3.14a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - pH DATA
Figure 3.14b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - pH DATA

MW23-A2D (50)
MW23-A4 (51)
MW-D3 (53)
Pond D (331)
Figure 3.15a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - ALKALINITY DATA
(Non-detectable analyses plotted as zero)
Figure 3.15b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - ALKALINITY DATA
(Non-detectable analyses plotted as zero)
Figure 3.16a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES
FINGER DRAINS - HARDNESS DATA
(Non-detectable analyses plotted as zero)
Figure 3.16b GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - HARDNESS DATA
(Non-detecable analyses plotted as zero)
Figure 3.17a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - CONDUCTIVITY
Figure 3.17b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - CONDUCTIVITY

MW-23-A2D (50)
MW-23-A4 (51)
MW-23-D3 (53)
Pond D (331)
Figure 3.18a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - SULFATE DATA
(Non-detectable analyses plotted as zero)
Figure 3.18b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - SULFATE
(Non-detectable analyses plotted as zero) (8/5/09, 3160)

mg/L

MW23-A2D (50)
MW23-A4 (51)
MW-D3 (53)
Pond D (331)
Figure 3.19a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:  
FINGER DRAINS - ARSENIC DATA  
(Non-detectable analyses plotted as zero)
Figure 3.19b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - ARSENIC DATA
(Non-detectable analyses plotted as zero)
Figure 3.20a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - ZINC DATA
(Non-detectable analyses plotted as zero)
Figure 3.20b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - ZINC DATA
(Non-detectable analyses plotted as zero)
Figure 3.21a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - CADMIUM DATA
(Non-detectable analyses plotted as zero)
Figure 3.21b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - CADMIUM DATA
(Non-detectable analyses plotted as zero)
Figure 3.22a GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - COPPER DATA
(Non-detectable analyses plotted as zero)
Figure 3.22b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - COPPER DATA
(Non-detectable analyses plotted as zero)
Figure 3.23a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - LEAD DATA
(Non-detectable analyses plotted as zero)
Figure 3.23b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - LEAD DATA
(Non-detectable analyses plotted as zero)
Figure 3.24a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:  
FINGER DRAINS - NICKEL DATA  
(Non-detectable analyses plotted as zero)
Figure 3.24b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - NICKEL DATA
(Non-detectable analyses plotted as zero)
Figure 3.25a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - IRON DATA
(Non-detectable analyses plotted as zero)

(12/11/02, 424)

(5/18/10, 800)

(5/18/10, 900)
Figure 3.25b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - IRON DATA
(Non-detectable analyses plotted as zero)
Figure 3.26a  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - MANGANESE DATA
(Non-detectable analyses plotted as zero)
Figure 3.26b  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
GROUND WATER - MANGANESE DATA
(Non-detectable analyses plotted as zero)
Figure 3.27  GREENS CREEK SITE 23/D INTERNAL MONITORING SITES:
FINGER DRAINS - FLOW
FIGURE 3.28  2010 ABA DATA FROM UNDERGROUND RIB SAMPLES

Class 4 (NNP<-300)
Class 3 (NNP>-300,<-100)
Class 2 (NNP>-100,<+100)
Class 1 (NNP>+100)

Acid Potential Potential (tCaCO3/kt)
Neutralization Potential (tCaCO3/kt)

Visual designation:
- Class 1
- Class 2
- Class 3
- Class 4
Acid Potential (tCaCO$_3$/kt)

Neutralization Potential (tCaCO$_3$/kt)

**FIGURE 3.29a SITE 23 ABA DATA**

Class 1 2010

Class 2 2010

Class 3 2010

Surface Grid 2006-2008

Class 1 previous years

Class 2 previous years

Class 3 previous years

NNP = 0
FIGURE 3.29b SITE 23 GRID ABA DATA
Borehole: Inclinometer
Project: Site 23
Location: IN-23-05-01
Northing: 20671.4520 ft
Easting: 17186.4160 ft

Spiral Correction: N/A
Collar Elevation: 948.840 ft
Borehole Total Depth: 222.0 feet
North Groove Azimuth:
Base Reading: 2006 Oct 07 10:28

FIGURE 3.30 Site 23 Inclinometer
Incremental Displacement
FIGURE 3.31  Site 23 Inclinometer
Absolute Displacement

Note: Zero reference is top of casing; at ~ 4.65 above ground surface.
**Fig. 3.32 Site 23 Chalet Oxygen Monitoring Data**

- Oxygen upper port
- Oxygen middle port
- Oxygen lower port
- Oxygen IDLH

- <19.5% IDLH, oxygen deficient atmosphere
- <16% impaired thinking, loss of coordination
- <10% loss of consciousness
- <6% death

**Fig. 3.33 Site 23 Chalet Carbon Dioxide Monitoring Data**

- Carbon Dioxide upper port
- Carbon Dioxide middle port
- Carbon Dioxide lower port

- ACGIH TLV-TWA 0.5%
- NIOSH IDLH 4%
APPENDIX 4

Site Photographs
Figure 2.38 Site E Removal Activities July 8, 2010

Figure 2.39 Northwest Expansion Area April 22, 2010
Figure 3.34  Site 23- August 2010

Figure 3.35  Site 23 Temporary Storage Area- August 2010
Figure 3.36  August 21, 2010 showing completed berm modification