LAC Minerals

DENR Hydroassessment:

DENR Review of Water Quality

Richmond Hill Mine, Lawrence County, SD

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1.0 INTRODUCTION

Site Overview: The Richmond Hill Mine is located 4 miles to the northwest of Lead, SD and 2 miles north of the Wharf Resources Mine in Lawrence County, South Dakota. This mine operated from 1988 to 1993. The bulk of mining operations ceased a few months after the discovery of acid rock drainage (ARD) at the site in 1992; however, mining resumed temporarily in 1993 to prepare the pit bottom for backfilling. LAC Minerals and the department began investigations into the source of the ARD at the mine and initially pinpointed it to sulfide ore that had been stockpiled on top of the Spruce Gulch Waste Rock depository during the winter of 1991 and 1992. The rock was to be stockpiled there temporarily and moved to the leach pads for leaching in 1992. During an inspection in February 1992, the department noted the pH from snowmelt along the edges of the sulfidic ore was between 3.5 and 4.5 SU. Further investigation into the acid generating sources at the site performed by LAC Minerals consultants discovered while the sulfidic ore was indeed generating acid, the waste rock in the depository was also a source of acid in this area.

As the investigation continued, it became evident the ARD issue at the mine was much broader. The open pit was also found to be a major source of acid generation. The ore body for the mine consisted of a tertiary breccia pipe and associated mineralized country rock. Oxidation to the mineralized zone of the mine had developed a hematitic-jarositic cap which was up to 250 feet thick in some places. Mining along the northwestern edge of the pit removed this oxidation cap, and a large area of sulfide rich rock was exposed along the pit walls and floor. This area of the mine pit had the highest acid generating potential.

The process area also had acid generating sources, although not to the degree as other areas of the mine. Approximately 702,000 tons of sulfidic ore was originally placed on Pad 3 for leaching out of a total of 2.23 million tons of ore. Also, potential acid material was used during construction of the geology storage building in the crusher area.

Runoff from the Spruce Gulch Waste Rock Depository was a great concern, and impacts to surface waters in the area were extensive. Contamination from acid drainage at the toe of the depository impacted to Cleopatra Creek. The Department of Game, Fish and Parks performed electrofishing along Cleopatra Creek in July 1992 and estimated a little over 2,000 adult trout and more than 8,000 juvenile trout were missing from Cleopatra Creek. In response, LAC Minerals instituted interim treatment methods in Spruce Gulch until an acid drainage mitigation plan could be developed. The company blended soda ash into the top of the depository. A retention pond was also installed below the depository to control and treat water to proper pH levels prior to discharge down Spruce Gulch and into Cleopatra Creek. From 1992-1995, these methods were essential to controlling ARD at the mine.

LAC submitted a permit amendment to the department in 1993 which outlined its acid drainage mitigation plan for the site. On February 16, 1994, the Board of Minerals and Environment approved the permit amendment and mitigation plan. In the plan, approximately 2.7 million tons of potential acid generating waste rock from the Spruce Gulch Waste Rock Depository and 390,000 tons of the highest acid generating potential spent ore from Leach Pad 3 were placed into the Richmond Hill Pit. The backfilled pit was named the Pit Impoundment. A multi-layer clay cap was placed over the compacted waste rock to minimize infiltration of both water and oxygen into the impoundment. Four monitoring nests were installed within the backfilled waste rock. Each nest contained devices to measure moisture content of the rock, oxygen/CO2 concentrations, and temperature. In addition, six barrel lysimeters, two basin lysimeters, and two piezometers were installed to measure water movement in the backfilled material.

After the waste rock was removed from Spruce Gulch, the native soils were amended with limestone to neutralize acidification from the waste rock prior to topsoil placement and seeding. Native drainage channels were also reconstructed.

In the Process area, after the highest acid generating spent ore was removed from Pad 3 and hauled to the Pit Impoundment, the vast majority of the remaining spent ore on Pad 3 was still acid generating. This spent ore along with potential acid generating run-of-mine material from the Richmond Hill Pit, ARD material from the Geology Building and the Pad 3 entrance haul road, and spent ore from Pads 1 and 2 were placed on this leach pad. Subsequently, all of this material was blended with limestone prior to the placement of a multi-layer cap over the pad to buffer any acid generation. After Pads 1 and 2 were neutralized with hydrogen peroxide, a multi-layer cap was also placed over the pads. The spent ore on Pads 1 and 2were not mixed with limestone prior to capping since the remaining spent ore on the pads had low acid generating potential. In addition, the two inlets to the former underdrain system for Pad 3 were capped. Drainage was routed away from the Pad 3 underdrain to the V-notch which was excavated through the ridge to the southwest of the pad.

Current Status and Concerns:

Since the reclamation performance criteria has been met on a majority of the reclaimed areas at the Richmond Hill Mine, LAC Minerals is requesting the Board of Minerals and Environment to release its reclamation liability and place the released portions of the mine into postclosure status since surface and ground water quality standards have not been met. Facilities in the Process and Spruce Gulch areas and the haul road will remain unreclaimed throughout the postclosure period until water treatment is no longer necessary at the site.

LAC Minerals is currently treating water in both the Process and Spruce Gulch areas. The leach pads still release on average of 16 million gallons annually which requires treatment prior to discharge for low pH cadmium, copper, and selenium. This water is treated in the water treatment plant located in the former process plant. In the Spruce Gulch area, the Three Trees Spring located near the toe of the former Waste Rock Facility is a source of low pH water. According to Todd Duex (LAC Minerals), this spring currently has a pH below the South Dakota Ground Water Quality Standard of 6.5 SU, but it is slowly improving. This spring is diverted into the Treatment Pond in Spruce Gulch and treated with caustic soda.

South Gulch, located on the south side of the pit impoundment, is also a source for poor water quality in this area. There are several potential sources of this contamination:

1. Perched water remaining in the bottom of the pit impoundment after the cap was installed;
2. Water from water infiltration into the pit impoundment; and
3. Natural sulfide rock sources in the South Gulch area.

The first and second options have some potential to be sources, but the input from these sources would most likely be minor. Perched water in the pit impoundment would have slower infiltration rates as it seeps into minor cracks within the bedrock. Therefore, while water quality within the pit impoundment may be of extremely poor quality, this effect would be heavily diluted as seepage from the pit impoundment comes into contact with the natural alluvial or bedrock aquifers in the area. The third option is probably the greatest source of impact to the South Gulch area as the rock surrounding the pit impoundment also contained natural sulfide deposits.

The water from South Gulch is captured and pumped to the Treatment Pond in Spruce Gulch and is treated with caustic soda before being released to compliance point #001.

Purpose of the Assessment: In the process of developing the hydroassessment, the department focused on three goals regarding water quality at the site. These are:

1. Identify areas within the mine permit boundary which may continue to have long term water quality impacts.

2. Define postclosure water treatment needs based on long term water quality impacts.

3. Define postclosure water quality monitoring needs to continue protection of downgradient water resources from long term water quality impacts at the mine.

With these goals in mind, the hydroassessment will review site hydrogeology, water quality trends, and current water treatment activities, and discuss future water treatment and water monitoring needs throughout the mine site. The goals will guide the department's recommendations during development of the postclosure plan.

GEOLOGY AND HYDROGEOLOGY

Mine Pits and Waste Rock Facility: The former Richmond Hill Pit, Turnaround Pit and Spruce Gulch Waste Rock Depository are located in the southern half of the Richmond Hill Mine site. The geology of the mine pit area is very complex. The primary ore zone was located within a Tertiary hydrothermal breccia. The pit area also contained small portions of undifferentiated Tertiary porphyries and some Pre-Cambrian basement materials. The Spruce Gulch Depository was located in an area with tertiary intrusive breccias as well as undifferentiated porphyries and some pre-Cambrian basement rocks. The Turnaround Pit area was located primarily on intrusive breccias and undifferentiated porphyries. Pre-Cambrian rock in this area is composed mostly of phyllites, schists and amphibolites.

Ground water occurs in two interconnected hydrostratigraphic units. Near surface flow occur in alluvial/colluvial material and weathered bedrock fractures. A deeper system, which flows generally toward the southwest, involves flow via bedrock fractures. Flow in the shallow system is heavily influenced by the degree of localized weathering and shear zones. Both shallow and deep flow gradients are heavily influenced by topography.

Process Area: The Process Area is located in the northern half of the mine site. The geology is also complex and consists primarily of Paleozoic sedimentary rock with Tertiary intrusives scattered throughout the area. The leach pads are located primarily on the Deadwood Formation. There are small exposures of Icebox Shale and Roughlock Siltstone Formation and some undifferentiated Tertiary porphyries also in the area of the leach pads. The surface geology around the Process Ponds and in the Pad 3 draw is composed of Tertiary trachyte porphyry. The land application area is also located on the trachyte porphyry.

Ground water in the vicinity of the former Process Area occurs in three hydrostratigraphic units. The uppermost unit consists of shallow flow in alluvial and colluvial material, primarily in Rubicon Gulch. The intermediate (upper) unit involves perched ground water in isolate zones within the upper Deadwood Formation, Madison Formation and Tertiary Porphyry deposits. The lower hydrostratigraphic unit consists of confined flow in the lower Deadwood Formation.

GROUND WATER QUALITY

PROCESS AREA: Alluvial Monitoring Network

Wells MW-14, MW-15, and LP3-MW monitor water quality of alluvial/colluvial aquifers in the Process Area. Screened intervals for MW-14 and MW-15 are 3 to 8 feet and 3 to 17 feet, respectively. These two wells have been monitored from 1988 through the present. Water quality graphs for these wells are located on Appendix B.1.

MW-14

MW-14 is located in Rubicon Gulch immediately downgradient of the Stormwater Pond in the Process Area. This well did have minor and temporary impacts during the mid-1990's as a result of mining activities at the site. During this time, the pH of the well dropped slightly and sulfates within the well rose briefly to nearly 400 mg/l. Cadmium and copper were also detected at low levels during the same time frame before dropping back to below detection levels. Water quality gradually improved until 2007 and 2008, when water quality in the well slightly degraded again with sulfates spiking to a high of 687 mg/l before dropping back down to a normal concentration range of 50 to 125 mg/l. Also, there were spikes in concentrations of copper, nickel, and zinc. There was minimal activity in the process area during this time frame. FD-1, a surface site located immediately upgradient of MW-14 at the confluence of the Pad 3 draw and Rubicon Gulch, also had spikes in these same parameters and in additional parameters as well beginning in 2004. This change in the water quality may have been due to leaks that developed in the Stormwater Pond during this time. There have been no additional impacts to the water quality within this well, and water quality appears to have returned to ambient concentrations.

MW-15

MW-15 is also located in Rubicon Gulch downgradient from MW-14. This well also exhibited minor impacts due to mine activities in the mid-1990's. Sulfates rose to nearly 500 mg/l, and there were also corresponding spikes in the aluminum, copper, and cadmium concentrations. The pH of this well was not impacted. There was a brief rise in sulfate concentrations in 1999. The impacts noted in MW-14 and FD-1 during 2007 and 2008, as mentioned above, were barely noted in the water chemistry of this well. The water quality has never exceeded ground water quality standards, and all historic changes in concentrations noted within the well are no longer occurring. Currently, the water quality within the well matches ambient baseline conditions.

LP3-MW

LP3-MW is the only other alluvial monitoring well within the Process Area. It is located in the Pad 3 draw upgradient of both MW-14 and MW-15 and monitors alluvial water quality below reclaimed Pad 3. As the pad was being leached and reclaimed from 1990 to 1995, this well showed elevated concentrations of sulfates, aluminum, cadmium, copper, nickel, and zinc. Of these constituents, only sulfate and cadmium exceeded South Dakota Ground Water Quality standards. The pH in this well was also highly variable during this time and ranged from 5.0 to 8.0 SU. Average pH in 1995 was 6.8 SU. After Pad 3 and associated French drains were capped, the water quality gradually improved. By the end of 2013, the metal and sulfate concentrations had declined. The only concern within the well is pH. The average pH in the well for the past 5 years is 6.37 SU which is slightly below the South Dakota ground water quality standard. All other water quality parameters currently meet ground water quality standards.

PROCESS AREA: Upper Bedrock Monitoring Network

MW-2, MW-5 and MW-13 are wells which are all associated with the upper bedrock monitoring unit for the Process Area. It is important to note, however, that while these wells are all associated with the upper

bedrock unit, they do not necessarily monitor the same formation. Due to the extensive intrusive activities in this area, the hydrology is very complex. MW-2 is drilled into Tertiary Porphyry and MW-5 is drilled through porphyry into the Madison Formation. The author was unable to track down a well completion report for MW-13; however, geologic cross sections from the permit application indicate the well would have been drilled through Deadwood Formation into Tertiary Porphyry deposits. Based on information from the hydrological baseline report from the mine permit, ground water within the upper monitoring network of the Process Area generally flows to the northwest. Water quality graphs for these wells are located in Appendix B.2.

MW-2

MW-2 is located in the northeast corner of the Process Area. The water quality in MW-2 showed very slight modifications over its sample history. In the early to mid-1990's, the pH in this well varied between 7.0 and 8.0 SU with only a few samples below 7.0 SU. Since that time, the pH has stabilized and remains between 7.5 and 8.0 SU. Sulfates have been primarily below detectable concentrations, with minor hits occurring in the early 1990's and again in the early 2000's. There were also more consistent hits of metals during the early sampling period for this well in the early 1990's. Over time, metal concentrations have mainly decreased to below detectable levels. The water quality of this well is excellent.

MW-5

MW-5 is located to the northwest of Pad #3. While technically this would make the well downgradient of the Process Area, a review of the potentiometric map for the Upper Bedrock Water Unit provided in the mine permit application indicates this well is located in what may be considered a potentiometric "high". Potentiometric contours of this unit show that water would be more likely to flow to either the north or west, but not necessarily in the direction of MW-5. MW-5 would still be considered a downgradient well, but based on the potentiometric surface map, impacts to this well would most likely be minimal. Also, the well is screened across the Madison Limestone and not a Tertiary Intrusive. Connectivity to Madison Limestone may be minimal in this area due to the presence of the Tertiary Intrusive.

In all parameters, the water quality in MW-5 is exceptional. Prior to 1995, there were some slight elevations in the concentrations of various water quality parameters in the well, although sulfates never rose above 20 mg/l. Copper and cadmium were also found in the well during the time frame, with concentrations were just barely above the detectable limit.

MW-13

The final well in the Process Area which monitors the upper bedrock monitoring unit is MW-13 which is located near the center of the process area near the north corner of the New Sludge Pond (former Barren Pond). This well did show minor impacts in water quality into 1996. This included slight elevations in concentrations of sulfate, aluminum, copper, cadmium, iron, and nickel. With the exception of sulfate, aluminum and nickel, these concentrations have all been found to be below detection during at least the past 15 years.

PROCESS AREA: Lower Hydrologic Unit Monitoring Network

The lower hydrologic monitoring unit is monitored by MW-4B, SW-2, SW-8, and SW-15. The geology of these wells shows they were drilled through the Ice Box and Roughlock Members of the Winnipeg Formation, Deadwood Formation, and Tertiary intrusives. Water quality graphs for these sites are located in Appendix B.3.

MW-4B

MW-4B, located to the southwest of the leach pads and south of the reclaimed V-notch area, was constructed in 1992 as a replacement well for MW-4. The well was drilled to a depth of 400 feet. It passes through the Icebox and Roughlock members of the Winnipeg Formation, the Deadwood Formation and several layers of Tertiary porphyry that breaks up the geologic column. Based on the potentiometric map for the lower bedrock monitoring unit provided in the hydrologic study of the mine permit application, this well is located downgradient of the Pad 3.

The water quality in MW-4B is very good. Though the nature of the well would indicate it would have minimal impact from the process area, there were noted impacts in the water quality of the well during the early to mid-1990's. During this time, the pH of the well dropped from about 7.25 to 6.75. Sulfate concentrations rose slightly above the detection limit, and aluminum and copper concentrations also increased. Since this time though, the pH has increased to around 7.25 SU and sulfate concentrations are only randomly found to be above the detection limit. Aluminum concentrations and copper concentrations have also dropped and are at or near detection. Overall impacts to this well appear to have been minor and temporary.

SW-2

SW-2 is located to the northeast of MW-4 above the process ponds and between Pads 1 and 2 and Pad 3. The well was drilled to a depth of 720 feet. Based on the well completion report, the geology of the well included the Ice Box Member of the Winnipeg Formation, Deadwood Formation, Precambrian basement and Tertiary porphyry. Reviewing the potentiometric map for the lower bedrock monitoring unit, this well is downgradient of Pads 1 and 2 but upgradient of Pad 3.

The water quality in SW-2 is very good. Sulfate concentrations are rising but only minimally. Sulfate was detected at levels above detection a few times during 1993 and 1994. However, since 1999, the concentrations have been consistently above the detection limit, increasing to just over 30 mg/l in 2013. Cadmium, copper, and zinc were detected in the well during active operations at the Process Area and during reclamation. The highest concentrations noted for these constituents were 0.007 (1992), 0.267 (1996), and 0.142 (1992), respectively. However, since the reclamation has been completed, the concentration of the metals has dropped back below detection limits.

SW-8

SW-8 is the next lower bedrock monitoring well in the Process Area. The geology of the well is a mix of Deadwood Formation and Tertiary Porphyry. The well construction report indicated porphyry intruded on the Deadwood Formation in six different levels throughout the depth of the well. The total depth of the well is 496 feet deep. Based on the potentiometric map for the lower bedrock monitoring unit provided in the hydrology section of the mine permit, the well is located downgradient of the Process Area.

As with the previous wells, this well showed minor impacts during the active and reclamation portion of the mining operations. The pH was highly variable, and there were also random detections of aluminum, cadmium, copper, iron, and zinc prior to 1997. The metal concentrations are currently below the detection limit. Sulfate has gradually risen above the detection limit in recent years, although the concentration is still less than 20 mg/l. The pH has also stabilized to around 7.2 SU.

SW-15

The final lower bedrock monitoring well in the Process Area is SW-15, located to the west of the Stormwater Pond. The potentiometric map for this monitoring unit indicates this well is primarily either upgradient or at a side-gradient to the Process Area. The geology of the well is similar to the other wells

in the area. It is drilled through the Icebox Member of the Winnipeg Formation, Deadwood Formation and Tertiary Porphyry to a depth of 770 ft. Porphyry intrudes at multiple levels within the well.

The water quality in SW-15 is excellent. The pH varied between 7.5 and 8.0 SU when the mine was operating. The pH of the well is now near neutral at an average of 7.2 SU. Sulfate was above detection limits during active mining and after 2002, although sulfate concentrations have never been above 25 mg/l. Metals commonly associated with the mine (aluminum, cadmium, copper, nickel, iron, and zinc) are all slightly above detection or not detectable with the exception of iron. Iron has exceeded 2 mg/l but is now more consistent at approximately 0.3 mg/l.

PIT IMPOUNDMENT and FORMER WASTE ROCK DISPOSAL AREA

In the southern half of the mine, the two primary areas of concern are the Pit Impoundment and the former Spruce Gulch Waste Rock Depository which have the worst ARD contamination at the mine. The Pit Impoundment is located at the top of South Gulch, North Gulch and West Gulch, while the former waste rock depository is located at the headwaters of Spruce Gulch.

The hydrology of the Pit Impoundment and Spruce Gulch Waste Rock Depository consists of two monitoring units. The uppermost unit is the alluvium/colluvium and may also consist of some near-surface fractured bedrock. The lower unit is the fracture flow in the bedrock. Water quality graphs for the shallow aquifer are located in Appendix C.1 while the graphs for the wells in the deeper bedrock monitoring unit are located in Appendix C.2.

Pit Impoundment: Alluvium/Colluvium and Near-Surface Bedrock Fractures

North Gulch

MW-23

There are two wells monitoring the ground water in North Gulch. MW-23 monitors the shallow aquifer. This well has not been sampled much since its installation because it is generally dry, so determining trends in this well is very difficult. The pH has remained relatively stable in this well. It has ranged from 6.35 to 7.15 SU with average concentration of 6.7 SU. The sulfate concentrations have also remained low, with the highest concentration of 210 mg/l. Normally, concentrations have been below 100 mg/l. Metals in the well have also been notably low and are often below detection limit. There appears to be little to no impacts from the Pit Impoundment on the shallow aquifer in North Gulch.

West Gulch

MW-22

An analysis of the West Gulch water quality is limited to the deeper aquifer and will be discussed later in the report. Well MW-22, which is the only shallow aquifer monitoring well in West Gulch, has been dry since it was installed.

South Gulch

Water quality in South Gulch is more heavily impacted by the Pit Impoundment than the other two drainages. In South Gulch, there are three sample sites to monitor the shallow aquifer. From upgradient to downgradient, they are MW-17, South Gulch Spring, and MW-29. Technically, South Gulch Spring is a surface site; however, as it is a spring, it will be used to assess water quality in the shallow near-surface aquifer in South Gulch. Due to the greater impacts in the water quality of the sample locations within this drainage, each site will be discussed separately.

MW-17

Well MW-17 was drilled to a total depth of 44.8 feet, but a baroid hole plug was installed in the well from 21 to 44.8 feet in depth. The producing portion of the well is drilled primarily through colluvium and alluvium, with the possibility of some fractured bedrock at the bottom of the well. In MW-17, the water quality has stabilized since the well was installed. Initially, the pH in the well ranged from 6.0 to 7.0 SU. However, since the start of sampling in the well, the pH steadily declined until it stabilized below 4.0 SU in 2004. It has remained consistent ever since. Sulfates in the well rose briefly during 1995 and 1996, but decreased as the Pit Impoundment cap was installed. Currently, sulfates within the well are below the ground water standard of 500 mg/l.

Cadmium concentrations in MW-17 currently exceed the South Dakota Ground Water Quality Standard of 0.005 mg/l. Baseline concentrations within the well were at or near non-detection levels. During the mining phase and capping of the Pit Impoundment, the cadmium concentrations in this well increased to a maximum concentration of 0.429 mg/l. After the impoundment was capped, the concentration dropped quickly and stabilized between 0.05 and 0.1 mg/l until 2009, when there was another gradual decline. Currently, the cadmium concentrations range between 0.015 and 0.035 mg/l.

Copper also exceeded South Dakota Ground Water Standards at one time. The South Dakota Ground Water Standard for copper is currently 1.0 mg/l. During the mining and mitigation stages of the mine, the copper concentrations in MW-17 reached a high of 6.6 mg/l. Initially, the concentrations of copper dropped quickly after the cap was installed on the Pit Impoundment. In 1998, they stabilized at 1.5 to 2 mg/l before beginning a gradual decline in 2008 when it averaged 0.71 mg/l. The copper concentration has not exceeded the South Dakota Ground Water Quality Standard for nearly five years.

Metals in the sample analysis, including aluminum, iron, and zinc, do not have a South Dakota Ground Water Quality Standard for comparison. However, some of these metals do have a Federal Secondary Drinking Water Standard which may be utilized to show how ARD has impacted the well. Please note the secondary standards are not enforceable and are in place as guidelines to protect water from having bad smell, taste, or appearance or may cause cosmetic effects to the individual drinking this water (i.e. skin or tooth discoloration). As with the other constituents of this well, the highest concentrations for these metals in the pit were noted during the mining and mitigation phases of operation. After the cap was installed, the concentrations of the metals dropped quickly for a few years before developing a more gradual decreasing trend. The secondary federal drinking water standards for aluminum, iron and zinc are 0.2 mg/l, 0.3 mg/l and 5 mg/l respectively. Of these, only zinc did not exceed the secondary standard for this well. In 2013, the aluminum concentration in the well averaged 26.7 mg/l and iron concentrations averaged 1.0 mg/l.

South Gulch Spring

The South Gulch Spring sampling site is a gathering and collection system to intercept the majority of flow along South Gulch drainage. Tertiary dikes present in this area push the alluvial/colluvial water to the surface at this site, forming the South Gulch Spring. While this is technically a surface site, it is also an indicator of water quality within the shallow aquifer within South Gulch.

The water quality at this site is comparable to water quality in MW-17 and MW-29, although during operation and capping of the Pit Impoundment, the various constituents sampled had higher concentrations than the two upgradient sites. The pH at this site dropped to its lowest point of 1.47 SU in October 1995. After the Pit Impoundment was capped, the pH in the spring increased briefly to a high of 7.0 SU in 1996. The increase in the pH was short lived, and it declined gradually for approximately 10 years, reaching a low of 2.78 in 2007. The pH increased since then, reaching a high of 4.33 in 2009. However, the trend began to decrease again. In 2013, the pH in the spring averaged 3.35 SU.

Sulfates within the spring were also higher than other sites within the gulch. It reached a high concentration of 3,000 mg/l in 1995 during construction of the Pit Impoundment cap. After the cap was completed, the sulfate concentrations within the spring dropped quickly. In 1997, the average sulfate concentration was 485 mg/l. This trend reversed and gradually increased until 2003, when it began decreasing again. In 2012, the average concentration of sulfates within the spring was at 415 mg/l. In 2013, the concentration again increased and averaged 715 mg/l which is above the South Dakota Ground Water Quality standard for sulfate of 500 mg/l.

The other two common parameters of concern in the spring are cadmium and copper. As with the other sampling sites, the highest concentrations of these parameters were noted in the spring during the mining stage and construction of the Pit Impoundment cap. The highest concentrations for these parameters in 1995 were 0.742 mg/l for cadmium and 10.3 mg/l for copper. The highest copper concentration within the well was actually noted in 1994 at 13.6 mg/l. These concentrations dropped quickly after the completion of the cap. Cadmium concentrations within the spring appear to have stabilized around 0.045 mg/l since 1997. The copper concentration within the spring dropped to a low average concentration of 0.47 mg/l in 1997. The concentration then increased and regularly exceeded the 1.0 mg/l standard several times over the next 11 years. After 2008, the concentration of copper seemed to drop consistently under the standard until June 2013, when the concentration again briefly rose above the standard before dropping. This anomalous reading may have been due to a flushing of the system caused by 12 inches of precipitation in May 2013.

Other metals noted in the waters of South Gulch are also elevated in the spring. Aluminum concentrations were the highest in this site during mining and construction of the Pit Impoundment cap. The highest concentration of aluminum was 170 mg/l. In 2013, the average aluminum concentration was 40.9 mg/l which shows a general decreasing trend in the spring, although the concentrations can be highly variable. Iron in the spring is also highly variable, although as with aluminum, the overall concentrations are lower after the cap was completed. Zinc concentrations within the spring were elevated during mining and cap construction and quickly dropped and stabilized. In 2013, the average zinc concentration in the spring was 0.409 mg/l. The current water treatment system in South Gulch is effectively capturing and treating the water in the drainage as there are minimal impacts to sites located further downgradient.

MW-29

This well is drilled to a depth of 37 feet and is located immediately down gradient of the South Gulch Spring capture system. MW-29 operates as a pump back well to intercept any groundwater flow past the South Gulch collection system. The top 24 feet of the well is located in gravel and alluvium fill material used to construct a berm as part of the South Gulch Collection System. The next 11 feet were drilled through fractured amphibolite, and the remaining two feet were drilled into bedrock. It is screened over both the alluvium and fractured bedrock. This well was drilled in 1995 and was already impacted by the acid rock drainage from the mine pit.

As with MW-17, this well showed its highest concentrations of constituents in 1995. The pH of the water was already impacted in this area prior to the installation of the well. In the initial sampling, the pH was below 4.0 SU, although it did rise briefly before dropping again. In 2013, the pH in this well averaged 3.5 SU. This is significantly below the South Dakota Ground Water Quality Standard of 6.5 SU. Initial well samples had elevated levels of sulfate at over 2,000 mg/l. Those concentrations have gradually dropped and currently average 576 mg/l which is only slightly above the sulfate ground water standard of 500 mg/l.

The cadmium concentrations within the well currently are at levels above the South Dakota Ground Water Quality Standard. The concentration in 1995 was as high as 0.318 mg/l before quickly dropping to between 0.02 and 0.08 mg/l. The concentration remained stable until 2008 when it gradually decreased

until 2011, when the average concentration dropped to 0.017 mg/l. Cadmium concentrations then began another gradual increasing trend in 2012 and 2013, with average concentrations of 0.024 and 0.035 mg/l, respectively.

Copper in the well is currently below the South Dakota Ground Water Quality Standard of 1.0 mg/l. As with cadmium, pH, and sulfate, the copper concentrations were very high at the start of sampling for this well in 1995. The highest concentration recorded was 5.17 mg/l. The concentration quickly dropped after the Pit Impoundment was capped. The concentration then varied around 1.0 mg/l for several years. The copper standard was last exceeded in this well in 2007. Copper concentrations varied between 0.24 and 0.97 mg/l and have come close to exceeding the standard several times from 2008 to 2013. In 2013, the average concentration was 0.72 mg/l, with the highest concentration at 0.92 mg/l.

Aluminum, iron and zinc concentrations are also elevated in this well. Concentrations and trends are very similar to those found in MW-17 for these constituents. In 2013, aluminum concentration averaged 28 mg/l and iron and zinc concentrations averaged 0.78 and 0.4 mg/l.

Pit Impoundment: Bedrock Aquifer

MW-9B

Well MW-9B, an original baseline well, is the only well not associated with one of the three gulches that monitor flow from the Pit Impoundment. It is located to the northwest of the Pit Impoundment and is on the ridgeline between North Gulch and West Gulch. It is drilled to a depth of 370 feet through silicified schist and/or altered schist. The pH in this well was in a gradual declining trend until 2010, when the trend reversed. In 2013, the pH was 7.03 SU. Sulfates also had a gradual increase in concentration until 2005, when the trend became much more pronounced and concentrations rose to an average of 549 mg/l in 2008. Since then, the concentrations have dropped and in 2013, the average sulfate concentration was 170 mg/l. There are no other parameters of concern in this well. All are at non-detect or are stable below any established water quality standard.

North Gulch

MW-24

The deeper aquifer in North Gulch is monitored by MW-24. This well was drilled to a depth of 260 ft. The screened portion of the well is across amphibolite schist which contains a small portion of visible pyrite. MW-24 was installed as part of the monitoring program for the cap on the Pit Impoundment. As a result, it was initially sampled in 1995 shortly after the cap was completed. The pH in the well indicated a decreasing trend shortly after sampling began. However, this trend stabilized around 6.5 SU in 2003. Since this time, the pH has gradually increased and as of 2013, the average pH in the well was 6.78 SU. By the end of 2013, the pH had not dropped below the 6.5 SU South Dakota Ground Water Quality Standard since May 2008.

Sulfate concentrations also marked an increasing trend in this well from 1995 until approximately 2006, when it showed a declining trend. The sulfate trend is currently rising again, although concentrations remain below 250 mg/l which is well below the ground water standard. Cadmium and copper, both primary metals of concern in North Gulch, are currently not detectable within the well. Aluminum, iron and zinc concentrations are very low. Iron has recently been detected above its secondary drinking water standard of 0.3 mg/l.

West Gulch

MW-25

In West Gulch, there are two wells that monitor the deeper bedrock aquifer. MW-25, which was installed in October 1994, is drilled through a pyritic amphibolite schist to a depth of 270 ft. When sampling

began, the well showed impacts from the mining operation. In 1995, the average pH for the well was 6.08 SU. The sulfate concentration was slightly elevated at 508 mg/l. In 1996, the arsenic concentration was regularly above the older 0.05 mg/l arsenic standard (the standard was modified in 2001 to 0.01 mg/l). Water quality has slowly improved over time since. The pH remained fairly stable while the sulfate dropped to an average of 139 mg/l. Arsenic within the well is below detection.

MW-30

MW-30 was installed in West Gulch after impacts in the water quality at MW-25 were noted. The well was used to determine if water quality impacts had progressed further downgradient than MW-25. The water quality in the well was good and has remained stable for the course of its history. There did not appear to be any impacts to this well from the mine.

South Gulch

MW-26

MW-26 is the only deep bedrock monitoring well in South Gulch. This well is drilled through 30 feet of tertiary porphyry followed by 300 feet of amphibolite. The final depth of the well is 337 feet. When installed, the pH was around 7.0 SU. Since 1995, the pH decreased fairly steadily until 2007, when the pH stabilized around 4.4 SU. There was a brief rise in the pH of the well in 2003 before the pH continued to drop.

Sulfates within the well rose steadily until about 2007 when they began to drop. At the start of sampling in 1995, the sulfate concentrations averaged 268 mg/l. By 2007, the average sulfate concentration increased to 634 mg/l. In 2013, the average concentration dropped to 490 mg/l. This is still fairly close to the ground water standard of 500 mg/l; however, it is anticipated the trend should continue to decrease.

Cadmium in the well is currently elevated above the South Dakota Ground Water Standard of 0.005 mg/l. It rose gradually from 1995 with an average concentration of 0.003 mg/l to 2005, when the average was at 0.004 mg/l. From 2005 until 2010, the concentrations rose more quickly. However, since 2010, the concentrations have dropped. In 2010 the cadmium concentrations reached an average high of 0.009 mg/l. By 2013 the average cadmium concentration had dropped to 0.006 mg/l.

Aluminum and copper also showed an similar trend to cadmium with a more gradual rise in concentrations from 1995 to 2005 and a faster increase until 2011, when they began dropping off. Copper concentrations reached a high in 2011 with an average of 0.19 mg/l. By 2013, the average copper concentration dropped to 0.137 mg/l. Aluminum concentrations also reached an average high in 2011 at 14.8 mg/l. By 2013, it dropped to 11.6 mg/l.

Nickel and zinc concentrations have also had a generally increasing trend. Nickel concentrations peaked in 2009 at 0.44 mg/l and have since decreased to an average of 0.33 mg/l in 2013. Zinc concentrations peaked in 2007 and have been very gradually declining since. In 2013, the average zinc concentration in the well was at 0.69 mg/l.

Former Spruce Gulch Waste Rock Facility: Alluvial/Colluvial or Near-Surface Fracture Aquifer

There are 4 sites in Spruce Gulch which monitor the shallower aquifer. Two wells are located at the top of the drainage and were installed after the waste rock was removed from the Spruce Gulch Waste Rock Depository. Two other wells were installed below the retention pond as part of the program to monitor impacts to the drainage caused by the presence of ARD generating waste rock. The water quality graphs for these site are located Appendix D.1.

The two upgradient wells are MW-27 and MW-28. MW-27 was drilled to a depth of 24 feet through colluvium into the underlying porphyry. MW-28 was drilled to a depth of 20 feet and was also drilled through the surface colluvium and into the underlying porphyry. These wells were both installed in February 1995. The two downgradient wells are MW-19 and MW-20. MW-19 is drilled to a depth of 20 feet, but the hole caved-in at 18.5 feet. Though no information on the geology of the hole was found, it is highly probable (given the geology of other wells in the area) that it is drilled primarily through a colluvium/alluvium material. MW-20 was drilled to a depth of 80 feet. As with MW-19, no information on the geology of the hole was found, but it is assumed the hole is drilled into alluvium/colluvium near the top of the well and into fractured bedrock through most of the remainder of the hole. It is possible a small portion of the lower section of the hole has been drilled into unfractured bedrock. These wells were installed August 1992.

MW-27

The most upgradient well in the drainage is MW-27 located in the old footprint of the former Waste Rock Depository. When sampling began at the well, all of the acid generating waste rock in the depository had been removed and placed into the Pit Impoundment. During early monitoring, the pH in the well was dropping. The pH stabilized in the early 2000's, and as of 2013, the average pH of the water in the well was 6.21 SU.

Sulfate concentrations in the well also showed initial impacts from the presence of the acid generating waste rock. Sulfate concentrations peaked in late 1995 at 630 mg/l. After 1995, the concentration dropped in the well and stabilized. In 2013, the average sulfate concentration in the well was 203 mg/l.

Aluminum concentrations in the well were highly variable during the first two years of sampling and varied from non-detect to 1.75 mg/l. Since then, the aluminum concentrations have stabilized and dropped. In 2013, the average aluminum concentration was 0.02 mg/l. Iron concentrations have been and continue to be highly variable. Nickel concentrations showed the same general trend as aluminum in the well, with the average concentration in 2013 being 0.012 mg/l.

Cadmium and copper are two metals that have been noted as constituents of concern at other wells in the area. Neither of these metals are a concern in MW-27 at this time. In 2013, both metals were below the detection limit.

MW-28

This well is just south of MW-27. Sampling in this well began at the same time as in MW-27. At the start of sampling, the pH was low which indicated the well was in an area where the ground water had been impacted by the presence of waste rock in Spruce Gulch. Over time, the pH has had very little variation. In 1995 and 1996, the average pH was 4.35 SU. Since then, a slight drop in the pH has brought the average concentration down to 4.05 SU.

The sulfate concentrations also indicated impacts to the drainage during the initial part of sampling. The sulfate concentration in the well in 1995 averaged 749 mg/l with the highest concentration at 983 mg/l. Since then, concentrations dropped and in 2013, the sulfates were at nearly half of the South Dakota Ground Water Quality standard averaging 247 mg/l.

Cadmium concentrations are still above the South Dakota Ground Water Quality Standard of 0.005 mg/l. In 1995, the cadmium concentrations were elevated showing impacts to the ground water from the waste rock. The average cadmium concentration during this time was 0.015 mg/l. Over time, the concentration of cadmium has very slowly dropped. In 2013, the average cadmium concentration was 0.006 mg/l.

Aluminum, nickel and zinc concentrations were also elevated at the start of sampling in 1995. These metals have also shown decreasing trends over time. In 2013, the average concentration of aluminum in the well was 5.43 mg/l. The highest aluminum concentration was noted in 1995 at 39 mg/l. Nickel concentrations averaged 0.12 mg/l in 2013, while the highest recorded nickel observation was 0.886 mg/l in 1995. Likewise, the average zinc concentration in 2013 was 0.126 mg/l, while the highest observed concentration was noted in 1995 at 0.469 mg/l.

MW-19

This well is located just below the retention pond in Spruce Gulch and above the confluence of South Gulch and Spruce Gulch. Upon the start of sampling, the pH in the well showed minor impacts to the drainage as a result of waste rock disposal at the top of the drainage. During the start of sampling, the pH averaged 6.02 SU which is below the South Dakota Ground Water Quality Standard of 6.5 SU. Since that time, the pH has increased slightly and in 2013, the average concentration was 6.56 SU.

Sulfate concentrations in the well also showed initial impacts from mining activities in 1992. The sulfate concentration initially was low, but rose quickly to a high of 1,712 mg/l in 1994. Shortly after the waste rock was removed from Spruce Gulch, the sulfate concentrations decreased. After an initial fast decline, the sulfate concentrations continued to improve at a more gradual pace. In 2013, the average concentration of sulfate was 349 mg/l.

Other constituents in the well also showed the impacts to water quality during the mining and acid mitigation phases of the mine. Aluminum, cadmium, copper and nickel all showed spikes in concentrations in the early part of sampling followed by decreasing trends. Of these parameters, only cadmium has an established South Dakota Ground Water Quality Standard which was exceeded in initial sampling for the well. Currently, however, cadmium concentrations are below detectable limits.

MW-20

This well is located adjacent to MW-19 at the toe of the retention pond and above the confluence of South Gulch and Spruce Gulch. It was drilled deeper then MW-19, and while it is still considered a shallow monitor well, MW20 does not monitor the alluvium/colluvium as MW-19 does. The well, which is drilled to a depth of 80 feet and screened across bedrock, monitors fracture flow in the bedrock.

There were very few water quality impacts noted in this well as a result of mining activities at Richmond Hill. The pH and sulfates had the greatest water quality impacts. The pH concentrations initially averaged around 6.76 SU with a few concentrations dropping below the ground water quality standard of 6.5 SU. After this, the pH had slight fluctuations for several years before stabilizing. The pH is now stable and near neutral, with average pH in 2013 of 7.14 SU.

Sulfate concentrations in the well were initially low. Concentrations in 1992 averaged 84 mg/l. However, the sulfate concentrations gradually increased until they stabilized in 2002. Since this time there has been very little variation in the sulfate concentrations. In 2013, the average sulfate concentration was 452 mg/l. As with pH, sulfate concentrations has only exceeded the ground water quality standard a few times during the history of sampling.

Cadmium samples were only above the detection limit 4 times in the sampling history for this well. One sample was above the ground water quality standard. All detections of cadmium were noted between 1992 and 1994 and are currently meeting water quality standards.

Former Spruce Gulch Waste Rock Facility: Bedrock Aquifer

MW-11

In Spruce Gulch, MW-11 is the only well which currently monitors the deeper bedrock aquifer. This well is located near the top of the drainage in the footprint of the former Spruce Gulch Waste Rock Depository along the ridgeline south of MW-28. This well was drilled to a depth of 340 feet through altered porphyry.

The water quality in the well showed minor impacts during the active mining and acid mitigation stages of the Richmond Hill Mine. The pH and sulfate concentrations have no shown significant change in chemistry over the sampling history of this well. Metals sampled showed slightly elevated concentrations during active operations at the mine. These concentrations have since decreased and many are now below detection limit. Currently, only aluminum, iron, and zinc are above the detection limit, but these concentrations are very low. The water quality graphs for MW-11 are located in Appendix D.2.

SURFACE WATER QUALITY

In addressing the surface water quality for the Richmond Hill Mine, it is noted that while there were elevated concentrations of various metals throughout the site, they are all now notably lower, and all parameters are currently meeting surface water quality standards as established in the current (2014) Surface Water Quality Discharge Permit. LAC Minerals was issued two Notices of Violation in 1992 and 1994 for exceedances of Surface Water Quality standards. The discussion below focuses primarily on the metals noted within these notices of violation.

Also, it should be noted there are not currently any established standards for aluminum and iron at this site. However, in the 1992 Notice of Violation, site specific standards were established for these parameters. These site specific standards do not currently apply to the mine and are not addressed in the existing Surface Water Quality Discharge Permit.

Selenium is not mentioned above in the ground water section of this report as it has not been a concern in ground water. While there were several detections of selenium in ground water around the mine site, there has never been an exceedance of the ground water quality standard of 0.05 mg/l. However, the standard in the Surface Water Discharge Permit is 0.0046 mg/l which is much lower than the ground water standard. Therefore, selenium is of greater concern in surface waters at this mine.

PROCESS AREA:

Surface waters in the former Process Area primarily flow toward the northwest via Rubicon Gulch. The far eastern edge of the Process Area drains toward the east into Chism Gulch. Rubicon Gulch flows approximately two miles toward the northwest before contributing to Spearfish Creek. The southern portion of Pad 3 flows to the south, through the V-notch in to the Cole Creek drainage, a tributary of Cleopatra Creek.

According to LAC's Surface Water Discharge Permit, the discharge point for Process Area water consists of "Any flow in Rubicon Gulch, below the Stormwater/Contingency Pond." Compliance at this discharge point is monitored at Compliance Point 004 located approximately 60 feet downstream of the Stormwater Pond. Seasonal flow at the head of Rubicon Gulch consists mainly of discharge from LAC's water treatment plant (~ 50 gpm) with minor contributions from french drains (spring diversions) underlying the Stormwater Pond and Leach Pad 3.

Pad closure activities greatly reduced the overall potential of the Process Area to impact Rubicon Gulch. However, high levels of selenium in leach pad effluent pose a potential threat to surface water quality. The leach pads generate an average of around 16 million gallons of effluent per year. In 1998, LAC initiated long term treatment of pad effluent to ensure compliance with discharge requirements. The treatment facility, which is housed in the former process building, has evolved over the past 13 years. The current process involves year-round biotreatment (reduction of selenium, copper, and cadmium) and

seasonal reverse osmosis treatment, as necessary. LAC's full-scale biological treatment facility (which is located in an addition to the former process building) allows the company to maintain consistent compliance with surface water discharge standards, ensuring overall water quality in Rubicon Gulch remains good.

In the Process Area and off of Rubicon Gulch, there are four surface water sites. The compliance point for the NPDES permit is #004. This compliance point is located on Rubicon Gulch just below FD-1. FD-1 is also a surface site in this drainage which monitors the underdrain system to the Storm Water Pond. It can be used as a pump back station to bring water back to the treatment plant if a leak develops in the Storm Water Pond. FD-2 is located near the top of the Pad 3 draw just below Pad 3. The last site is S-5, which is located approximately half way down Rubicon Gulch from the mine. Of these four sites, FD-1 will not be discussed in detail as the water at this site is either pumped back up to the mine for treatment or, if treatment is not needed, it discharges downstream directly into sample site #004. Water quality graphs for these three sites are located in Appendix E.

FD-2

The most upgradient site in the Process Area is FD-2. This site monitors water quality at the outflow of the french drain system underlying the Pad 3 liner which was constructed primarily of sulfide-bearing materials. Water from FD-2 flows down the Pad 3 draw for approximately 1,400 feet, before flowing into Rubicon Gulch just above Compliance Point #004. This is the most impacted surface water site in the Process Area. This site is not a compliance point for surface water discharges from the mine.

There was a significant drop in the pH of this site during the mid-1990's due to the sulfide materials in the french drain. The lowest pH recorded at the site was 3.0 SU in March 1993. The pH continued to range between 3.0 and 4.5 through 1995. After completion of the Pad 3 cap, the capping of the french drain, and the completion of the V-notch to divert flow away from the french drain, the pH improved. By 1998, it improved to between 5.5 and 6.5 SU. Over time, the pH has continued to improve and stabilize, although the pH concentrations for the most part are still below the 6.5 compliance limit at compliance point #004.

As with pH, there were notable impacts to the sulfate concentrations at the site. Sulfates jumped to approximately 2,500 mg/l before dropping back down. Concentrations are currently well below 500 mg/l. There are no defined sulfate concentration limits in the surface water discharge permit for Rubicon Gulch. However, the primary interest in sulfates is that it a primary indicator of ARD.

Several elevated metal concentrations were also noted at this surface water site. Concentration spikes, were noted in all metals sampled at the site during leaching and capping of Pad 3 from 1995 to 1997. After completion of the Pad 3 and french drain caps and the V-Notch, the concentration of metals at the site dropped. Currently, most metals at the site are at or near non-detect except for fairly low concentrations of aluminum and nickel.

Compliance Point #004

This site is located immediately downgradient of FD-1 and monitors discharge from both draws of the Process Area. As mentioned above, one of these draws is the Pad 3 draw which is directly associated with drainage from FD-2. The second draw includes flow from Pads 1 and 2, the water treatment plant, process ponds, and the Crusher Area.

At this site, the greatest impacts noted in the historic water quality are during the operational and acid mitigation activities in the Process Area during the early to mid-1990's. This is primarily noted in the metals concentrations. Elevated concentrations of cadmium, copper, and mercury were specifically noted

at this location. However, these concentrations met the Surface Water Discharge Permit limits that were in effect at that time.

Surface water quality standards for selenium at Compliance Point #004 were initially established in the early 1990's. Since that time, selenium exceeded the standard in some instances at the compliance point. The Department of Environment and Natural Resources (DENR) in 1994 issued a Notice of Violation to LAC Minerals for several violations of the selenium effluent limit at the compliance point. Concentrations were elevated primarily during the operational and acid mitigation phases of the mine operation. All other parameters showed the typical improvement of general water quality at downstream sites. However, selenium concentrations at Compliance Point #004 were notably higher than those in FD-2. This would suggest the primary source of the selenium was from the discharge from the newly commissioned water treatment plant. It was determined the primary source of the selenium was from treated leach pad effluent. As a result of the elevated selenium and in accordance with the compliance schedule outlined in the NOV, LAC installed a selenium treatment circuit to the water treatment plant.

It is noted however, the historical water quality at this site is better than the water quality upgradient at site FD-2.

S-5

This site is the most downgradient site on Rubicon Gulch and was used to establish baseline on Rubicon Gulch prior to the start of mining. It is located approximately one-half mile downstream from CP#004 and is near the aquatic monitoring site. Though water quality is better than what has been noted at CP#004, water quality impacts were also noted at this site during the operational and acid mitigation stages of the mining operation. During this time, there was a spike in the sulfate concentrations in the creek as well as numerous detections of several metals including cadmium and copper. In more recent years however, the concentrations of the various metals sampled at this site are frequently below the detection limit. Sulfate concentrations have also dropped overall at this site. All water quality standards are currently being met.

PIT IMPOUNDMENT:

The pit impoundment is located in the southern half of the mine and has three primary drainages flowing from the site which are North Gulch, West Gulch and South Gulch. Compliance points #002 and #003 are located on West Gulch and North Gulch, respectively. There are no compliance points or immediate surface water sampling locations on South Gulch. Ground and surface water in South Gulch is collected and piped to the Spruce Gulch Water Management Facility, where it is treated with caustic to raise the pH and precipitate metals. Without diverting this water, South Gulch would naturally flow into Spruce Gulch below the Retention Pond. Spruce Gulch flows through compliance point #001 before continuing into Cleopatra Creek (this surface site will be discussed later in the Former Waste Rock Facility section of the report). The water quality graphs for these two compliance points are located in Appendix F.

#002

CP#002 is located on West Gulch just above the confluence of the gulch and Cleopatra Creek. There was little impact to the water quality at this site during mining, removal of waste rock from Spruce Gulch, and capping of the Pit Impoundment. While there may have been a general increase in various parameter concentrations at this site during these phases of the mining operation, all concentrations were very low. Currently, with the exception of aluminum and iron, the metal concentrations are normally detected at or below the detection limit. The pH concentrations at the site were more variable during the operational phase of mining and reclamation and ranged between 6.5 and 8.0 SU with only a few exceptions. In more recent years, pH sample results have shown more stable concentrations between 7.0 and 8.0 SU. Sulfate

concentrations also show little impact from any acid mine drainage at the site. Sulfate concentrations in this drainage were never elevated, with the highest concentration just over 160 mg/l.

#003

This sampling location is located in North Gulch just above the confluence of the drainage with Cleopatra Creek. As with CP#002, there were little to no impacts due to the acid rock drainage from the pit and the waste rock depository. The concentrations of both sulfate and pH, the two primary components of acid mine drainage, showed little variability in concentrations during this time. The pH at the site has generally fluctuated between 7.0 and 8.0 SU, while sulfate concentrations have remained mainly below 150 mg/l. Metals sampled at the site have also indicated little impact to the site. While there were greater detections of various metals during the earlier sampling days when the mine was operational and in mitigation, these concentrations were very low. Now, most metals are found to be below the detection limit. The exception to this is aluminum which is probably coming from natural sources.

FORMER WASTE ROCK FACILITY AND SPRUCE GULCH:

Spruce Gulch was the most impacted drainage from the effects of acid mine drainage at the Richmond Hill Mine. This is mainly due to the presence of waste rock and stockpiled sulfidic ore located at the top of the drainage. The three surface water sampling sites along Spruce Gulch are the Waste Dump Toe, Retention Pond Below, and Compliance Point #001. Water quality graphs for these sites can be found in Appendix G.

Waste Dump Toe

This site is located at the top of Spruce Gulch, and as the name implies, is located at the toe of the former Spruce Gulch Waste Rock Depository. During mining, waste rock and stockpiled sulfidic ore were placed in the headwaters of the Spruce Gulch drainage until it was discovered the material was causing acid mine drainage. This sample site was the most heavily impacted of the sites on Spruce Gulch. The acid mine drainage from Spruce Gulch lowered the pH of the water at this site as well as elevated sulfate and metal concentrations. These impacts were primarily noted during removal of waste rock and construction of the Pit Impoundment since the site was not sampled prior to this time. The constituents improved once mitigation activities were completed.

In 1992, DENR issued a Notice of Violation (NOV) to LAC Minerals for discharging acid mine drainage into the environment. The Waste Dump Toe sample location was noted in the NOV as a site where discharge was occurring at the mine. In the surface water tables associated with this NOV, exceedances of both chronic and acute standards in aluminum, cadmium, copper, iron and zinc were noted.

The lowest pH taken at this site was 2.15 SU in October 1995 which is a highly acidic concentration. During this time, acid generating waste rock was removed from the Spruce Gulch Waste Rock Depository. After the rock was removed, the area showed an overall increase in the pH, although the pH concentrations were highly variable. In 1995, concentrations ranged from 2.15 SU to 8.22 SU (August 1995). As the site gradually attenuated after the removal of the waste rock, the pH increased and stabilized at this site. By 2000, the pH of the site had risen back to an average of 7.2 SU. Currently, the pH is stable and in 2013, it was 7.5 SU.

The sulfates at this site also rose during the early portion of sampling at this site. Concentrations peaked in February 1994 at just over 3,000 mg/l. Concentrations of sulfate slowly decreased as waste rock was removed. By late 1995, the sulfate concentrations dropped back below 1,000 mg/l. Concentrations have remained stable since that time.

Metal concentrations at this site showed a similar trend to sulfates. All metals showed a large spike in concentrations in 1994 to 1995 during the mitigation phase of the mining operation. Once the waste rock

was removed from the depository, the concentrations of all metals dropped. As of 2013, all metals sampled at this site with the exception of aluminum, cadmium, copper, iron and nickel were below detection levels. The remaining metals had average concentrations of 0.39 mg/l, 0.002 mg/l, 0.006 mg/l, 0.365 mg/l, and 0.035 mg/l, respectively. Of these, aluminum is causing a visual impact to the water as white deposits of aluminum oxide were noted during past mine inspections in the areas where water was flowing above the Retention Pond.

In the graphs, the data set for sampling date June 8, 1993 was mostly excluded since several of the data points showed excessively high concentrations, often by an order of magnitude or more when compared to the remainder of the data for the site. The data was not able to be verified after 21 years and was therefore marked as an outlier and removed from the analysis.

Retention Pond Below

As its name implies, this surface site is located immediately below the retention pond dam in Spruce Gulch. This pond was installed in 1992 as the initial response to acid mine drainage from the waste rock depository. Caustic is added to the pond water to raise the pH. This sample site monitors seepage at the toe of the retention pond. The water quality at this site has nearly identical trends to the Waste Dump Toe site mentioned above. The water quality at the site degraded during the operational and mitigational stages of the mine.

The pH at the site dropped to its lowest concentration in May 1995. This sample event would have occurred roughly during the time the waste rock was being removed and placed into the Pit Impoundment. For the most part, the pH at this sample site has stayed between 6.0 and 8.0 SU and has improved with the concentrations becoming less variable. In 2013, the pH of the site averaged 7.36 SU.

Sulfate concentrations at this site were also impacted by the presence of the waste rock upstream. Sulfate concentrations rose briefly to near 3,000 mg/l before dropping after the waste rock was removed. In 2013, the average sulfate concentration at this site was 273 mg/l.

Metal concentrations at this sample location also showed spikes in the concentrations during the 1994-1996 time range. All metals decreased once mitigation at the mine was completed. As of the end of 2013, the primary metals still being detected at the site were aluminum and nickel. Nickel concentrations in 2013 were at or near the detection level, while aluminum concentrations averaged 0.03 mg/l.

Selenium concentrations at this site are notable in that the concentrations of this metal were higher than those noted upstream at the Waste Dump Toe during the mitigation activities at the mine. This would indicate one or more additional sources of water impacting this area besides the water coming from the Waste Rock Depository at the time. It is assumed this water was coming from the Pit Impoundment or from other springs noted in the area above the Retention Pond (i.e. Three Tree Springs). Currently, impacts from these other potential water sources do not appear to be negatively impacting the sample location, and selenium is no longer detected at the site.

Compliance Point #001

Compliance point #001 is located at the bottom of Spruce Gulch immediately above the confluence of Spruce Gulch with Cleopatra Creek. This site is a compliance point defined in the Surface Water Discharge Permit for the mine. As with the other sites in this drainage, there were impacts to this site during the early to mid-1990's when the mine was operating and acid drainage mitigation work was conducted.

In 1992, DENR issued a Notice of Violation which included a site just downstream from this site. In the Surface Water Discharge Permit, this site is located on Spruce Gulch 10 yards above the confluence with

Cleopatra Creek. In the NOV, the sample site RH-Spruce Gulch was located at the mouth of Spruce Gulch about 2 meters above the confluence of Squaw Creek (later renamed Cleopatra Creek). Samples taken in 1992 and used in the NOV all showed RH-Spruce Gulch to have exceedences of surface water chronic and acute limits for aluminum, cadmium, copper, iron and zinc. It should be noted under normal conditions, there are no established surface water quality standards for aluminum and iron; however, due to the heavy impacts to area streams caused by the acid rock drainage, site-specific standards are noted in the 1992 NOV for these two parameters. The aluminum and iron standards noted in the NOV are not currently being applied at these sites.

The pH and sulfate concentrations are the two primary indicators for acid mine drainage at this site. During the mitigation and operations at the mine site, the pH was highly variably and ranged from 3.5 to 8.35 SU. After mitigation was completed, the pH improved and concentrations averaged 7.79 SU in 2013. Sulfate concentrations also were elevated, and in August 1994 they peaked at 2,212 mg/l. Once mitigation was completed, the sulfate concentrations at the site dropped and in 2013, the average sulfate concentration at this site was 256 mg/l.

Metals at this site were also elevated in the early to mid-1990's. There were elevated concentrations of cadmium, copper, mercury, selenium, and zinc at this site. However, none of the metals exceeded surface water quality standards at the time except for selenium. In 1994, LAC Minerals did receive a Notice of Violation for exceeding the selenium discharge limits at this site. No other parameters were noted as being in violation of permit limits in this NOV. Once mitigation activities at the mine were completed, the water quality at this site improved quickly. By 2013, nearly all metals, with the exception of aluminum and nickel, were near or below detection limits and all discharge standards are being met.

CLEOPATRA CREEK and OTHER TRIBUTARIES

There are multiple sample sites along Cleopatra Creek. None of these sites are compliance points for the Surface Water Discharge Permit at the site. However, these sites were at one time used as part of the biological monitoring plan at the site and to assess the effectiveness of the closure activities at Richmond Hill. While a number of these sites are no longer a part of biological monitoring, water samples are still collected at these some of these sites. These sites are listed as follows, from upstream to downstream: OEA-1, OEA-1B-S7, OEA-2A, OEA-2, OEA-2B, OEA-3A-S4, OEA-3, and OEA-3B. Other tributary sites include Labrador Gulch and Cole Creek. Sample sites on these two tributaries include OEA-4 (Labrador Gulch) and S-3 (Cole Creek). Water quality graphs can be found in Appendix H. Due to the number of sites, the appendix has been split into 2 sections. Appendix H.1 showing graphs for sample sites above the confluence of Cleopatra Creek and Cole Creek, while Appendix H.2 contains graphs for surface sites on Cole Creek and on Cleopatra Creek below the confluence with Cole Creek.

OEA-1

This site is located upstream of LAC Minerals just below the confluence of the main branch of Cleopatra Creek with the east branch of the creek. OEA-1 is upstream of all impacts from the Richmond Hill Mine and monitors water quality coming into the section of the creek along the Richmond Hill mine site.

The site has maintained a good pH concentration throughout its sampling history. The pH at this site has remained between 6.5 and 8.5 SU except when the pH rose briefly to 9.8 SU in June 1995. Sulfate concentrations at this location have not changed throughout the sampling history. All concentrations of sulfates have remained below 100 mg/l at this site with the exception of a few more recent (since 2010) events which have been between 100 and 150 mg/l.

Aluminum concentrations are highly variable at this site; however, this variability is persistent throughout the sampling history of the site. The highest aluminum concentration noted at the site was 3.38 in April

2008 when there have also been several samples below the detection limit. Cadmium concentrations at this site are nearly always below detection with only a few exceptions occurring early in the sample history for the site. Also, copper concentrations are mostly below detection, although in the early sample history of the site, several samples were above the detection limit with the highest concentration at 0.017 mg/l in 1993. Iron concentrations have been highly variable throughout the history of sampling and range from a concentration of below detection to just above 2 mg/l. Concentrations of the final three metals (nickel, selenium, and zinc) are mostly below detection limits. Nickel and zinc have been above detection limits once early in the sampling history for the site and once from 2007 to 2010. Selenium has only exceeded detection limits three times in more recent years (2011 to 2012).

OEA-1B-S7

This site is located approximately 150 to 200 yards downstream of OEA-1 and upstream of potential impacts to surface waters from the Richmond Hill Mine. The sample location was placed here because of the historic Eagle Bird Mine located immediately upstream of the site, which has the potential to generate ARD. It monitors potential pre-existing ARD in the creek.

For the most, water quality at this sample location was similar to that at OEA-1. The biggest differences were noted in iron and zinc. The pH concentrations have been relatively consistent, although the pH was slightly more variable in earlier sampling history. In the late 1980's through mid-1990's, the pH of the site varied between 6 and 8.5 SU except for one August 1988 sample that had a pH of 4.2 SU. Since then, the pH at this site has become more stable, and since 2000, the range has stayed fairly consistently between 6.5 and 8 SU. Sulfate concentrations have also been relatively low and consistent throughout the history of the site and have remained below 100 mg/l.

Aluminum concentrations at this sample location have been highly variable throughout the history of the site. The concentrations have ranged from 0.1 to just above 2.0 mg/l. Aluminum levels were higher at this site than at OEA-1 during the early to mid-1990s. Since constituents generally decrease in concentration downstream, this would indicate a potential for a new source of aluminum being introduced into the stream channel between sites OEA-1 and OEA-1B-S7. This additional source of aluminum may not be from mining activities in the area, but from natural sources such as changes in the geology of the area. However, given the short distance span between OEA-1 and this site as well as the obvious presence of historic mining activity, the most likely source would be the historic Eagle Bird Mine. In more recent years, however, the concentration of aluminum has decreased and remains lower than the concentrations noted at the upstream OEA-1 site. The same trends were noted for iron and zinc as well.

Other metals at the site have been noted in very minor amounts. Selenium has never been detected at this site. Cadmium, copper and nickel all were noted briefly during the early 1990's and have since been primarily below the detection limit. Zinc had higher concentrations than upstream sites in the early 1990's as mentioned above. However, since that time, the concentrations of zinc at this sample location have been primarily below detection.

OEA-2A

OEA-2A is the first sample location in Cleopatra Creek below the confluence with Spruce Gulch. Since the primary impacts of ARD were noted in Spruce Gulch, this site would have detected the greatest impacts to Cleopatra Creek from ARD at the mine.

The pH at this site was variable during the mid-1990's, with the lowest pH noted at 5.5 SU. Overall, during the earlier sampling period at this site, the pH ranged from 6.5 to 8.2 SU. Since this time, the variability in the pH concentrations at this site has improved. From 2008 to 2013, the pH ranged primarily from 7.5 to 8 SU. Sulfate concentrations also were slightly elevated during the mid-1990s. Concentrations for sulfate jumped as high as 529 mg/l in 1994. This concentration was much higher than

sulfate concentrations noted at OEA-1B-S7, indicating Spruce Gulch was the likely source of elevated sulfates within this section of Cleopatra Creek. Sulfate concentrations did improve after the mitigation work was completed at the mine with levels consistently below 100 mg/l since 2003.

Aluminum concentrations at this sample location have been highly variable throughout the sampling history of the site. The data may show that historically, the site had higher concentrations of aluminum while there were ARD issues at the mine. However, it is important to note that the sampling frequency was also greater during the mid-1990s which may contribute overall to the higher aluminum concentration average noted during this time. Overall, there does not appear to be any trends associated with aluminum concentrations over time at this sample location. Iron concentrations have also followed a similar trend. The concentrations are highly variable, but consistent throughout the sampling history of this location.

Copper, cadmium, nickel and zinc concentrations at this sample location all follow similar trends. During the mid-1990's, there were several detections of each metal. These elevated detections were in some instances higher than OEA-1B-S7, which shows impacts to this section of Cleopatra Creek from Spruce Gulch. Copper concentrations were noted as high as 0.16 mg/l in 1994. The highest cadmium concentration was 0.019 mg/l in 1994. Also, nickel and zinc recorded their highest concentrations at 0.299 mg/l and 0.606 mg/l, respectfully, in 1994. Since this time, these concentrations have dropped and these metals are consistently below the detection limits.

<u>OEA-4</u>
Sample location OEA-4 is located on Labrador Gulch just above the confluence with Cleopatra Creek. Since this drainage flows into Cleopatra Creek from the south, there is no impact on this drainage from the acid rock drainage concerns noted at LAC Minerals. There are also no known impacts to this creek from other mining activities in this area.

The pH concentrations at this site have remained consistently between 7.0 and 9.0 SU without only a few exceptions since 1993. Sulfate concentrations are also very low, with a few detections of sulfate early on in 1994 and from 2002 to 2004. These detections were all below 20 mg/l.

Aluminum and iron concentrations at this location are highly variable. Aluminum concentrations range from below detection to 2.15 mg/l. Aluminum concentrations may be perceived to be increasing, as they have not been below the detection limit since 2003. However, this perception may be incorrect as the majority of these samples were collected on a bimonthly basis before 1998. Also, the detection limit for aluminum was changed to 0.01 mg/l after 2003, which is below the previous detection limit of 0.05 mg/l. Iron concentrations at this sample location range from below detection to a high of 1.39 mg/l. There is no discernible trend in the data for iron.

Other metals at this sample location are primarily below the detection limit. Selenium has never been detected at this location. Cadmium, copper, zinc, and nickel all had detectable concentrations when the sampling frequency was greater. All detectable concentrations were very low.

<u>OEA-2</u>
This site is located on Cleopatra Creek just downstream of the confluence of Labrador Gulch with Cleopatra Creek. Since this site is downstream of Spruce Gulch, the site was vulnerable to impacts from the acid drainage at the mine.

The pH at this site was higher than the other upstream sample locations on Cleopatra Creek. Concentrations ranged primarily from 7.0 to 9.0 SU and were very similar to those noted at site OEA-4. Sulfate concentrations at this site were slightly elevated in the mid-1990's, but were lower than

concentrations noted at OEA-2A. The highest sulfate concentration noted was 290 mg/l in 1994. Sulfate concentrations at this site have improved since then and have been below 50 mg/l since 2009.

Aluminum and iron at this site are highly variable and have similar trends to those noted above in OEA-4 and OEA-2A. Other metals at this site are primarily below the detection limit. Cadmium, zinc, and nickel all followed similar trends to those noted in OEA-2A and were below detection limits. However, detectable levels were noted primarily from 1992 to 1996. After the completion of acid drainage mitigation work in Spruce Gulch, levels returned to below detection limits.

However, selenium and copper had higher concentrations than those noted at either OEA-4 or OEA-2A. A selenium concentration of 0.014 mg/l was recorded in 1994. There were no detections of this metal at either of the sites immediately upstream of this location. During the early to mid-1990's, copper was detected at this site, and two of these detections in 1993 and 1994 were 0.316 mg/l and 0.198 mg/l, respectively which were higher than those noted at upstream sites. The source of these metal detections at this location is unknown, but since there were only a few detectable samples, they may be outliers. However, as the data was similar to data noted in OEA-2A, they were left in the data set.

OEA-2B

This site is on Cleopatra Creek downstream of OEA-2 and the confluence of West Gulch and Cleopatra Creek. Two smaller unnamed intermittent or ephemeral drainages also flow into Cleopatra Creek from the west above this sample location. Primary impacts to this section of the creek are from the Richmond Hill Mine.

The pH concentrations averaged between 7.0 and 9.0 SU throughout the sampling history of this site. The only exceptions to this were in 1994 and 1995 when the pH values were above 6.5 SU and below 7.0 SU. Sulfate concentrations at this site have also been primarily below 100 mg/l, with a few notable exceptions in 1994 and 1995 when concentrations were as high as 303 mg/l. This is slightly higher than the highest concentration noted at OEA-2. During the mid-1990's, the general trend of sulfates showed impacts to the creek from the mine which were quickly mitigated once waste rock was removed and the Pit Impoundment was completed. Sulfate concentrations at this site have been below 50 mg/l since 2004.

As with the sites upstream of this location, aluminum and iron concentrations are highly variable. While it may appear the trend for these two metals may be decreasing over time, again this may be an illusion since fewer samples are collected now than in the past. Currently, these two metals have no discernible trends.

For the remainder of the metals, selenium has never been detected at this site. Cadmium, copper, nickel and zinc concentrations were noted early in the sampling history for the site in the early to mid-1990's. Since this time, a majority of the samples have shown the concentrations of these metals to be below detection. Only a couple exceptions were noted in cadmium, nickel, and zinc, and these concentrations were noted to be right at the detection limits.

OEA-3A-S4

This site is located on Cleopatra Creek immediately above the confluence of Cleopatra Creek and Cole Creek. This site is located nearly two miles downstream of OEA-1 and slightly more than a half mile downstream of OEA-2B. Between sites OEA-2B and OEA-3A-S4, North Gulch flows into Cleopatra Creek which adds potential from the Pit Impoundment.

The pH concentrations at this site have primarily been between 7.0 and 9.0 SU. Some exceptions to this range were noted early in the sampling period for this site in 1988. Samples taken in 1988 were all below 7.0 SU, with one sample going as low as 5.0 SU; however, the validity of this data point is in question

since the lab pH for this same sample was determined to be 8.0 SU. Sulfate concentrations at the site have remained below 100 mg/l for most of the sampling history at the site. There are only a few exceptions to this, and those samples were collected in 1994. The highest concentration noted at the site was 286 mg/l.

As with the other sample sites on Cleopatra Creek, the aluminum and iron concentrations at the site were highly variable. There are no discernible trends for these metals, and concentrations are slightly lower than those noted at upstream sites.

Cadmium, copper, nickel, selenium, and zinc have all been detected at this location with the majority of detections occurring from 1988 to 1996. After 1996, these metals were consistently non-detectable except for some random detectable levels of nickel and zinc. Selenium was detected in one sample at this site in 1988.

S-3

This site is located on Cole Creek just above the confluence with Cleopatra Creek. The headwaters of Cole Creek are located at the Richmond Hill Mine. Primary impacts to Cole Creek are from the Turnaround Pit and the V-Notch areas. Lesser impacts would be from the Process Area (Pad 3) and the Pit Impoundment. Sampling at this site began in 1996 after the completion of mitigation work at the mine. The primary metal analysis for most surface water sites is for total recoverable metals; however, until 2001, only dissolved metal analysis was conducted. Dissolved metals analyses were conducted since the site was a monitoring location associated with the ground water discharge permit for the land application area just north of the Process Area. As a result, the graphs in the Appendix for this site show a gap in the metals data during the five year period when only dissolved metals were analyzed for this site.

The sulfate and pH concentrations at this sample location were steady throughout the sampling period. The pH concentrations for the site have remained mostly between 7.0 and 8.5 SU. Only two exceptions were noted, with one pH value dropping to 6.74 SU and one value rising as high as 8.87 SU. Sulfate concentrations have been very low throughout the sampling history, with concentrations remaining below 50 mg/l except for one sample with a concentration of 51.6 mg/l.

Regarding metals, iron, aluminum, and zinc are the only constituents of primary concern at this site. Zinc has only been detected a few times at this site. Both the iron and aluminum concentrations at the site are highly variable, but appear to be greatly affected by the season. The site is sampled twice annually in the spring and late summer. The spring sample events tend to have higher concentrations of these metals than the summer samples. This may be due to the metals flushing from upstream sources during the spring snowmelt.

OEA-3

This site is located on Cleopatra Creek immediately below the confluence of this creek with Cole Creek. Both S-3 and OEA-3A-S4 are just upstream from this site on Cole Creek and Cleopatra Creek respectively.

The pH levels at this site had greater variability during the mid-1990's. The pH concentrations ranged from 6.5 to 9.0 SU. This variability has gradually decreased over time, and since 2007, this range has decreased to 7.5 to 8.5 SU. The sulfate concentrations at this site also showed some impacts during the early sampling period in the mid-1990's. The highest sulfate concentration noted at the site was in 1994 at 202 mg/l. Since then, sulfate concentrations have dropped and have been below 50 mg/l since 2004.

As with other Cleopatra Creek surface sites the aluminum and iron concentrations at this sample location are variable and have no discernible trend. Aluminum concentrations range between none-detect to 1.17 mg/l. Iron concentrations also ranged between non-detect to 0.879 mg/l.

Other metals at this site were primarily below the detection limits. However, cadmium, copper, nickel, and zinc were all detected in a small number of samples at this location during the mid-1990's. There have been no detections of selenium at this location.

OEA-3B

This site is the final sample location on Cleopatra Creek and the last of the currently active sample locations at the mine. This site is located nearly a mile further down Cleopatra Creek from OEA-3. It is located immediately upstream of the confluence of Cleopatra Creek and Spearfish Creek.

The pH at this site was highly variable in the mid-1990's with a range from 6.5 to 9.5 SU. This variability has gradually improved at the site and has remained mostly between 7.5 to 9.0 SU since 2007. Sulfate concentrations at this site were slightly elevated in the mid-1990's with a maximum concentration of 216 mg/l. Since then, concentrations have consistently been below 100 mg/l.

Iron and aluminum concentrations at this site have been highly variable, although there were some slightly higher concentrations during the mid-1990's. Concentrations of aluminum have remained below 1.5 mg/l since 1995, and iron concentrations have been below 1.0 mg/l since 1997. Recently, the concentrations of these two metals have shown seasonal trends with the higher concentrations tending to occur during the wet months of the year, primarily in spring.

Cadmium, copper, nickel, and zinc concentrations have been primarily below the detection limit. However, these metals were detected several times in the mid-1990's. Since that time, concentrations have decreased with very few detectable concentrations noted after mitigation work at the mine was completed. . Selenium has only been detected at this site once in 1999 at a concentration of 0.006 mg/l which is just above the detection limit of 0.005 mg/l.

Future Water Impact Concerns and Monitoring

As discussed above, there were significant impacts to water quality from ARD near the Richmond Hill Mine during the operational and mitigational stages of the operation. Once mitigation was completed, there has been a marked improvement in water quality throughout the site with the exception of some sites in South Gulch. At these sites, water quality continued to degrade until recently when it began to show improvements. Overall, water quality at the mine is stable or improving.

Process Area

Primary concerns for future impacts to water quality are associated primarily with potential leach pad cap failures and final reclamation work at the site. Discharges from the leach pads are currently captured and treated before being discharged from the site. It is not known how long water treatment will be required for the pads.

Capping of the pads has successfully mitigated acid rock generation at the site. Barring a catastrophic failure of the caps over Leach Pads 1 and 2 which would restart the acid generation process and produce greater amounts of poor quality water, the existing system is adequate to treat and discharge water from the Process Area. It should be noted that a cap failure of Leach Pad 3 may not restart acid generation as ARD has been controlled on Leach Pad 3 due to the limestone amendment. A cap failure on Leach Pad 3 would lead to an increase in water quantity, without necessarily decreasing water quality. Also, the revised water quality monitoring plan approved by the department in October 2014 (see LAC Minerals' Technical Revision No. 67) provides for adequate surface and ground water monitoring to determine if

there are any future negative impacts in the immediate vicinity of the Process Area. This will allow for adequate warning time to establish mitigation measures should they become necessary.

Since it is unknown how long water treatment will be needed at this area of the mine, LAC Minerals and the department have agreed to a 100-year postclosure period. This will allow for 95 years of water treatment in the Process Area prior to removal of the water treatment plant and ponds during final reclamation. However, this time frame may be shortened based on improving selenium trends at the site. LAC officials currently believe if the trends continue, the company may be able to eliminate selenium treatment in approximately 40 years. Once water treatment is completed and the plant and ponds are reclaimed, water quality monitoring is recommended to continue for an additional 5 years to ensure it is not impacted by reclamation activities.

Pit Impoundment and Former Spruce Gulch Waste Rock Depository

The Pit Impoundment and the former Spruce Gulch Waste Rock Depository are the portions of the mine with the greatest potential for water quality impacts during the postclosure period. The ore body associated with this mine was a sulfidic ore deposit with a large oxidized component. The oxidized portion of the ore body, however, still had some potential to generate acid mine drainage from certain portions of the ore body. Also, in the course of mining, a large section of unoxidized sulfide rock was exposed in the bottom of the pit impoundment. This sulfide material was the main source of acid mine drainage at the site from both the waste rock and ore materials associated with it.

During acid mitigation at the mine, acid producing waste rock from the depository was removed and backfilled into the Pit Impoundment. Even though the waste rock was removed, native soils in Spruce Gulch were impacted from acid drainage. After the waste rock was removed, the soils were amended with limestone to neutralize acid generated from the waste rock prior to topsoil placement and seeding. While trends are showing improvements since the mitigation work was completed, there are still some impacts to this portion of the Spruce Gulch water regime. It is not known what the ambient conditions were at this site. Should trends begin to show a degradation of water quality, additional mitigation measures may need to be developed and implemented for this area.

The Pit Impoundment poses the greatest potential water quality concern at the mine, as it holds the rock with the greatest potential for generating acid at the site. A multi-layer cap has been installed on the Pit Impoundment, and various instruments installed throughout the cap monitor water infiltration rates, oxygen, and temperature changes beneath the cap. Since its installation in 1995, the cap has proven to be very successful. Monitoring instruments show very little external impacts to the material beneath the cap thereby reducing the amount of acid mine drainage produced through this facility. Based on water quality information for the site, ground water flows from the Pit Impoundment area may be to the south and west, since the greatest impacts have been noted in monitoring locations in South Gulch, though natural sulfide deposits most likely provide the greatest impacts to this drainage.

A liquid caustic water treatment system has been established in Spruce Gulch (the Spruce Gulch Water Management Facility). This treatment system raises the pH of the water being treated, which neutralizes acid and precipitates metals and salts. It treats water flowing through the former depository area in Spruce Gulch and also from South Gulch Spring, which is pumped over to the treatment facility This treatment system has been in place for a nearly 20 years and has successfully discharged water that meets surface water quality standards.

Also, the revised water quality monitoring plan approved by the department in October 2014 (see LAC Minerals' Technical Revision No. 67) provides for adequate surface and ground water monitoring to determine if there are any future negative impacts in the Spruce Gulch and Pit Impoundment area. This will allow for adequate warning time to establish mitigation measures should they become necessary.

Currently, the greatest concern to the overall impact to water quality is the maintenance of the cap on the Pit Impoundment. If this cap fails, water quality associated with the Pit Impoundment may degrade quickly and uncontrollably until effective mitigation measures are instituted. Reversely, water quality monitoring may also be a great indicator of potential problems with the cap, and monitoring is necessary of both the cap and water quality to ensure proper operations at the site.

During development of a mitigation plan for the postclosure period, action levels for postclosure monitoring should be set to allow a period of time to monitor and verify if water quality trends are persistently exceeding established action levels which may indicate potential acid generation from the capped areas or other areas of the mine. If trends show that action levels are being exceeded, plans need to be developed to verify the source of any acid drainage in the drainage (i.e. tracer tests) to determine the type of mitigation work necessary to protect the water quality in the drainages around the mine site.

Summary

The Richmond Hill Mine has a history of water quality impacts to areas around the mine due to acid mine drainage associated with the mining of a sulfide rich ore body in the Richmond Hill Pit. After these impacts were mitigated, water quality around the mine has improved. Continued maintenance of the caps on the leach pads and the pit impoundment is necessary to maintain and improve water quality at this site. Also necessary for maintaining water quality is on-going water treatment in both the Process Area and Spruce Gulch. The revised water monitoring plan at the site is adequate for tracking water quality at this site and to give early warning of problems occurring. A postclosure plan for this site must ensure proper monitoring of the caps, adequate water quality monitoring to ensure protections in place are properly maintained, and mitigation measures which may be necessary should repairs need to be made or treatment increased at the site to continue maintenance of the water quality at the site.