

SELENIUM MANAGEMENT CHALLENGES AT KEMESS MINE

J. McConnachie, A.Ag.
G. Lysay, P.Eng.
H. Bent, P.Geo.

Northgate Minerals Corporation – Kemess Mine
Box 3519 Smithers, BC

ABSTRACT

In 1997, Kemess Mine began to place waste rock in permanent storage immediately west of the open pit. Waste rock placement occurred within the watershed boundary of a second-order tributary to Attichika Creek in the larger Finlay River watershed. Although diversion systems were constructed around the Waste Rock Dump, much of the small watershed remains intact, with several perennial and ephemeral sources of water, such as localized wetlands south of the Waste Rock Dump, interception ditches diverting water away from the Pit, and seepage water from the toe of the Waste Rock Dump. All of these sources inevitably report to Waste Rock Creek, and provide habitat for a resident Dolly Varden population. Although the waste rock is non-acid generating, the third source, seepage water from a portion of the Waste Rock Dump, was found to contain elevated selenium concentrations.

Selenium concentrations in Waste Rock Creek have consistently exceeded the BC Approved Water Quality Objective since late 2003. In 2004, following a review of cumulative water quality data for Waste Rock Creek and discussions with Kemess staff, selenium was recognized as an element of concern at Kemess Mine by the BC Ministry of Environment (MOE). As a result, comprehensive investigations have followed to: identify the predominant selenium source through data analysis of material characterization and geochemical modeling; develop monitoring programs to adequately characterize trends in the receiving environment water, sediments, benthos, and fish; and develop strategies for effective risk assessment and mitigation. This paper summarizes the findings of enhanced monitoring programs and maps the challenges faced while developing an appropriate mitigation strategy.

KEY WORDS: selenium management, Dolly Varden, monitoring

INTRODUCTION

The Kemess South Mine is a gold-copper open pit mine owned and operated by Northgate Minerals Corporation. The Kemess South mining and milling operation is located in the Omineca mountain range of north-central British Columbia, approximately 300 km northwest of Mackenzie, British Columbia. An all-weather main line industrial road from Mackenzie (Omineca Resource Access Road (ORAR)) provides for transportation of mine supplies and Cu-Au concentrate, while personnel are flown to site from select locations in the BC interior. The Kemess South Mine site consists of an open pit mine, waste rock dump (WRD), tailings storage and mill with a capacity to process over 52,000 tonnes per day of ore.

The Kemess South mine site is primarily located in the Kemess Creek drainage basin. Kemess Creek has a median basin elevation of 1550 m and a drainage area of ~120 km². The creek discharges southward into Attichika Creek, which flows west into Thutade Lake, the headwater of the Finlay River. The Kemess Creek watershed has two main tributaries, South Kemess and North Kemess Creeks. The tailings

impoundment is located in the upper reaches of South Kemess Creek. The open pit, mill, concentrator, and camp are located on the west side of the Kemess Creek mainstem.

The non-acid generating waste rock storage area (i.e., NAG Waste Rock Dump) is the only major mine feature not located within the Kemess Creek watershed. The NAG Waste Rock Dump is located within the catchment of a small, second-order tributary (i.e., Waste Rock Creek, see Figure 1) to Attichika Creek that drains through wetlands on the Attichika floodplain and into the mainstem channel approximately 3 km upstream from Thutade Lake. The Attichika Watershed is approximately 625 km² in area, comprising approximately one-third of the entire Thutade Lake drainage basin.

BACKGROUND

Sources of Selenium at Kemess South Mine

Selenium was first identified as an element of potential concern during static and kinetic testing completed in 2000 of the waste rock types. As noted in Davidson and Chapman (2006), the main rock types of concern based on kinetic testing are Leach Cap and graphitic Asitka. The Leach Cap Waste material is isolated on the main non-acid generating (NAG) Waste Rock Dump, while the graphitic Asitka was segregated to a stockpile adjacent to the Pit awaiting subaqueous storage when the Pit is available. Of these rock types, the Leach Cap Waste contributes to the receiving environment water quality, while the graphitic Asitka does not have a pathway for connection to the receiving environment. The Asitka NAG group, as modeled by Klohn Crippen Berger (2008a), also has some contribution to the receiving environment water quality due to the sheer quantity of this material that is stored in the NAG Waste Rock Dump.

Development in Waste Rock Creek and Implications to Fish Habitat

Waste Rock Creek - Pre-Mining

Waste Rock Creek supports a resident population of Dolly Varden (DV) char. Construction of the Omineca Resource Access Road (ORAR) approximately 30 years ago isolated a portion of this population on the upstream of the road, separating Upper and Lower WRC. Early fish assessments in 1993 indicated that this upper DV population was self-sustaining prior to the time of the mine development. Fish salvage and transplant was conducted on those sections of Upper Waste Rock Creek that were to be impacted by the establishment of the waste dumps. In 1996, 610 DV were salvaged and transplanted to Diagonal Mountain Creek, a previously barren system at the south end of Thutade Lake. These fish established a viable population in this system, ensuring the genetic diversity of the Waste Rock Creek DV population was maintained.

Waste Rock Creek – Post-Waste Rock Placement

Within the Upper WRC and Upper Pond section, most of the suitable spawning areas (approximately 90%), as well as critical seepage tributaries and ponds providing overwintering habitats, were lost with the development of the waste rock dump. These areas were identified prior to the development of the project and compensated for as outlined in the 1996 Fisheries Compensation Agreement (FCA). A limited number of DV now reside in the Upper WRC and Upper Pond section.

Lower Waste Rock Creek (downstream from the perched culvert at the ORAR crossing) flows in the original creek channel for 250-300 m and then to a large wetland complex within the Attichika Creek floodplain. Observations indicate that DV spawners, unable to ascend Waste Rock Creek past the road culvert, spawn in gravel pockets in the Lower WRC stream section below the road culvert. Sampling in Lower Waste Rock Creek in September 2008 indicated a healthy mix of fry (based on small size, <50 mm fork length) and yearling DV were also present. Lower Waste Rock Creek flows into the Attichika wetlands, where it combines with seepages from Attichika Creek. The wetlands provide rearing habitat primarily for DV and a small number of juvenile rainbow trout. The presence of the fish suggests that successful spawning and larval development occurred in 2007 and 2008 in fish habitat within or connected to Lower Waste Rock Creek. This area was not included in the Fisheries Compensation Agreement and thus is the main area of concern in terms of potential effects of elevated selenium concentrations in Waste Rock Creek.

Collection and Pumping of Elevated Selenium Seepage Water

Short-Term Management

Results of water quality monitoring in Upper Waste Rock Creek (WRC) indicate that selenium concentrations have been increasing since 2002. The source of elevated selenium levels in Waste Rock Creek is determined to be seepage water from the southern toe of the NAG WRD. Based on the water quality monitoring, as well as supporting information from biological and sediment sampling programs (as discussed below), a collection pond was constructed in late 2007 at the toe of the WRD to contain seepage water and enable better quantification of flows (and selenium loading) and allow for seepage diversion capability if warranted. At that time, an enhanced monitoring program was proposed to regulators with the intent of collecting information that would feed into appropriate mitigation strategies. In the summer of 2008, it was determined that more immediate action was required, and a plan was devised to install a pumping system to direct seepage water into the mill tailings circuit for disposal into the Tailings Storage Facility (TSF). The system was activated in September 2008 as a short-term management strategy coinciding with enhanced monitoring to assess potential implications of pumping water out of the Waste Rock Creek system.

Enhanced Monitoring Program – Habitat Assessments and Hydrology

Associated with the short-term management strategy of collecting and pumping the seepage water from Waste Rock Creek are the unknown implications for decreased flows to fish habitat in Lower WRC.

Prior to the summer of 2008, available hydrologic data were not sufficient to adequately assess potential changes to flow. Thus, in conjunction with pumping, an enhanced monitoring program was developed to (1) quantify water sources to Waste Rock Creek and (2) assess potential changes to fish habitat.

Surface Water Sources to Upper Waste Rock Creek

With the development of the waste dumps, the present day upper watershed now comprises a small section of original channel upstream of the Waste Rock Dump, a collection ditch and pond system (Southern Collection System) on the southern end of the WRD, an Upper Pond area located immediately downstream of the WRD southern collection ditching, and a mainstem channel from the Upper Ponds to the ORAR culvert crossing (Figure 1).

The Southern Collection System collects seepage water from the toe of the WRD, which comprises water from the remnant, undiverted flow upland of the WRD, infiltration from the surface of the WRD, diversion water from the Pit highwall ditch, and run-off from mine road surfaces. The Upper Ponds source water from the Southern Collection System and an undisturbed wetland complex hydraulically isolated from the Southern Collection System. The mainstem channel (Upper Waste Rock Creek) is approximately 900 m in length and transports water from both source areas.

Hydrometric data from all of these sources indicate that, with the exception of a rapid snowmelt response from the wetland complex, the flow in Waste Rock Creek is attributed to changing contributions from the Pit highwall ditch and WRD seepage water. While this indicates that not all the WRD seepage is currently captured in the collection pond, the uncollected water is largely maintaining water levels in WRC, especially when flows are not available from the Pit highwall ditch (i.e., January to April).

Surface Water Sources to Lower Waste Rock Creek and Attichika Wetlands

Downstream of the compliance monitoring station, but still within the Upper Waste Rock Creek mainstem, a small, ephemeral source of water enters the stream from the Western Collection System. The Western Collection System carries water from the local wetland with some input from the Waste Rock Dump, and potentially only contributes 1% of the peak flow in Waste Rock Creek.

There are no discernable inputs downstream of the ORAR crossing and upstream of the Attichika wetlands in the 250-300 m of Lower Waste Rock Creek channel. Within the Attichika wetlands, water from Waste Rock Creek is supplemented with seepages sourced from Attichika Creek.

Habitat Assessments in Lower Waste Rock Creek

In conjunction with hydrologic monitoring, habitat surveys were conducted (Bustard, 2009) to evaluate the potential change in fish habitat in Lower Waste Rock Creek related to decreased flows resulting from the diversion of elevated selenium seepage water. Several criteria were measured in order to develop a weighted usable width (based on mean velocity, mean depth, and substrate characteristics) relationship with discharge to compare with established habitat criteria for parr, fry, and spawning adults. Habitat

criteria for this study, were based on local information collected from the Thutade watershed for parr and spawning requirements, while fry criteria were based on past bull trout studies, as no suitability data are available for Dolly Varden in British Columbia.

Preliminary observations suggest that winter low flows are the critical period with respect to removing water from Waste Rock Creek. To date, decreased flows do not appear to significantly alter fish habitat potential for other times of the year, although migratory flows have yet to be assessed as Dolly Varden spawn in September in Waste Rock Creek. The Attichika wetland downstream of the contributions from observed seepages is suitable overwintering habitat, as the seepages appear to provide consistent flow during all periods. Winter habitat assessments indicate that the flows remaining in the Lower Waste Rock Creek system, after the initiation of pumping the collected NAG seepages, are adequate to support overwintering fish in the 250-300 m reach.

Current Status of Selenium in the Aquatic Receiving Environment

Water Quality Monitoring

Water quality monitoring in Waste Rock Creek began in 1996. Waste rock placement started in 1997 and concentrations of selenium in waters of Upper Waste Rock Creek began to increase in 2002 from typically non-detectable levels (i.e., $<0.5 \mu\text{g/L}$) to concentrations near $100 \mu\text{g/L}$ in December 2007 (Figure 1). Complementary monitoring of groundwater and surface seepages indicates that the spatial extent of elevated selenium concentrations is limited to Waste Rock Creek. Collection and pumping of NAG seepage has resulted in a decrease in selenium concentrations to levels less than those measured in 2006. Water quality monitoring in Attichika Creek downstream of Waste Rock Creek began in 2002 and selenium concentrations have remained low throughout the period of record.

Tissue and Sediment Monitoring

Biological monitoring of Waste Rock Creek, specifically to determine the effects of increasing selenium concentrations, commenced in 2004. Other regional waterbodies were included in the assessment in 2007. Based on the results collected in 2007, the sampling program in 2008 targeted the Lower Waste Rock and Attichika Creeks to support the derivation of a site-specific selenium tissue residue threshold (TRT), using North Kemess Creek as an undisturbed reference site.

Selenium concentrations in tissue (e.g., muscle, egg, and whole-body) have been quantified for Dolly Varden (DV), as they are the predominant species using WRC. Mean whole-body and egg selenium concentrations in DV from Lower Waste Rock Creek (i.e., below the ORAR Road) are elevated relative to reference areas, although concentrations measured in 2008 were similar to those in 2006 and 2007. Despite elevated selenium concentrations in tissues, DV char densities in Lower Waste Rock Creek are similar to other regional waterbodies over time. However, in the upper reaches of Waste Rock Creek (i.e., upstream of the road) fish densities have declined considerably since placement of waste rock began. Decreasing DV densities in Upper WRC is related to elimination of spawning habitats in the upper watershed, as well as potentially related to elevated Selenium in water.

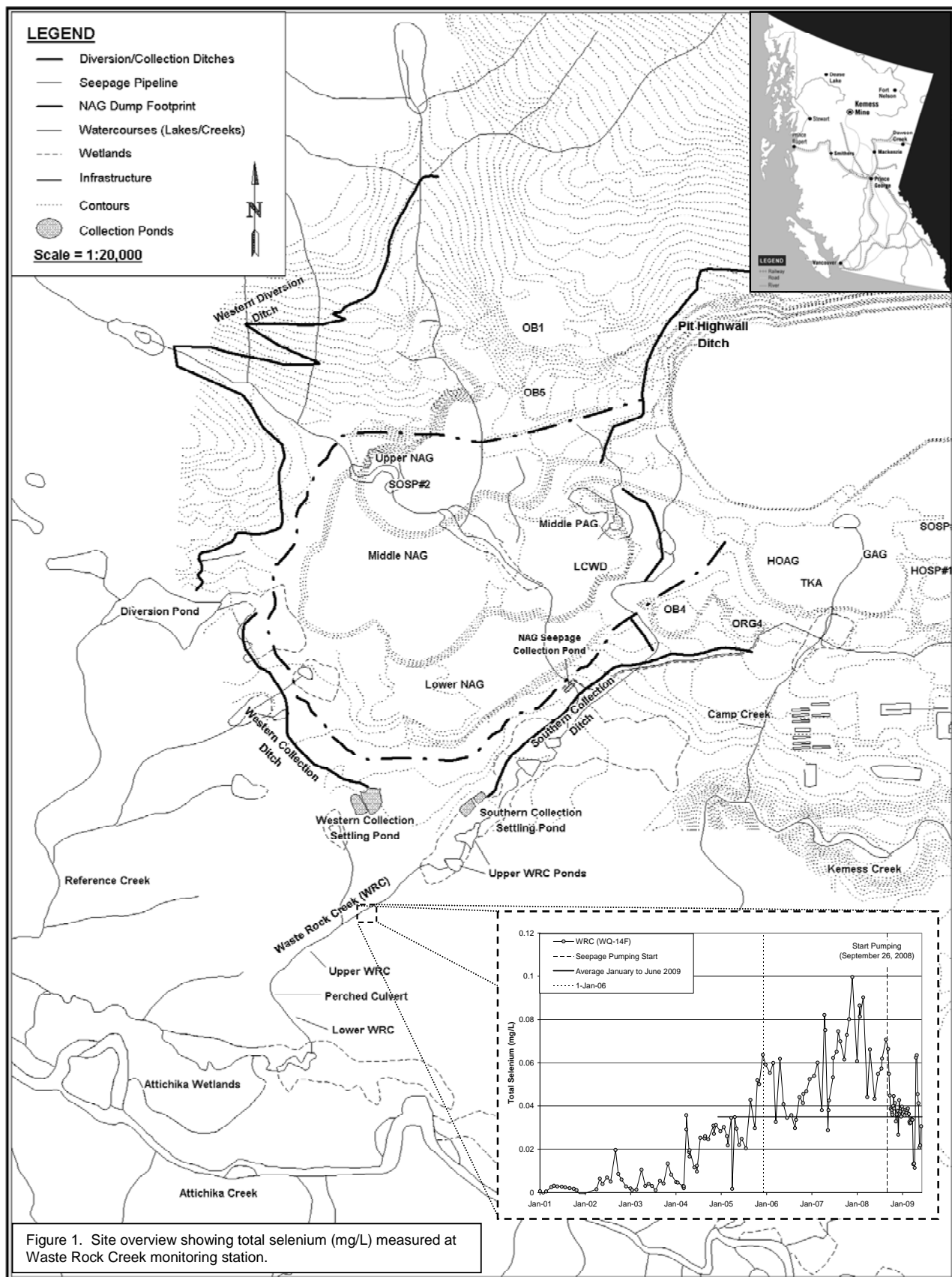


Figure 1. Site overview showing total selenium (mg/L) measured at Waste Rock Creek monitoring station.

Depositional sediments, periphyton, and benthos selenium concentrations have been measured since 2006 in Waste Rock Creek and the Attichika wetlands. Sediment selenium concentrations were generally higher in 2008 than in previous years, except at the mouth of Waste Rock Creek, where a value lower than either 2006 or 2007 was observed. Periphyton did not show any clear trends in 2008, and selenium concentrations in benthos were higher in 2008 in Waste Rock Creek than in previous years. Additional details of the 2008 biological monitoring program are presented by Hatfield Consultants (2009).

SELENIUM GUIDELINES

Site Specific Selenium Guideline

Current research (Chapman et al. 2009) suggests that a single, universal water quality value is inappropriate for predicting toxicity. The BC water quality guideline is currently 2 µg/L and the BC aquatic life tissue interim residue guideline (TRG) is 1 µg/g body weight (wet). Selenium-derived toxicity depends on the species of selenium present, confounding environmental factors (physical, chemical, and biological), and the species of fish present, all of which are generally site-specific. As such, the selenium concentration benchmark that is necessary to protect one site may be either insufficiently protective or unnecessarily protective at another site.

Egg selenium concentration is recommended as the most useful basis for a selenium tissue guideline or criterion (Golder Associates, 2008; Chapman et al. 2009). This recommendation is supported by basic toxicological principles, observed residue-response relationships, and observed variability in tissue-tissue relationships.

As noted by Chapman (2007), the USEPA draft fish whole body selenium criterion provides a conservative level of protection for cold water fish as found downstream of the Kemess Mine. As such, and at the request of BC MoE, a study was carried out in fall 2008 through to early 2009 to determine a site-specific tissue residue threshold (TRT) for Waste Rock Creek Dolly Varden. The study was designed by Golder Associates, the field work was carried out jointly by Hatfield Consultants, Dave Bustard and Associates, and Nautilus Environmental. Fertilized eggs were incubated at Nautilus Environmental's laboratory, and the results were compiled and interpreted by Golder Associates (2009a).

Determination of TRT

Mature and ripe Dolly Varden were collected from WRC and North Kemess Creek (as a reference site). Eggs were collected from female fish with a range of selenium concentrations and fertilized with milt collected from North Kemess Creek fish. Fertilized eggs were transported to Nautilus Environmental's toxicology laboratory and incubated at 5°C for approximately five months. The incubation was terminated when more than 90% of the developing larval fish had reached swim-up stage. Each surviving larval fish was examined and scored for selenium-related malformations (including skeletal, craniofacial deformities, finfold deformities, and edema) using a graduated severity index.

The resulting relationships between selenium egg concentrations and the frequency of larval deformity were assessed using a variety of statistical techniques. Best fit models were used to calculate an EC₁₀ and EC₂₀ of 54 and 60 mg/kg dry weight in eggs, respectively (i.e., the selenium egg concentrations that correspond to frequencies of deformity of 10% and 20%). As per Parametrix (2008), the EC₁₀ is recommended as an appropriate effect level for developing a tissue-based selenium criterion with an adequate level of protection.

Application of TRT to Selenium Management at Kemess

There is a high degree of confidence in the determined DV char TRT values, as the study included an appropriate gradient of selenium egg concentrations and was conducted in accordance with a robust quality assurance and quality control program. As such, Northgate has proposed to use these threshold values (TRT) as the Kemess-specific guideline for selenium in Lower Waste Rock Creek, in place of current MoE guidelines or USEPA criteria. This request is currently under review by MoE.

KEMESS SELENIUM MANAGEMENT PLAN

The objectives of the Kemess Selenium Management Plan (SeMP) are to:

- Contain/isolate elevated selenium exposure pathways;
- Apply a site specific guideline for selenium in WRC based on a technically-defensible TRT study;
- Manage selenium levels in WRC to meet the site specific TRT by utilizing upstream mitigation (pumping, cover);
- Monitor WRC to confirm that the TRT is met; and
- Maintain low selenium levels in Attichika Creek.

These objectives are discussed in terms of monitoring and management strategies in the following sections.

Monitoring

Water quality and biological monitoring will continue in the short-term in order to confirm the applicability of the newly-derived site specific TRT for selenium concentration in DV eggs as the main guideline for compliance. In order to measure the effectiveness of mitigation strategies, the selenium levels in WRC and in Attichika Creek will continue to be monitored. The monitoring frequencies and target stations will be decided through discussion with MOE, and are expected to change over time (adaptive monitoring).

Monitoring for DV, aquatic invertebrates, and sediments will occur on an annual basis during operations, coinciding with the provincial EEM program, to assess the level of success of implemented mitigation strategies. Specifically, collection of DV tissue in Lower WRC will be conducted in fall 2009 and 2010 to determine the effect of reduced selenium concentrations (due to pumping). The selenium concentration in the DV tissue will be compared to the site specific TRT. It is expected that, with reduction of water

column selenium concentration to less than 2006 levels, there will also be a related depuration in Lower WRC DV. The biological monitoring program for 2011 and beyond will be based on data collected through 2010.

It is expected that monitoring frequency will reduce as selenium concentrations in the DV (water and fish) reduce below levels of concern (e.g., below the TRT for DV). Discussions with regulatory agencies will be required to determine an appropriate long-term compliance location and monitoring frequency for the site-specific selenium TRT.

Management

The focus of short-term selenium management will be to contain and isolate elevated selenium exposure pathways by pumping the NAG seepage water into the TSF and Pit. The primary long-term strategy is to achieve reduction of selenium entering the local receiving environment from the source, which is the Leach Cap Waste Dump. This will be accomplished by construction of a cover system, the appropriateness of which will be determined via field trials of cover alternatives. Pumping of the NAG seepage will continue until reduction of selenium loading can be demonstrated after cover construction.

The long-term strategy will change with time as data are collected through the monitoring program. As such, it is presented in three separate phases.

PATH FORWARD

The focus of short-term selenium management will be to contain and isolate elevated selenium exposure pathways by collecting and pumping the NAG seepage water into the TSF and Pit. Pumping of the NAG seepage to the TSF started in September 2008, and will continue until the West Pit is available. Pumping to the Pit will continue as required.

The primary long-term management strategy is to achieve reduction of selenium entering the local receiving environment from the source, which is known to be the Leach Cap Waste stored adjacent to the Main Waste Rock Dump. This will be accomplished by application of a cover system, the appropriateness of which will be determined via field trials of two cover alternatives. Pumping of the NAG seepage to the Pit will continue after cover construction until appropriate reduction of selenium loading from the Waste Rock Dump can be demonstrated.

Monitoring will continue in order to assess the effectiveness of the mitigation strategies. Annual biological sampling will occur in conjunction with the provincial EEM program to monitor depuration of selenium from the exposed fish population and decreases in other media (e.g., sediment, benthos). Water quality at specific locations will also be monitored as an indicator of mitigation success.

Comparison of the annual biological monitoring results to the site-specific TRT will provide an indication of the effectiveness of the mitigation strategies. At this time, Northgate believes that the proposed strategies will result in an appropriate level of environmental protection as defined by the TRT EC₁₀ for

Dolly Varden. However, these strategies can and will be adapted as required based on the results of the monitoring programs.

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