POST CLOSURE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT AT TECK COMINCO'S KIMBERLEY OPERATIONS, BC OVERVIEW OF REGULATORY PROCESS AND FINDINGS OF THE PROBLEM FORMULATION

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ABSTRACT

The Sullivan sulphide ore body was discovered in 1892; Teck Cominco Metals Ltd. (Teck Cominco) and its predecessors operated underground lead/zinc mining, milling, and other industrial operations from 1909 until December 2001. The total area of land disturbance (mine, associated facilities and waste impoundments only) is on the order of 1,090 ha. Since the 1960s, Teck Cominco has been planning and implementing measures to restore and/or protect the environment impacted by mining activity. In 1991, at the request of the BC Ministry of Energy and Mines, Teck Cominco developed a comprehensive Decommissioning and Closure Plan that is being implemented under Mines Act Permit M-74.

The BC Ministry of Water, Land and Air Protection required site investigations and remediation to address contaminants and impacts not addressed in the Closure Plan (e.g., hydrocarbons). Remediation has included contaminant removal (where possible), and risk assessment/risk management, to meet Teck Cominco's post closure objectives. The main contaminants are metals generated directly from mining activity (e.g., waste rock piles, tailing impoundments, fugitive dust) and from subsequent releases due to acid rock drainage.

The Risk Assessment (RA) Problem Formulation (PF) for human, terrestrial and aquatic components is complete, and the RA is nearing completion. The PF process was successful in screening out receptor/contaminant combinations where negligible risks were predicted using conservative assumptions, and in identifying specific receptor/contaminant combinations that require additional investigation. The St. Mary River and Mark Creek are identified as primary receiving environment components and are key drivers of the RA. A hydrogeological and geochemical assessment of upgradient waste impoundments is being conducted concurrently with the RA to allow predictions of post closure groundwater and surface water concentrations.

This paper focuses on the environmental regulatory framework, and the challenges faced due to two parallel regulatory processes under the *Mines Act* and *Waste Management Act*. An overview is also provided regarding the approach taken to conducting this RA at a large mine site where both anthropogenic activities and natural mineralization have resulted in elevated metals concentrations.

INTRODUCTION

Teck Cominco Metals Ltd. (Teck Cominco) commissioned a study team led by Morrow Environmental Consultants Inc. (Morrow) to conduct a Post Closure Human Health and Ecological Risk Assessment (HH/EcoRA) of their Kimberley Operations site in Kimberley, BC. The study team includes Morrow, Azimuth Consulting Group Inc. (Azimuth), and EVS Environment Consultants (EVS). The HH/EcoRA was required by the BC Ministry of Water, Land and Air Protection (MWLAP) under the *Waste Management Act*, Contaminated Sites Regulation (CSR) in order to confirm the effectiveness of Teck Cominco's Decommissioning and Closure Plan. Reclamation of the mine site, including mitigation of the effects of acid rock drainage (ARD) from waste rock dumps and waste impoundments, had already been initiated to meet the BC Ministry of Energy and Mines (MEM) closure requirements under the *Mines Act*.

The first step in the HH/EcoRA process is that of the problem formulation (PF). The PF is a tool that allows stakeholders in the risk assessment process (in this case Teck Cominco, regulatory agencies, and non-government stakeholder groups) to identify and achieve understanding on issues relevant to the quantification of environmental risk (i.e., risk to humans or ecological resources), in the context of Teck Cominco's Decommissioning and Closure Plan for the Kimberley Operations site.

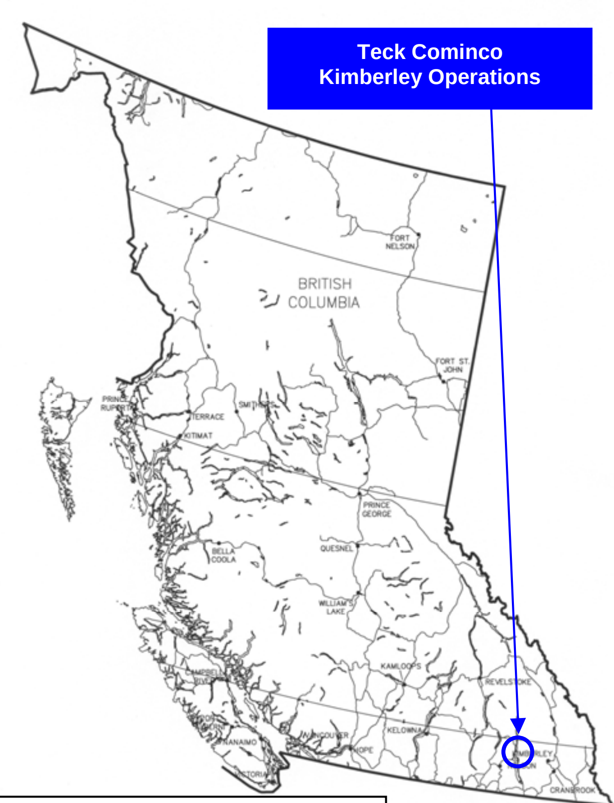


Figure 1: Location Plan

Note that risk assessment has been used as a management tool at contaminated sites in the province for the last decade or so. However, until recently it was not one of the tools typically applied at mine sites, as these sites often have a variety of unique features. Most notably, they are situated in areas of naturally elevated mineralization and often located adjacent to wild lands. BC is currently in the process of developing risk assessment guidance for the mining sector to address these and other unique aspects. While mine sites pose distinctive challenges, the core elements and principles of risk assessment are essentially the same as those for other "contaminated" sites.

The location of the Teck Cominco Kimberley Operations site is shown in Figure 1.

BACKGROUND

The Sullivan ore body was discovered in 1892 approximately 2 km north of what would be the future site of the City of Kimberley. The Consolidated Mining and Smelting Company (now Teck Cominco Metals Ltd.) acquired the ore body from the Fort Steele Mining Company in 1909. The ore body, which averaged 6% lead, 5.7% zinc, and 24.8% iron, was one of the largest lead/zinc discoveries in the world, and contained several other valuable metals, including silver and tin. Prior to 1923, the ore was processed at several local smelters;

in 1923 the on site concentrator was constructed. The mine was primarily an underground operation, although a small open pit also exists. During the 1950s and 1960s, fertilizer, iron and steel operations were constructed to make use of some of the sulphur-containing tailings. The total area of land disturbance (mine, associated facilities and waste impoundments only) is on the order of 1,090 ha.

In the 1960s Teck Cominco initiated measures to protect the environment. In 1979, the company commissioned the operation of the Drainage Water Treatment Plant (DWTP) to treat acidic waters from the mine operation, concentrator tailing decant water, and seepage water from the tailings and gypsum ponds. Effluent from the DWTP is discharged (under Permit from MWLAP) to the St. Mary River, and sludge from the process is deposited in an exfiltration holding pond. The DWTP will operate for the foreseeable future.

Continuous upgrades to ARD seepage collection systems around waste dumps, tailings and gypsum ponds have significantly improved the water quality in primary (St. Mary River, Mark Creek) and secondary receiving environments associated with the site.

REGULATORY FRAMEWORK AND OBJECTIVES OF THE RISK ASSESSMENT

Reclamation Objectives under Mines Act

In 1991, at the request of MEM, Teck Cominco developed a comprehensive Decommissioning and Closure Plan (Plan). The Plan was based on standards for reclamation that are outlined in Part 10 of the *Health, Safety and Reclamation Code for Mines in British Columbia*, 1997 (hereafter referred to as the Code), under the *Mines Act.*

The Plan included a program for the protection and reclamation of land and watercourses affected by the mine and related activities. The Kootenay Regional Mine Development Review Committee (government, non-government and other public stakeholders) reviewed the Plan at a series of meetings in 1992 and 1993, and was generally satisfied with the program. Teck Cominco prepared a revised Plan in 2000 for submission to the Chief Inspector of Mines, which described programs for management of ARD and protection of watercourses, reclamation of disturbed land to productive use, protection of human health and safety, and post closure management. Information developed through investigations and monitoring programs and experience gained from on-going closure and reclamation activities formed the basis for program revisions and provided additional details for plans considered to be conceptual in the original Plan.

All of the disturbances related to mining, milling and fertilizer production (including the tailings sites, waste rock disposal sites, subsidence area and other waste sites) are on Teck Cominco owned land. Reclamation plans have been developed for these disturbed lands; the plans are specific to each type of disturbance and take into account the nature of the site prior to the disturbance, the severity of disturbance and the potential for on site and off site impacts. As described in the Plan, it is reasonable to expect that land use patterns in the region of the site will shift toward uses more nearly associated with leisure, retirement, tourism and renewable resource utilization. It is Teck Cominco's intent to retain all lands disturbed by mining and related activity as dormant industrial land, with nature-oriented buffer zones interfacing with whatever other land use patterns emerge in the area.

Included in the revised Plan are references to the site investigations and remediation activities that Teck Cominco has implemented, or plans to implement, under the CSR. These investigations have been in progress since 1995, and have been undertaken in conjunction with Teck Cominco's execution of the Plan, with full disclosure of findings to MWLAP to ensure that the process followed was consistent with their requirements under the CSR.

<u>Remediation Objectives under the Waste Management Act</u>

The trigger into the contaminated site assessment and remediation process (prior to the CSR) at the Kimberley Operations site was Teck Cominco's need for a demolition permit in 1995 to allow them to demolish facilities and structures in the Lower Mine Yard area. Subsequent to that work, Teck Cominco embarked on phased assessment and remediation of contaminant issues in other operational areas which are related to former industrial operations but are not addressed in the Plan or reclamation permit (e.g., hydrocarbons). As the work progressed, assessment of the potential impacts from metals, resulting from mining and non-mining operations, were also included in the investigations.

Under the CSR Part 6, Section 17, remediation of soils and water can be undertaken to meet applicable numerical standards outlined in the regulation; i.e., a numerical standards based approach. Based on site zoning and the revised Plan, the applicable soil standards for post closure land use are the CSR industrial land use (IL) standards. Remediation of water can be undertaken to meet the applicable CSR standards (for groundwater) or BC surface water criteria (for surface water receiving environments) protective of aquatic life.

A risk assessment/risk management approach can be followed either as an alternative to, or in combination with, the numerical standards based approach. The risk-based approach is outlined in the CSR Part 6, Section 18, in which the determination as to whether a site has been satisfactorily remediated is based on an evaluation of risk through the completion of a site-specific HH/EcoRA.

Remediation by a combined numerical standards-based approach and risk-based approach is being undertaken at the Kimberley Operations site, consistent with activities outlined in the Plan. That is, where remediation to meet numerical land or water use standards is practical, this approach is being followed. For example, impacts from hydrocarbons and other organic contaminants were remediated using the numerical standards-based approach (i.e., excavation and disposal). In areas where such an approach was not practical or feasible (e.g., groundwater impacted by ARD), the risks posed by residual contaminant levels are being evaluated. The HH/EcoRA is intended to confirm whether or not post closure site management strategies are adequate to address current and future risks.

The completion of the HH/EcoRA requires assumptions about current and future land use. As noted above, the key assumption is that Teck Cominco will retain all disturbed lands as dormant industrial land, and that post closure conditions will apply (as described in the Plan). Any exceptions to this assumption would require a review of the assumptions of the HH/EcoRA and completion of a specific HH/EcoRA of any area where a change of land use is proposed.

Strict application of the CSR process has created problems as Teck Cominco works together with the City of Kimberley to divest property and/or change the land use of property within Teck Cominco's land holdings. The Sullivan Mine site is unique in that it surrounds the City of Kimberley. The CSR process has resulted in costs and time delays both to the company and the City in their attempts to create revenue-generating initiatives to sustain the post mine economy of the area. For example, the CSR requires that a site be defined as a contaminated site if soil or groundwater under the site contains metals concentrations exceeding the numerical standards. In the case of groundwater, if it can be proven that the groundwater impacts did not originate on the site (i.e., the impacts originated from an upgradient source which could include a mine operation or a naturally occurring mineral outcrop), the site is still defined as a "contaminated site" and limitations on development are imposed according to the regulation. Such limitations include covenants on land title, financial security, and the requirement of a "conditional" certificate of compliance from the MWLAP. These types of limitations create problems for land redevelopment initiatives.

Consistency of Objectives but Overlap of Regulatory Processes

Based on the above, it is clear that the regulatory objectives to be met at the Kimberley Operations site through the HH/EcoRA are consistent with respect to the Mines Act and WMA. The distinction is that the Mines Act and the Health, Safety and Reclamation Code allow for more flexibility under a performance-based approach to protection of human health and the environment, whereas the CSR is a more prescriptive approach.

While there is consistency in terms of overall regulatory objectives, there is also duplication due to two parallel regulatory processes, and uncertainty regarding jurisdictional control. Some of this duplication has been addressed in amendments to the WMA in 2002, but regulatory issues still remain. For example, MEM is responsible to ensure environmental protection and mitigation of impacts related to ARD. However, since metals concentrations in groundwater, if they exceed numerical standards, define a site as "contaminated", MWLAP has responsibility to ensure that groundwater impacts are remediated under the CSR. Teck Cominco has undertaken extensive investigations to meet MWLAP's requirements for characterization of residual metals concentrations. Many phases of remedial excavation followed, including confirmatory soil sample analysis for comparison to numerical standards. Where possible, data collected to meet MEM reclamation and monitoring requirements have been used to reduce overlap in site characterization and in determining CSR remediation requirements.

Other problems with application of the CSR on mine sites include the liability provisions, which are currently defined as “joint, several, absolute and retro-active”. In layman’s terms, the net (for responsible parties) is cast wide and it never goes away.

In response to concerns voiced from both the mining industry and government agencies caught in this cumbersome, bureaucratic, and costly process, some amendments were made to the CSR in 2002 and others are in progress. Recent key amendments and/or recommendations for change are as follows:

Waste Management Amendment Act, Bill 32: The Waste Management Amendment Act, 2002 was passed on May 6, 2002. Part 4.1, “Remediation of Mineral Exploration Sites and Mines”, outlines a new process whereby responsibility for mine sites is split between the MEM (for “core” mine areas) and the MWLAP (for “non-core” areas). Core areas include waste rock dumps, tailing impoundments, pits, underground workings, etc. Non-core areas include facilities and operations such as maintenance shops, mills, mineral treatment, etc. In general, the legislation limits MWLAP’s powers to require remediation, and provides limitations on liability (not linked to past owners). This sharing of responsibility is great in concept, but for it to work in “real life”, risk assessment guidance for use at mine sites (referred to earlier) must be provided that will be recognized and applied by both agencies. Also, there are problems with trying to make a “cut and dried” separation between core and non-core areas, as this is not always so clear in practice. For Teck Cominco’s Kimberley Operations, if this legislation had been in force five or so years ago the level of investigation and costs of meeting the CSR investigation requirements would have been reduced. However, the requirement for HH/EcoRA would have remained in terms of assessing the post closure site conditions.

Procedure for Contaminated Sites Cost Recovery Fees for Mines: Effective August 26, 2002, this procedure was issued to provide clarity on the circumstances under which MWLAP will impose fees under the CSR.

Advisory Panel on Contaminated Sites Report, January 2003: While not specific to mine site issues, this report provides an overview of the problems associated with the CSR process, and outlines recommendations for reform. Recommendations include: greater use or acceptance of a risk based approach to defining and assessing a contaminated site (currently risk assessment cannot be used to define a contaminated site, only to remediate one); ways to improve speed of process and reduce costs; and limitations on future liability. Also recommended is the resolution of unnecessary duplication and lack of consistency between closure and reclamation requirements of MEM and the WMA/CSR process that have not been addressed through Bill 32. The report recommends that a lead Ministry be appointed with responsibility for mine closure, decommissioning and remediation issues.

Environmental Management Act (EMA), Bill 57: On May 13, 2003, the Government of BC introduced Bill 57 containing key legislative changes to the contaminated sites regime. The highlights of the EMA (which will replace the Waste Management Act) include: risk-based definition of “contaminated site”; no more “conditional” certificates of compliance (i.e., single form of comfort letter); elimination of Ministry’s ability to re-open certificates of compliance based on future revisions to numerical standards. Substantial changes to the CSR are also planned (related to the findings of the Advisory Panel report) which will be introduced once the EMA is proclaimed.

It is interesting to note that MEM is currently involved in a review of the Mines Act and the Code, to move from the "performance based" system to "results based" standards for mine reclamation in BC. This initiative, as well as the CSR reform noted above, is indicative of government's direction to off load responsibility and accountability to the private sector, including greater use of registered professionals for approvals.

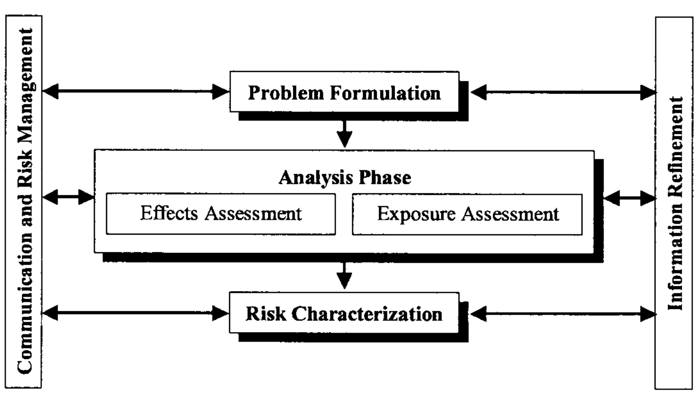
Objectives of the Risk Assessment

Having identified the commonality and overlaps of objectives of the MEM and MWLAP processes for the Teck Cominco Kimberley Operations site, the following represent the main objectives for the overall HH/EcoRA:

- Develop a conceptual model for the site (i.e., through the problem formulation process), based on post closure site conditions and Teck Cominco's plan to retain all disturbed lands as dormant industrial lands;
- Complete the risk assessment to identify existing (current) and potential (future) risks to human and ecological receptors from historical mining and industrial activity on the site in the context of the protection goals identified in the conceptual model;
- If unacceptable risks are identified for any exposure pathway/receptor combination, develop risk management/mitigation options for consideration to address the risk.

The general RA framework for the Kimberley Operations site is illustrated in Figure 2.

Figure 2: Generic risk assessment framework for the Kimberley Operations site.

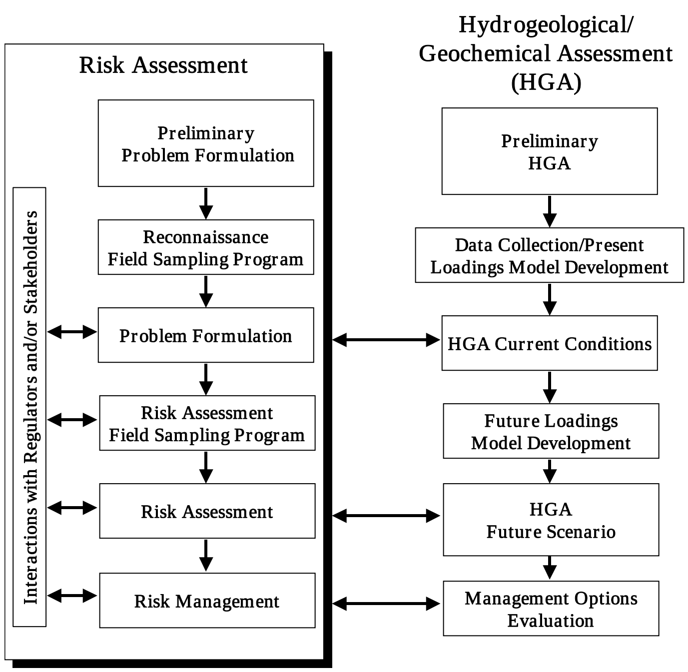


Given its long history of activity and large size, the Kimberley Operations site is quite complex. The site contains many contaminant sources, transport pathways and receiving environments. The problem formulation stage of the risk assessment has been completed. Typical of most problem formulations, data from historical and ongoing monitoring was used, as well as data collected (in 2001) to fill data gaps. The results were used to determine the potential for risks to humans, terrestrial and aquatic ecological resources. To better understand the drivers of potential risks at the site and help identify any further data gaps, additional effort (i.e., beyond a typical problem formulation) was directed at conducting a screening-level assessment of certain receptors.

In addition, a contaminant loading model was developed as part of the hydrogeology and geochemistry assessment to evaluate the significance of various source areas to overall contaminant loads in the receiving environment. Potential changes in site conditions over time, particularly with regard to contaminant discharges to the aquatic receiving environment, must be incorporated into the risk assessment. Consequently, the risk assessment process has been set up with a close linkage to the hydrogeology and geochemistry assessment. (See Figure 3).

For the risk assessment, more detailed sampling programs were undertaken in 2002 and 2003, and additional work is in progress in 2004, in order to refine the data sets, fill in gaps, and/or test specific species to confirm or refute actual risk potential. All relevant data will be analyzed to complete the short-term closure scenario (i.e., the period immediately after the closure plan has been fully implemented). In addition, Morrow's hydrogeology and geochemistry assessment team has conducted predictive modelling of contaminant release and transport dynamics from waste impoundments to estimate the potential impacts of future changes in the site on water quality in the receiving environment.

Figure 3: Risk assessment overview for the Kimberley Operations site.



OVERVIEW OF FINDINGS - PROBLEM FORMULATION AND SCREENING LEVEL RISK ASSESSMENT

<u>Human Health Risk Assessment</u>

The methods used to estimate human health risks will be based on risk assessment procedures recommended by MWLAP but also commonly used by regulatory agencies across Canada and the United States. For assessment of risks to persons spending time in the area of the Kimberley Operations site, potential exposures will be primarily based on environmental concentrations measured at the site. In cases such as fugitive dust levels and fish/wild game tissue concentrations, metal concentrations will be estimated based on accepted models rather than actually measuring levels. The toxicological literature will be then reviewed to identify rates of exposures to metals that have been determined to be “safe” (or more specifically, rates of exposure without appreciable risk to human health). The final step in the risk assessment will be the comparison of the estimated rate of exposure to dose rates considered to be “safe” for humans. Standards provided in the CSR provided the primary measures of what are considered acceptable levels of risks (i.e., Hazard Quotient values of 1 and Incremental Lifetime Cancer Risk estimates of $1x10^{-5}$).

The exposure pathways to be evaluated are dependent upon the persons to be evaluated and the chemical source (e.g., soils/dusts, surface water, and food sources). Exposure pathways will include incidental ingestion, dermal contact, and inhalation.

The risk assessment will be completed on persons who may be present at or near the Kimberley Operations site under post closure conditions. These include frequent trespassers, infrequent trespassers, maintenance workers, and off-site residents.

Ecological Risk Assessment Terrestrial Component

The receptors of concern (ROCs) for this study were chosen based on a number of scientific and human value considerations. The final list included plants and soil invertebrates, reptiles, mammals, and birds. The latter two receptor groups were subdivided by ecological niche (e.g., feeding guild and size). Listed species (i.e., threatened or endangered) are afforded a higher level of protection than non-listed species. To act as surrogates for each ROC group, various representative species were selected based on the availability of reliable biological and ecotoxicological information necessary for conducting the risk assessment.

For the terrestrial ecosystem at the Kimberley Operations site, the pathways considered most relevant include: root uptake of contaminants of primary concern (COPCs) in surface soil for plants; soil ingestion and direct contact of COPCs in surface soil for soil invertebrates and reptiles; and ingestion of COPC-contaminated food and soil (i.e., incidental exposure) for small and large mammals, birds, and reptiles. Information was integrated into the conceptual model, which is a graphic or written description of contaminant sources, pathways and receptors.

For the screening level terrestrial risk assessment, exposure via direct contact was considered for plants and soil invertebrates; CSR soil standards were used to indicate potential effects. Localized effects were identified in the formerly active areas of the site; limited contamination was found elsewhere. Recommendations were provided for follow-up investigations.

A food chain model was used to conservatively estimate contaminant intake by mammals and birds. Only limited potential risks were identified for non-listed species; moderate to high potential risks were identified for listed species, although there is uncertainty as to what listed species actually use the site. These results do not necessarily indicate that adverse effects are occurring since the assessment relied on conservative assumptions. This is currently being addressed in the Risk Assessment, by undertaking a listed species survey.

Little ecotoxicological information is available for reptiles. Potential risks to reptiles are typically assessed through field investigations that tend to target rare and endangered species occurring at the sites being investigated. Recommendations for follow-up investigations, including a survey of listed species, are being implemented currently.

Ecological Risk Assessment Aquatic Component

The Kimberley Operations site either encompasses or is situated adjacent to numerous freshwater bodies ranging in size and ecological importance. Determination of whether a water body represents a primary or secondary receiving environment was done based on both human and ecological values, and based on input from MWLAP. The St. Mary River and Mark Creek were considered primary receiving environments; all other smaller surface water bodies were grouped as secondary. The former are afforded a higher degree of protection; the latter were not directly assessed for ecological risks, but were considered as contaminant transport pathways to the primary receiving environments. Data from both historical sources and the 2001 sampling program were screened against provincial ambient water quality criteria to identify COPCs. Loadings of COPCs to the primary receiving environments were calculated from the property wide hydrogeological and geochemical modelling exercise referenced earlier.

The ROCs were chosen based on a number of scientific and human value considerations. A variety of ROCs were selected including aquatic plants, invertebrates, fish, birds, and amphibians. As with the terrestrial component, listed species will be afforded a higher level of protection than non-listed species. The pathways considered most relevant include: direct exposure to site-related COPCs in surface water and sediment pore water for aquatic plants and invertebrates; direct exposure to site-related COPCs in surface water and ingestion of food with elevated COPC concentrations for fishes; and indirect exposure via ingestion of food with elevated COPC concentrations for aquatic birds and mammals. This information was integrated into the conceptual model.

For the screening level aquatic risk assessment, the 2001 benthic sampling program indicated no major differences among stations for aquatic invertebrates. Laboratory toxicity testing for aquatic invertebrates and aquatic plants indicated adverse effects for samples from one area of the site; recommendations for follow-up investigations were implemented. For fish, the toxicity testing conducted as part of the 2001 sampling program did not show any adverse effects, but testing was limited in nature. Recommendations were provided for follow-up investigations.

A food chain model was used to conservatively estimate contaminant intake by birds at the site (no mammals were identified that depended primarily on the aquatic environment for food resources). Only limited potential risks were identified for non-listed species; moderate to high potential risks were identified for listed species, although there is uncertainty as to what listed species actually use the site. These results do not necessarily indicate that adverse effects are occurring since the assessment relied on conservative assumptions. This is being addressed in the Risk Assessment. Recommendations, including a listed species survey, are being implemented.

Little ecotoxicological information is available for amphibians. Potential risks to amphibians are typically assessed through field investigations that tend to target rare and endangered species occurring at the sites being investigated. Recommendations for follow-up investigations, including a survey of listed species, are being implemented.

NEXT STEPS – RISK ASSESSMENT

Environmental conditions at the site are currently in a state of flux due to the on-going implementation of reclamation activities. Areas that were inaccessible during the 2001 sampling program (since the mine was still operating), and areas which have since been reclaimed, required additional soil characterization.

The COPC loading model described earlier has been modified to assess potential changes in the geochemistry of the waste impoundments (e.g., ARD dynamics) and in the buffering capacity of the main transport pathways and their effects on future receiving environment water quality.

For the Human Health Risk Assessment, estimated or measured COPC concentrations will be obtained for various items potentially related to the site.

For the terrestrial component of the Ecological Risk Assessment, further investigations for all terrestrial ROCs have included: occurrences of listed species, confirmation of non-listed species, and habitat (i.e., specific requirements, distribution at the site). The risk assessment considers the correspondence between various habitats, ROCs, and patterns of contamination, to predict exposure of each ROC to COPCs.

For the aquatic environment, further investigations supporting the risk assessment include studies of potential impacts to the St. Mary River through further field and laboratory studies of periphyton, benthic and fish species. Further toxicity testing has addressed issues such as the effect of water hardness on zinc toxicity and the sensitivity of native species relative to cultured laboratory organisms. Conditions related to spring freshet and other seasonal toxicity effects are also being considered.