SUNCOR ENERGY

Project Millennium Application

2D

Submitted to **Alberta Energy and Utilities Board** and **Alberta Environmental Protection**

Volume 2D
Environmental Impact Assessment
Appendices

April, 1998

Project Millennium
Taking Suncor into the 21st Century

APPENDIX I

FINAL TERMS OF REFERENCE
ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT
FOR THE PROPOSED
SUNCOR ENERGY INC.
PROJECT MILLENNIUM
FORT MCMURRAY, ALBERTA

Alberta
ENVIRONMENTAL PROTECTION

Environmental Assessment

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March 4, 1998

Mr. M. Shaw
Director, Sustainable Development
Suncor Energy Inc.
Oil Sands
P.O. Box 1001
Fort McMurray, AB
T9H 3E3

Dear Mr. Shaw:

RE: FINAL TERMS OF REFERENCE FOR THE
PROPOSED PROJECT MILLENNIUM
ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT

Enclosed is the final Terms of Reference, dated March 4, 1998, issued by Alberta Environmental Protection under Section 46(3) of the Environmental Protection and Enhancement Act (EPEA), for the Environmental Impact Assessment (EIA) report for the proposed Project Millennium, to be located in the Athabasca Oil Sands Region, north of Fort McMurray, Alberta. The Terms of Reference also reflect the requirements of the Energy & Utilities Board (EUB) and the federal government pursuant to the Canada-Alberta Agreement for Environmental Assessment Cooperation.

I appreciate your cooperation in the preparation of these final Terms of Reference and look forward to reviewing your EIA report upon its completion.

Sincerely,

Robert L. Stone
Director of
Environmental Assessment

Enclosure

cc: R. Houlihan (Energy and Utilities Board)
F. Hnytka (Department of Fisheries and Oceans)
R. Christie (Canadian Environmental Assessment Agency)

FINAL TERMS OF REFERENCE

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT

FOR THE PROPOSED

SUNCOR ENERGY INC.

PROJECT MILLENNIUM

FORT MCMURRAY, ALBERTA

Issued By: Alberta Environmental Protection

Date: March 4, 1998

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this document is to identify for Suncor Energy Inc. (Suncor) and for the public the information required by government agencies for an Environmental Impact Assessment (EIA) report. Suncor will prepare and submit an EIA report which examines the environmental effects of the construction, operation and reclamation of its proposed Project Millennium extension of the Steepbank Mine (the Project).

1.2 Scope of Environmental Impact Assessment (EIA) report

The EIA report will address these Terms of Reference and the environmental information requirements prescribed under the Environmental Protection and Enhancement Act (EPEA) and Regulations, the Energy & Utilities Board (EUB) Act and Regulations and the Canadian Environmental Assessment Act and Regulations. The EIA report will assist the public and government in understanding the environmental consequences of the Project's development, operation and reclamation plan and will assist Suncor in its decision-making process.

The EIA report will identify development activities, describe environmental effects, mitigation options and residual effects that are relevant to the assessment of the Project including, as appropriate, those related to the Steepbank Mine and Lease 86/17 necessitated by Project Millennium. Impact predictions should be presented in terms of magnitude, frequency, duration, seasonal timing, reversibility and geographic extent. The EIA report will also discuss measures to prevent or mitigate impacts, monitoring of environmental protection measures and will identify residual impacts and their significance, including cumulative impacts and regional development considerations. Proposed mitigation measures, protection plans, monitoring or research programs and other follow-up actions related to proposed activities, environmental performance objectives and anticipated regulatory requirements will be discussed.

The EIA report will form part of Suncor's application to the EUB. A summary of the EIA report will also be included as part of the EUB application.

1.3 Public Participation

The purpose of public participation is to inform those who may be affected by the Project and to provide individuals the opportunity to participate in the process. This includes residents and organizations in Fort McMurray, Fort McKay, Fort Chipewyan and other communities of the Regional Municipality of Wood Buffalo. Industrial, recreational, environmental and other recognized groups and individuals who have an interest in the Project are also included. The proponent will provide public notification that it is preparing an EIA report and will advise the public of opportunities to obtain information on the Project and how to express their concerns so that they may be addressed through the environmental assessment process. Suncor will document all comments received from the public with regards to the Project.

2.0 PROJECT OVERVIEW

2.1 The Proponent and Project History

Provide the name of the proponent and the name of the legal entity that will develop, manage and operate the Project.

Describe Suncor and its history in the Athabasca Oil Sands, with specific reference to the existing Suncor oil sands processing plant and mine, proposed development, resource characterization and environmental studies.

2.2 The Project Area

The Project Area includes all lands subject to direct disturbance from the Project and associated infrastructure.

Provide the legal description of the Project. Indicate the boundaries of Suncor's leases and currently approved mining activities. Show the area proposed to be disturbed. Include existing topographic features, township grids and watercourses.

2.3 Project Components and Development Schedule

Outline and locate the major project components, including mining equipment, processing and treatment facilities, sand and waste disposal sites, buildings and infrastructure, utilities, pipelines and access routes. Describe the proposed stages of development, including pre-construction, construction, operations, reclamation and decommissioning and a likely development schedule. Identify the key factors controlling the schedule and uncertainties.

Provide a description and schedule of land clearing required for mining areas, access roads, pipelines and utilities. Provide a description and schedule for other site preparation activities.

2.4 Project Need and Alternatives

Discuss the need for the Project. Identify any alternative means of carrying out the Project that are technically and economically feasible and indicate their potential environmental effects and impacts. Compare identified alternatives to the Project and its anticipated environmental effects and impacts. Discuss reasons for not selecting any identified alternatives.

2.5 Regulatory Approval

Identify the environmental and other specific regulatory approvals and legislation that are applicable to the Project at the municipal, provincial and federal government levels. Identify government policies, resource management, planning or study initiatives pertinent to the Project and discuss their implications.

Identify and delineate major components of the Project which are to be applied for and constructed within the duration of approvals under the Environmental Protection and Enhancement Act (EPEA) and the Water Resources Act (WRA).

3.0 PROJECT DESCRIPTION

Describe the major project components, including mining equipment, processing and treatment facilities, buildings, sand and waste disposal sites and infrastructure, utilities, pipelines and access routes. Describe the proposed stages of development, including pre-construction, construction, operations and reclamation.

Discuss the reasons for selecting the major features of the Project and describe how specific technical, geotechnical, economic and environmental criteria were incorporated into the decision-making process. Address the siting of the various project components.

Discuss the potential use of alternative technologies and methods to reduce the discharge of contaminants (e.g., magnitude and duration), eliminate or reduce waste storage and disposal requirements, and minimize the area and duration of surface disturbances.

Discuss contingencies for the selected major project components of the Project should they prove to be unfeasible.

3.1 Process Description

Describe the oil sands preparation, extraction and bitumen upgrading processes and provide material and energy balances and basic flow diagrams.

Describe the proposed technology and alternative technologies considered. Describe the effects of the proposed technology on water requirements, waste generation, chemical use, tailings characteristics (e.g., quantity, quality and bulking), air emissions and bitumen recovery.

Provide hydrocarbon and sulphur balances and information on the energy efficiency of the technology chosen.

3.2 Mining Description

Describe the proposed mining methods. Discuss alternative mining methods considered and their environmental implications.

Describe the effect of the minimum ore grade selected for mining on tailings volumes, fine tailings volumes, water requirements and long-term reclamation.

3.3 Utilities and Transportation

Describe and locate on maps of appropriate scales the utilities required for the Project.

Discuss the amount and source of energy required for the Project.

Discuss the options considered for supplying the thermal energy and electric power required for the Project and their environmental implications.

Describe road access to and within the Project Area and identify needs to upgrade existing roads or construct new roads. Discuss the need for access management. Provide the results of consultation with the local road authority.

Describe the methodology and determine the projected frequency and location of increased traffic volumes on Highway 63 during the construction and operating periods. Discuss mitigation options. Discuss options for cooperative development of infrastructure with other oil sand and industry operators.

Identify the type and location of road construction and restoration materials, the volume of material needed and the availability of material in the area.

Describe any river and stream crossing of utility lines, roads and pipelines. Outline design features to prevent spills, contingencies for spill response and environmental risks associated with spills.

3.4 Air Emissions Management

Develop an emissions profile (e.g., type, rate and source) for each component of the Project, including construction and vehicle emissions. Consider both normal operating conditions and upset conditions.

Discuss the emission control technologies proposed for the Project in the context of available technologies.

Estimate the incremental loading of greenhouse gases to the atmosphere as a result of the Project. Place emission estimates in context with total emissions, provincially and nationally. Discuss the proponent's overall greenhouse gas management plans and comment on the effect of this Project on its greenhouse gas management plans.

3.5 Water and Wastewater Management

Provide a water management plan for the Project. Address site runoff and containment, groundwater protection, muskeg dewatering, mine pit dewatering, and the discharge of aqueous contaminants beyond operating lease boundaries.

Provide a description of permanent or temporary alterations or diversions to natural watercourses and their effects. Describe new water intake structures required for the Project and explain how the design has addressed fish entrainment issues and river navigational concerns.

Provide a wastewater management plan for the Project. Describe the expected volumes and quality of wastewater that will be generated from the Project. Discuss treatment technologies proposed for the Project. Explain how these wastewaters will be managed. For those wastewaters requiring treatment, discuss the preferred treatment option. For any proposed effluent discharges and reclamation water releases, describe the volumes, quality, location and duration of such releases. Provide load estimates for significant contaminants in these proposed releases.

Describe alternatives to reduce freshwater consumption, including wastewater recycling.

Provide a total water balance of the Project for the duration of an approval under the WRA.

Discuss discharges to the surrounding watershed and to the Athabasca River from reclaimed sites, including the tailings ponds. Describe the management strategy for handling such releases.

Include a description of potable water and sewage treatment systems that will be installed as components of the Project.

Discuss how the findings of the Northern River Basins Study (NRBS) relate to the Project.

3.6 Hydrocarbon, Chemical and Waste Management

Identify the location, nature and amount of onsite hydrocarbon storage. Discuss containment and other environmental protection measures.

Provide a listing of chemical product consumption for the Project. Identify products containing substances that are: Canadian Environmental Protection Act (CEPA) toxics, on the Priority Substances List (PSL 2), on the National Pollutant Release Inventory (NPRI), or Track 1 substances targeted under Environment Canada's Toxic Substances Management Policy.

Describe, in general terms, how these products will be stored and managed. Identify how future changes to these chemical products will be handled to ensure safety and environmental protection.

Characterize and estimate volumes of waste streams generated by the Project. Identify how each waste stream will be managed. Demonstrate how the selected options are consistent with industry practice.

Describe the management plan for the produced tailings, overburden and other mining wastes, as well as, for byproducts including coke, sulphur and gypsum. Include evaluations to minimize fine tailings production considering mining methods and minimum ore grades selected for mining and extraction processes.

Discuss the strategy for onsite waste disposal versus offsite waste disposal. Identify the location of onsite waste disposal locations, including industrial landfills.

Demonstrate how the principles of pollution prevention and waste minimization have been incorporated into the Project design.

3.7 Environmental Management Systems

Provide an overview of Suncor's existing environmental management systems and describe how these will be incorporated into the Project.

Review monitoring done independently by Suncor, as well as, monitoring performed in conjunction with other stakeholders and publicly available monitoring information. Describe Suncor's history of active participation in the Southern Wood Buffalo Zone's ambient air quality monitoring and environmental effects monitoring programs. Describe new monitoring initiatives which may be required as a result of the Project. Consider air emissions, water emissions, waste tracking, process inputs and outputs.

Modify existing plans or develop new conceptual contingency plans that consider the environmental effects of serious malfunctions or accidents that represent deviations from normal operating performance. Include an emergency response system to deal with the situation and minimize adverse environmental effects.

Comment on contingency plans that have been, or will be developed to respond to unpredicted negative impacts that are realized during and after project development.

4.0 ENVIRONMENTAL ASSESSMENT

4.1 Assessment Requirements

Provide information on the environmental resources and resource uses that could be affected by the Project. Provide a sufficient base for the prediction of positive and negative impacts and the extent to which negative impacts may be mitigated by planning, project design, construction techniques, operational practices and reclamation techniques. Quantify and assess impact significance where possible, including consideration of spatial, temporal and cumulative aspects. Describe, where appropriate, how biodiversity has been considered, e.g., fauna, habitat, landscape units and ecosystems.

Discuss the sources of information used in the assessment. Include a summary of previously conducted environmental assessments related to Suncor's operations. Identify any limitations or deficiencies that the information may place on the analysis or conclusions in the EIA report. Discuss how these limitations or deficiencies will be addressed within the current EIA report. Information sources will include literature and previous EIA reports and environmental studies, operating experience from current oil sands operations, industry study groups, traditional knowledge and government sources. Where required, undertake studies and investigations to obtain additional information.

From a broad-based examination of all ecosystem components, including previous environmental assessment work, describe and rationalize the selection of key components and indicators examined. Discuss the consultative process which Suncor utilized in the selection of environmental components and indicators.

For each environmental parameter:

i) Describe existing conditions. Comment on whether the available data is sufficient to assess impacts and mitigative measures. Identify environmental disturbance from previous activities which have now become part of baseline conditions.

ii) Describe the nature and significance of the environmental effects and impacts associated with the development activities.

iii) Present plans to minimize, mitigate, or eliminate negative effects and impacts. Discuss the key elements of such plans.

iv) Identify residual impacts and comment on their significance.

v) Present a plan to identify possible effects and impacts, monitor environmental impacts, and manage environmental changes in order to demonstrate the project is operating in an environmentally sound manner.

vi) Present a plan that addresses the adverse impacts associated with the Project which may require joint resolution by government, industry and the community. Describe how this plan will be implemented and how it will incorporate the participation of government, industry and the community.

4.1.1 Cumulative Environmental Effects

Identify and assess the likely cumulative environmental effects of the Project:

- Define the Study Area and time boundaries. Provide a rationale of the assumptions used to define those boundaries for each environmental component examined;

- Assess the cumulative environmental effects that are likely to result from the Project in combination with other existing and proposed projects or foreseeable activities in the region that could reasonably be considered to have a combined effect. Include other existing and proposed industrial projects, as well as, activities associated with land use and infrastructure;

- Demonstrate that any information or data used from previous oil sands and other development projects is appropriate for use in this EIA report. Describe any deficiencies or limitations in the existing database. Supplement where required and consider all relevant components of the environment; and

- Explain the approach and methods used to identify and assess cumulative impacts, including cooperative industry initiatives. Provide a record of all assumptions, confidence in data and analysis to support conclusions.

4.2 EIA Study Area

The EIA Study Area shall include the Project Area which encompasses lands subject to direct disturbance from project activities and associated infrastructure. As well as, the Study Area shall include the spatial and temporal aspects of individual environmental components outside the Project boundaries where an effect can be reasonably expected.

Describe the consultation process, rationale and assumptions used in establishing the Study Area boundaries, including those related to cumulative effects. Maps should include township and range lines for easy identification and comparisons with other information within the EIA report.

4.3 Cooperative Opportunities

Identify cooperative ventures which Suncor is planning or could initiate with other oil sands operators to minimize the environmental effects of the Project or the environmental impact of regional oil sands development. Discuss how Suncor will work to develop such cooperative opportunities and identify a timeframe for their implementation.

4.4 Climate, Air Quality and Noise

Discuss baseline climatic and air quality conditions. Review current emission sources and discuss changes as a result of anticipated future development scenarios within the EIA Study Area. Consider emission point sources, as well as, fugitive emissions and emissions from mine mobile sources (vehicles).

Identify components of the Project that will affect air quality from a local and regional perspective. Discuss appropriate air quality parameters such as sulphur dioxide (SO_2), hydrogen sulphide (H_2S), total hydrocarbons (THC), oxides of nitrogen (NOx), volatile organic compounds (VOC), ground-level ozone and particulates.

Estimate ground-level concentrations of appropriate air quality parameters. Discuss any expected changes to particulate deposition or acidic deposition patterns. Justify the selection of the models used and identify any model short comings or constraints on findings.

Identify the potential for decreased air quality (including odours) resulting from the Project and discuss any implications of the expected air quality for environmental protection and public health. Discuss consideration of interactive effects that may occur as a result of co-exposure of a receptor to various emissions and discuss limitations in the present understanding of this subject.

Describe how air quality impacts resulting from the Project will be mitigated.

Identify ambient air quality monitoring that will be conducted during construction and operation of the Project.

Identify components of the Project that have the potential for creating increased noise levels and discuss the implications and measures to mitigate.

4.5 Aquatics

4.5.1 Fisheries and Fish Habitat

Describe the existing fish resource in the waters likely to be impacted by the Project. Identify species composition, distribution, relative abundance, movements and general life history parameters. Discuss the use of the fish resources by existing or potential domestic, sport or commercial fisheries.

Describe and map, as appropriate, the fish habitat of the Athabasca River, Steepbank River, Shipyard Lake and other tributaries likely to be affected by the Project. Identify critical or sensitive areas such as spawning, rearing, and overwintering habitats. Discuss seasonal habitat use. Describe the existing information base, any deficiencies in information and any studies proposed to evaluate the status of the fish and aquatic resources in the Study Area. Identify key indicator species and provide the rationale and selection criteria used.

Identify pre-construction, construction, operation and reclamation activities that may potentially affect fish and fish habitat. Describe how stream alterations and changes to substrate conditions, water quality and quantity may affect fish and fish habitat in the Study

Area. Consider fish tainting, survival of eggs and fry, chronic or acute health effects and increased stress on fish populations from release of contaminants, sedimentation and habitat changes.

Discuss the design, construction and operational factors to be incorporated into the Project for the protection of fish resources.

Identify residual impacts on fish and fish habitat and discuss their significance in the context of local and regional fisheries. Identify plans proposed to offset any loss in the productivity of fish habitats. Indicate how environmental protection plans address applicable provincial and federal policies on fish habitat, including the development of a 'No Net Loss' fish habitat objective. Discuss any cooperative mitigation strategies which might be planned with other oil sands and industrial operators.

Discuss the potential for increased fishing pressures in the Study Area that could arise from increased access, including any implications for the fish resource.

Identify any monitoring programs that will be initiated by Suncor or conducted in cooperation with other oil sands operators to assess regional fisheries impacts and the effectiveness of mitigation strategies to ensure protection of the fisheries resource in the area.

4.5.2 Water Quality

Describe the water quality in the Study Area before and after project development and operation.

Discuss the seasonal variations in water quality which may be expected due to natural conditions and with respect to the construction, operation, or reclamation of the Project. Assess any changes between summer and winter conditions and high/low flow conditions.

Identify components within each stage of the Project that may influence or impact both surface and groundwater quality. Describe the potential impacts of the Project on surface water quality within the Study Area with respect to location, magnitude, duration and extent and significance.

Predict water quality in the Athabasca River and any other affected watercourses downstream from Suncor. Compare the predicted water quality and existing water quality using, as appropriate, the Alberta Ambient Surface Water Quality Interim Guidelines, relevant United States Environmental Protection Agency Guidelines, and the Canadian Water Quality Guidelines. Consider the recommended procedure for using existing guidelines which is described in the document entitled: "Protocol to Develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life." Discuss the implications of any predicted non-compliance with the surface water quality guidelines. Consider impacts on sediments and compare these with the Canadian Interim Sediment Quality Guidelines.

Discuss how the assessment addresses the oil sands and other relevant issues identified by the NRBS program.

Identify and discuss the existence of any watercourses in the Regional Study Area that may be sensitive to acidic deposition, and discuss the potential impacts of the Project on the waterbodies.

Discuss and describe water quality after reclamation of the site under the proposed reclamation scenario. Discuss the impact that consolidated tailings (CT) water discharges will have to the land, soils and vegetation and receiving watercourses.

Discuss the impact CT waters will have on Shipyard Lake. Discuss how water quality, both in Shipyard Lake and in the streams feeding into Shipyard Lake will be monitored and managed.

Describe aquatic quality monitoring programs in the Study Area with respect to variables such as polycyclic aromatic hydrocarbons (PAHs), related aromatics, metals and other relevant contaminants. Consider seasonality and sampling medium (water, sediment).

4.5.3 Surface Water Hydrology and Hydrogeology

Describe the surface hydrology in the Study Area before and after the Project.

Describe the pre- and post-disturbance watercourse configuration for draws, ephemeral streams and permanent streams which collect and disperse surface water flow.

Discuss the effects on surface water quantity, including changes in timing, volume and deviation of peak and minimum flows due to physical changes in topography, landscape and drainage patterns caused by the Project.

Identify temporary and permanent alterations, diversions, withdrawals or disturbances and the resultant impacts under a variety of operating conditions and scenarios, including emergency operating conditions. Discuss the effect of these changes on hydrology (timing, volume, and peak flow rates), including the significance for downstream basins and implications for reclaimed and down-stream vegetation, soil erosion, water quality and habitat quality.

Discuss how permanent alterations, diversions, disturbances can be used to enhance existing or rebuilt streams to increase the productivity of fish habitat and recreational potential.
Using the 1:100 year floodplain, discuss the potential for flooding during heavy precipitation events and spring runoff. Discuss the effects of probable maximum flood or probable maximum precipitation events, especially on tailings ponds and containment structures.
Discuss the potential effects of ice jams on the Athabasca River flood levels.

Identify project activities that will result in land disturbance, water diversions or other effects to stream beds and shores in the Study Area. Outline the mitigative measures to be used to reduce impacts to the streams and associated features.
Discuss implementation of a monitoring program for surface water runoff in order to assess performance of water management systems.

Describe the groundwater regime in the Study Area, particularly, where groundwater may be impacted by the proposed development.

Describe the effect the Project might have on the groundwater. Discuss options to manage and protect groundwater systems.

Discuss the interrelationship of the groundwater to the surface water in the Study Area and the potential for impacts on water quality, quantity, and discharge to streams, Shipyard Lake, and the Athabasca River.

Discuss the potential effects that alterations to the groundwater regime might have on terrestrial and riparian vegetation and surface water.

Discuss the implications of development activities on the surface and groundwater flows to associated wetlands.

Discuss the potential impacts on other water users, including wildlife and fisheries, of withdrawing water from the Athabasca River or any other potential surface water source to meet the requirements for the Project. Describe the impact on downstream watercourses. Consider seasonal fluctuations in both the water demand and the river flows.

4.6 Terrestrial

4.6.1 Land Use

Identify the land use, resource management, planning and other initiatives pertinent to the Project. Consider the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (IRP). Demonstrate that the development is consistent with the guidelines and objectives of this policy. Identify the criteria and assumptions used in locating the major project components with consideration of the IRP. Identify any mitigation or research requirements proposed to satisfy the IRP guidelines.

Indicate the proposed setbacks from the Athabasca and Steepbank Rivers, and demonstrate that the location of proposed facilities comply with the setbacks established in the IRP.

Identify unique sites or special features in the Study Area, such as Natural Areas, Environmentally Significant Areas or Heritage Rivers. Discuss any impacts of the Project on these features. Indicate the location and significance of any Special Places candidate sites, if present.

Identify the existing land uses, including oil sands development, tourism, forestry, fishing, hunting, cultural use, and outdoor recreation. Determine the impact of development on these uses and identify possible mitigation strategies.

Discuss implications of the Project for regional recreational activities, public access and other land uses, during and after development activities. Identify anticipated impacts on public access for land use in the region.

Discuss how reclamation will replace existing land uses.

4.6.2 Geology, Terrain and Soils

Describe and map the bedrock, surficial geology and topography of the Study Area.

Identify the aggregate resources potentially affected by the Project. Develop a plan for management of this resource.

Provide an assessment of the anticipated changes (type and extent) to the pre-disturbed topography, elevation and drainage patterns resulting from disturbance during pre-construction, construction, operations and reclamation. Identify these changes sequentially on maps.

Describe and map the soil types and their distribution in the Project Area.

Assess and map the pre- and post- disturbance land capability of the Project Area and describe the impacts to land capability due to the Project.

Describe the availability and suitability of soils within the Project Area for reclamation. Outline the criteria to be used in salvaging soils for reclamation within the Project Area.

Identify areas where soil will be salvaged and stockpiles located. Provide an estimate of the volume of soil salvaged and required to reclaim the Project Area.

Identify any soil related constraints or limitations which would affect reclamation. Identify constraints or limitations on revegetation based on anticipated soil conditions. Discuss the potential for soil erosion and identify measures to minimize the effects of such erosion. Identify activities which may cause soil contamination.

Discuss the results of any studies on regional soil sensitivity to acid deposition and reference any work planned by the Southern Wood Buffalo Zone or the Clean Air Strategic Alliance (CASA).

Collect all baseline biophysical information in a manner which enables a detailed ecological land classification (ELC) of the Project Area to be completed.

Describe the impact on each ELC unit from disturbance based upon key soil characteristics.

4.6.3 Vegetation

Map and describe plant communities affected by the Project using the Alberta Vegetation Inventory Standards Manual (AVI) Version 2.2.

Describe the plant communities for each ecosite phase in the Project Area. Identify species which are important to wildlife as food or shelter, or which act as indicator species for environmental effects. Where ecosite phases are rare, or where a significant percentage of specific type may be removed by the Project, describe their regional significance.

Provide ecological land classification (ELC) maps that show the pre- and post-disturbed landscapes. Comment on the importance of the size, distribution, and variety of these ELC units for wildlife habitat, timber harvesting and other land uses from both a local and regional perspective.

Identify rare, vulnerable, threatened or endangered species outlined in the Alberta Rare Plant Classification and the Canadian Organization of the Status of Endangered Wildlife in Canada (COSEWIC). Identify opportunities to avoid and mitigate impacts to these species, if present.

Determine the amount of commercial and non-commercial forest land base that will be disturbed within the Project Area. Classify the commercial forest land base according to the conifer, deciduous and mixedwood land base. Compare the pre- and post-disturbance percentages and distribution of all forested communities in the Project Area. Comment on how the disturbance of this renewable resource impacts present and future needs.

Identify the amount of vegetation to be disturbed during each stage of the Project. Discuss temporary and permanent changes to plant communities. Comment on the significance of the effects and their implications on other environmental resources (wildlife habitat diversity and quantity, water quality, erosion potential, soil conservation, recreation and other uses).

Provide a strategy to minimize the impact of the Project on vegetation. Outline expectations and roles for representatives of Alberta Environmental Protection (AEP) staff and other stakeholders as part of this strategy and consider future options for revegetation and reclamation of the land base.

Develop a plan for mitigating the adverse effects of site clearing, with emphasis on the timing of vegetation clearing and the effects of site clearing on runoff and water quality.

Provide an inventory of peatlands and wetlands affected by the Project using the Alberta Wetland Inventory Standards Manual (AWI) Version 1.0. Consider their importance for local and regional habitat, sustained forest growth and the hydrologic regime. Determine the rarity or abundance of peatlands and wetlands.

Predict the anticipated effect of the Project on peatlands and wetlands in conjunction with other project-induced variations in hydrology, habitat quality and wildlife populations. Discuss how Suncor will minimize the impact.

4.7 Wildlife

Describe the use and potential use of the Study Area by wildlife.

Identify rare, vulnerable, threatened or endangered species as outlined in the Status of Alberta Wildlife and the Canadian Organization of the Status of Endangered Wildlife in Canada (COSEWIC), as well as, species of international significance. Describe their habitat requirements. Discuss potential for adverse impacts on wildlife, wildlife utilization, habitat quality and food supply during the pre-construction, construction, operation and reclamation phases of the Project. Consider abandonment, loss, fragmentation or alteration of habitat, vehicle and wildlife collisions, obstructions to daily or seasonal movements, noise, hunting, mortality due to improved or altered access and potential impact to wildlife as a result of changes to air, water and soil quality.

Discuss significant local habitat for indicator wildlife species, seasonal habitat use patterns (calving, rearing and nesting areas, escape terrain), extent of range in both summer and winter and seasonal movement corridors.

Discuss the regional and temporal effects and the potential to return the area to pre-disturbed wildlife habitat conditions.

Provide a strategy to minimize impacts on habitat and wildlife populations through the life of the Project. Provide a mitigation plan and schedule for wildlife and significant wildlife habitat areas impacted by the Project. Indicate how the plan will address applicable provincial and federal wildlife habitat policies. Identify the need for access controls or other management strategies to protect wildlife.

Identify and discuss any monitoring programs that will be implemented to assess wildlife impacts from the Project and the effectiveness of mitigation strategies to ensure the protection of the wildlife resources in the area.

Discuss how the current bird deterrent system will be expanded to incorporate the Project. Discuss any limitations to the current system, anticipated effectiveness and potential improvements for the Steepbank and Millennium pond areas. Explain any impact on adjacent reclaimed and undisturbed land from the use of such deterrents.

5.0 RECLAMATION/MINE CLOSURE

Provide a comprehensive, conceptual reclamation mine closure plan for the current Suncor development and the Project. Outline reclamation concepts and objectives, proposed end land use objectives and other factors necessary for this plan to be implemented including:

- consideration of pre-development information with respect to land capability, vegetation, forest productivity, recreation, wildlife, birds, fisheries, aesthetics and land use resources;
- mine development phasing;
- integration of mining, closure planning and reclamation activities;
- reclamation sequencing for each phase of development;
- soil and reclamation material salvage and soil handling procedures;
- re-establishment of self-sustaining topography, drainage and surface watercourses;
- soil replacement and revegetation;
- post-development forest productivity;
- water, wastewater and tailings management; and
- end pit lakes, wetlands or other alternatives to reclaim the land.

Provide the anticipated timeframes for completion of reclamation phases and release of lands back to the Crown, including public access.

Describe how the final landform is incorporated into mine planning and development.

Discuss how Suncor will return land to the pre-disturbed equivalent capability having regard for regulatory requirements and stakeholder end land use preferences.

Discuss how Suncor will incorporate the resources and values identified in the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (IRP) into the reclamation plan.

Discuss how the reclamation plan will promote biodiversity.

Describe the aquatic components of the post-reclamation landscape, including end pit lakes. Address issues related to the design of a self-sustaining and productive aquatic ecosystem. Include a hydrological analysis of the post-reclamation landscape. Contrast the pre-disturbed aquatic ecosystem to the post-reclamation situation.

Describe how the reclamation plan incorporates diversity, size and extent of wetlands into the final design.

Develop a conceptual ecological land classification (ELC) map for the post-reclamation landscape considering all potential land uses. Show how the landscape and soils have been designed to accommodate future land use.

Identify the species which will be used for permanent revegetation of disturbed terrestrial and aquatic areas. Provide a rationale for species selection based on the need for development of a self-sustaining, biologically diverse ecosystem.

Describe the physical and biological parameters that Suncor will use to monitor and evaluate the reclaimed terrestrial and aquatic ecosystems. Provide an outline of the key milestone dates for reclamation and discuss how progress will be measured in the achievement of these targets. Describe plans to demonstrate reclamation success to stakeholders.

Discuss any constraints to reclamation such as timing of activities, availability of materials and influence of natural processes and cycles.

Discuss the needs for further reclamation research and development programs. Discuss options for a research program which will address the establishment of ecosystems equivalent to pre-disturbance characteristics and promote biodiversity.

6.0 PUBLIC HEALTH AND SAFETY ISSUES

Describe those aspects of the Project that may have implications for public health or the delivery of regional health services.

Discuss the potential for changes to water quality, air quality and the bioaccumulation of contaminants in natural food sources in the Study Area to increase human exposure to contaminants. Analyze samples of selected species of vegetation known to be consumed by humans. If results are available and are relevant, incorporate data from the Oil Sand Community Exposure Assessment Program. As appropriate, identify anticipated follow-up work, including regional cooperative studies.

Provide a summary of Suncor's emergency response plan and discuss mitigation plans that will be implemented to ensure workforce and public safety during pre-construction, construction, operation

and reclamation of the Project. Include prevention and safety measures for wildfire occurrences, accidental release or spill of chemicals to the environment and failures of structures retaining water or fluid wastes.

Identify and discuss potential health and safety impacts due to higher regional traffic volumes and the increased risk of accidental leaks and spills.

Document health and safety concerns raised by stakeholders during consultation on the Project.

7.0 HISTORICAL RESOURCES/TRADITIONAL LAND USE

Provide evidence of consultation with the Historical Sites and Archives Service, Alberta Community Development. Provide the Historical Resource Impact Assessment (HRIA) required by Alberta Community Development for the Project Area.

Provide a general overview of the results of any previous heritage resource studies that have been conducted in the Study Area. Summarize the results from the field program performed to assess archaeological, palaeontological and historical significance of the Project.

Provide the results of consultation with aboriginal stakeholders. Identify the existing and historical aboriginal land uses, including fishing, hunting, traditional plant harvesting, cultural use and outdoor recreation. Determine the impact of development on these uses and identify possible mitigation strategies.

Document any stakeholder concerns with respect to the impact of the Project on the historical significance of the Study Area or on its current use by traditional land users.

8.0 SOCIO-ECONOMIC ASSESSMENT

Provide information respecting the socio-economic impacts of the Project on the communities of the region and on Alberta, including:

- local employment and training;
- local procurement;
- population changes;
- stresses placed on local and regional infrastructure and community services;
- regional and provincial economic benefits; and
- trapping, hunting, and fishing.

Describe Suncor's policies and programs regarding the use of regional and Alberta goods and services.

Provide a summary of estimated industrial benefits. Include Alberta, other Canadian, and non-Canadian percentages of total project cost for engineering and project management, equipment and materials, construction labour and total overall project. Provide a description of the overall engineering and contracting plan for the Project.

Discuss workforce requirements for construction and operation. Identify local employment and business development opportunities the Project may create.

Outline plans to work with aboriginal and other local residents and businesses with regard to employment, training needs and other economic development opportunities arising from the construction and operation of the Project.

Evaluate the impact on local services and infrastructure, taking into consideration other projects that are reasonably anticipated during the life of the Project. This will include consideration of housing, transportation, education/training, health and social services, urban and regional recreation use, law enforcement and emergency preparedness. Discuss options for mitigating impacts.

Document the work with other industry partners and the Regional Municipality of Wood Buffalo to develop strategies to mitigate any socio-economic concerns that may arise. Describe plans to continue consultation and follow-up during the development and operation of the Project.

9.0 PUBLIC CONSULTATION

Describe the public consultation program implemented for all the communities within the Study Area, including the aboriginal communities and peoples. Document all public consultation and information meeting programs and the methods for publicizing the meetings.

Discuss the type of information and how information was provided to the public, the nature of the responses received and how they were addressed. Describe how this public input has influenced the design, operation, mitigation and monitoring proposed for the Project.

Discuss Suncor's communication program with employees, contractors, local communities, aboriginal communities, the general public and other key stakeholders. Discuss how Suncor will continue the public consultation process during the pre-construction, construction, operation, reclamation and decommissioning phases of the Project.

APPENDIX II

List of Scientific Names

Common Name	*Scientific Name*
VEGETATION	
Club-moss Family	**LYCOPODIACEAE**
Stiff Club-moss	*Lycopodium annotinum*
Running Club-moss	*L. clavatum*
Tree Club-moss	*L. obscurum*
Little Club-moss Family	**SELAGINELLACEAE**
Little Club-moss	*Selaginella selaginoides*
Horsetail Family	**EQUISETACEAE**
Common Horsetail	*Equisetum arvense*
Swamp Horsetail	*E. fluviatile*
Meadow Horsetail	*E. pratense*
Woodland Horsetail	*E. sylvaticum*
Dwarf Scouring Rush	*E. scirpoides*
Adder's-tongue Family	**OPHIOGLOSSACEAE**
Grape Fern	*Botrychium virginianum*
Fern Family	**POLYPODIACEAE**
Narrow Spinulose Shield Fern	*Dryopteris carthusiana*
Oak Fern	*Gymnocarpium dryopteris*
Ostrich Fern	*Matteuccia struthiopteris*
Cypress Family	**CUPRESSACEAE**
Ground Juniper	*Juniperus communis*
Pine Family	**PINACEAE**
Balsam Fir	*Abies balsamea*
Larch	*Larix laricina*
White Spruce	*Picea glauca*
Black Spruce	*P. mariana*
Jack Pine	*Pinus banksiana*
Cattail Family	**TYPHACEAE**
Common Cattail	*Typha latifolia*
Bur-reed Family	**SPARGANIACEAE**
Narrow-Leaved Bur-reed	*Sparganium angustifolium*
Giant Bur-reed	*S. eurycarpum*
Pondweed Family	**POTAMOGETONACEAE**
Various-leaved Pondweed	*Potamogeton gramineus*
Pondweed	*P. obtusifolius*
Clasping-leaf Pondweed	*P. richardsonii*
Arrow-grass Family	**JUNCAGINACEAE**
Arrow-grass	*Triglochin maritima*
Slender Arrow-grass	*T. palustris*
Scheuchzeria Family	**SCHEUCHERIACEAE**
Scheuchzeria	*Scheuchzeria palustris*
Water-plantain	**ALISMATACEAE**
Arrowhead	*Sagittaria cuneata*
Grass Family	**GRAMINEAE**
Tickle Grass	*Agrostis scabra*
Macoun's Wild Rye	*Agrohordeum macounii*

Common Name	*Scientific Name*
Slender Wheat Grass	*Agropyron trachycaulum*
Water Foxtail	*Alopecurus aequalis*
Slough Grass	*Beckmannia syzigachne*
Fringed Brome	*Bromus ciliatus*
Awnless Brome	*B. inermis*
Marsh Reed Grass	*Calamagrostis canadensis*
Northern Reed Grass	*C. inexpansa*
Narrow Reed Grass	*C. stricta*
Drooping Wood Reed	*Cinna latifolia*
Tufted Hair Grass	*Deschampsia cespitosa*
Canada Wild Rye	*Elymus canadensis*
Hairy Wild Rye	*E. innovatus*
Northern Rough Fescue	*Festuca saximontana*
Tall Manna Grass	*Glyceria grandis*
Sweet Grass	*Hierochloe odorata*
Foxtail Barley	*Hordeum jubatum*
Rough-leaved Rice Grass	*Oryzopsis asperifolia*
Northern Rice Grass	*O. pungens*
Reed Canary Grass	*Phalaris arundinacea*
Common Reed Grass	*Phragmites australis*
Wood Blue Grass	*Poa interior*
Fowl Bluegrass	*P. palustris*
Kentucky Bluegrass	*P. pratensis*
False Melic	*Schizachne purpurascens*
Cord Grass	*Spartina pectinata*
Slender Wedge Grass	*Sphenopholis intermedia*
Needle Grass	*Stipa curtiseta*
Sedge Family	**CYPERACEAE**
Silvery-flowered Sedge	*Carex aenea*
Water Sedge	*C. aquatilis*
Golden Sedge	*C. aurea*
Bebb's Sedge	*C. bebbii*
Brownish Sedge	*C. brunnescens*
Hair-Like Sedge	*C. capillaris*
Beautiful Sedge	*C. concinna*
Short Sedge	*C. curta (in. C. brunnescens group)*
Dewey's Sedge	*C. deweyana*
Two-stamened Sedge	*C. diandra*
Two-seeded Sedge	*C. disperma*
Northern Bog Sedge	*C. gynocrates*
Sand Sedge	*C. houghtoniana*
Inland Sedge	*C. interior*
Lakeshore Sedge	*C. lacustris*
Bristle-stalked Sedge	*C. leptalea*
Hairy-fruited Sedge	*C. lasiocarpa*
Mud Sedge	*C. limosa*

Common Name	*Scientific Name*
Norway Sedge	*C. norvegica*
Beacked Sedge	*C. utriculata*
Few-fruited Sedge	*C. oligosperma*
Bog Sedge	*C. paupercula*
Peck's Sedge	*C. peckii*
Meadow Sedge	*C. praticola*
Raymond's Sedge	*C. raymondii*
Ross' Sedge	*C. rossii*
Turned Sedge	*C. retrorsa*
Sartwell's Sedge	*C. sartwellii*
Sprengel's Sedge	*C. sprengellii*
Hay Sedge	*C. siccata*
Twin-flowered Sedge	*C. tenuiflora*
Sheathed Sedge	*C. vaginata*
Needle Spike-rush	*Eleocharis acicularis*
Creeping Spike-rush	*E. palustris*
Close-sheathed Cotton-grass	*Eriophorum brachyantherum*
Slender Cotton -grass	*E. gracile*
Tall Cotton-grass	*E. polystachion*
Sheathed Cotton-grass	*E. vaginatum*
Tufted Bulrush	*Scirpus cespitosus*
Small-fruited Bulrush	*S. microcarpus*
Arum Family	**ARACEAE**
Sweet Flay	*Acorus americanus*
Water Arum	*Calla palustris*
Duckweed Family	**LEMNACEAE**
Common Duckweed	*Lemna minor*
Ivy Duckweed	*L. trisulca*
Rush Family	**JUNCACEAE**
Wire Rush	*Juncus balticus*
Toad Rush	*J. bufonius*
Chestnut Rush	*J. castaneus*
Slender Rush	*J. tenuis*
Big-head Rush	*J. vaseyi*
Small-flowered Wood Rush	*Luzula parviflora*
Lily Family	**LILIACEAE**
Fairybells	*Disporum trachycaulum*
Rough-fruited Fairybells	*D. trachycarpum*
Western Wood Lily	*Lilium philadelphicum*
Wild Lily-of-the-valley	*Maianthemum canadense*
Star-flowered Solomon's-seal	*Smilacina stellata*
Three-leaved Solomon's-seal	*S. trifolia*
Twisted-stalk	*Streptopus amplexifolius*
Sticky False Asphodel	*Tofieldia glutinosa*
Iris Family	**IRIDACEAE**
Common Blue-eyed Grass	*Sisyrinchium montanum*

Common Name	*Scientific Name*
Orchid Family	**ORCHIDACEAE**
Pale Coral-root	*Corallorhiza trifida*
Yellow Lady's-slipper	*Cypripedium calceolus*
Lesser Rattlesnake-plantain	*Goodyera repens*
Northern Green Orchid	*Habenaria hyperborea*
Blunt-leaved Orchid	*H. obtusata*
Round-leaved Orchid	*H. orbiculata*
Bracted Orchid	*H. viridis*
Round-leaved Orchid	*Orchis rotundifolia*
Ladies'-tresses	*Spiranthes romanzoffiana*
Willow Family	**SALICACEAE**
Balsam Poplar	*Populus balsamifera*
Trembling Aspen	*P. tremuloides*
Little-tree Willow	*Salix arbusculoides*
Beaked Willow	*S. bebbiana*
Hoary Willow	*S. candida*
Pussy Willow	*S. discolor*
Satin willow	*S. drummondiana*
Sandbar Willow	*S. exigua*
Grey-leaved Willow	*Salix glauca*
Shinning Willow	*S. lucida*
Yellow Willow	*S. lutea*
Myrtle-leaved Willow	*S. myrtillifolia*
Bog Willow	*S. pedicellaris*
Basket Willow	*S. petiolaris*
Flat-leaved Willow	*S. planifolia*
Mountain Willow	*S. pseudomonticola*
Balsam Willow	*S. pyrifolia*
Scouler's Willow	*S. scouleriana*
Autumn Willow	*S. serissima*
Sweet Gale Family	**MYRICACEAE**
Sweet Gale	*Myrica gale*
Birch Family	**BETULACEAE**
Green Alder	*Alnus crispa*
River Alder	*A. tenuifolia*
Bog Birch	*Betula glandulosa*
Alaska Birch	*B. neoalaskana*
White Birch	*B. papyrifera*
Dwarf Birch	*B. pumila*
Beaked Hazelnut	*Corylus cornuta*
Nettle Family	**URTICACAEAE**
Common Nettle	*Urtica dioica*
Sandalwood Family	**SANTALACEAE**
Bastard Toad-flax	*Comandra umbellata*
Northern Bastard Toad-flax	*Geocaulon lividum*
Mistletoe Family	**LORANTHACEAE**

Common Name	*Scientific Name*
Dwarf Mistletoe	*Arceuthobium americanum*
Buckwheat Family	**POLYGONACEAE**
Water Smartweed	*Polygonum amphibium*
Striate Knotweed	*P. erectum*
Pale Persicaria	*P. lapathifolium*
Alpine Bistort	*P. viviparum*
Western Dock	*Rumex occidentalis*
Narrow-leaved Dock	*R. triangulivalis*
Goosefoot Family	**CHENOPODIACEAE**
Strawberry Blite	*Chenopodium capitatum*
Pink Family	**CARYOPHYLLACEAE**
Nodding Chickweed	*Cerastium nutans*
Blunt-leaved Sandwort	*Moehringia lateriflora*
Long-leaved Chickweed	*Stellaria longifolia*
Long-stalked Chickweed	*S. longipes*
Water-lily Family	**NYMPHAEACEAE**
Yellow Pond-lily	*Nuphar variegatum*
Hornwort Family	**CERATOPHYLLACEAE**
Hornwort	*Ceratophyllum demersum*
Crowfoot Family	**RANUNCULACEAE**
Red and White Baneberry	*Actaea rubra*
Canada Anemone	*Anemone canadensis*
Cut-leaved Anemone	*A. multifida*
Small Wood Anemone	*A. parviflora*
Prairie Crocus	*A. patens*
Blue Columbine	*Aquilegia brevistyla*
Marsh Marigold	*Caltha palustris*
Floating Marsh-marigold	*Caltha natans*
Goldthread	*Coptis trifolia*
Tall Larkspur	*Delphinium glaucum*
Small-flowered Crowfoot	*Ranunculus abortivus*
Seaside Crowfoot	*R. cymbalaria*
Yellow Water Crowfoot	*R. gmelinii*
Boreal Buttercup	*R. hyperboreus*
Lapland Buttercup	*R. lapponicus*
Macoun's Buttercup	*R. macounii*
Bristly Buttercup	*R. pensylvanicus*
Cursed Buttercup	*R. sceleratus*
Flat-fruited Meadow Rue	*Thalictrum sparsiflorum*
Veiny Meadow Rue	*T. venulosum*
Fumitory Family	**FUMARIACEAE**
Golden Corydalis	*Corydalis aurea*
Pink Corydalis	*C. sempervirens*
Mustard Family	**CRUCIFERAE**
Hairy Rock Cress	*Arabis hirsuta*
Lyre-leaved Rock Cress	*A. lyrata*

Common Name	*Scientific Name*
Pennsylvanian Bitter Cress	*Cardamine pensylvanica*
Green Tansy Mustard	*Descurainia pinnata*
Grey Tansy Mustard	*D. richardsonii*
Annual Whitlow-grass	*Draba nemorosa*
Wormseed Mustard	*Erysimum cheiranthoides*
Common Peppergrass	*Lepidium bourgeauanum*
Common Peppergrass	*L. densiflorum*
Yellow Cress	*Rorippa palustris*
Pitcher-plant Family	**SARRACENIACEAE**
Pitcher-plant	*Sarracenia purpurea*
Sundew Family	**DROSERACEAE**
Sundew	*Drosera rotundifolia*
Saxifrage Family	**SAXIFRAGACEAE**
Golden Iowense	*Chrysosplenium iowense*
Bishop's-cap	*Mitella nuda*
Grass-of-Parnassus Family	**PARNASSIACEAE**
Northern Grass-of-Parnassus	*Parnassia palustris*
Currant or Gooseberry Family	**GROSSULARIACEAE**
Skunk Currant	*Ribes glandulosum*
Wild Black Currant	*R. hudsonianum*
Bristly Black Currant	*R. lacustre*
Wild Gooseberry	*R. oxyacanthoides*
Wild Red Currant	*R. triste*
Rose Family	**ROSSACEAE**
Saskatoon	*Amelanchier alnifolia*
Woodland Strawberry	*Fragaria vesca*
Wild Strawberry	*F. virginiana*
Yellow Avens	*Geum macrophyllum*
Silverweed	*Potentilla anserina*
White Cinquefoil	*P. arguta*
Plains Cinquefoil	*Potentilla bipinnatifida*
Shrubby Cinquefoil	*P. fruticosa*
Graceful Cinquefoil	*P. gracilis*
Rough Cinquefoil	*P. norvegica*
Marsh Cinquefoil	*P. palustris*
Three-toothed Cinquefoil	*P. tridentata*
Pin Cherry	*Prunus pensylvanica*
Choke Cherry	*P. virginiana*
Prickly Rose	*Rosa acicularis*
Dwarf Raspberry	*Rubus arcticus*
Cloudberry	*R. chamaemorus*
Wild Red Raspberry	*R. idaeus*
Dewberry	*R. pubescens*
Pea Family	**LEGUMINOSAE**
American Milk Vetch	*Astragalus americanus*
Yukon Milk Vetch	*A. bodinii*

Common Name	*Scientific Name*
Canadian Milk Vetch	*A. canadensis*
Pretty Milk Vetch	*A. eucosmus*
Wild Licorice	*Glycyrrhiza lepidota*
Alpine Hedysarum	*Hedysarum alpinum*
Northern Hedysarum	*H. boreale*
Creamy Pea Vine	*Lathyrus ochroleucus*
Showy Loco-weed	*Oxytropis splendens*
Wild Vetch	*Vicia americana*
Geranium Family	**GERANIACEAE**
Bicknell's Geranium	*Geranium bicknellii*
Flax family	**LINACEAE**
Wild Blue Flax	*Linum lewisii*
Milkwort Family	**POLYGALACEAE**
Fringed Milkwort	*Polygala paucifolia*
Touch-me-not Family	**BALSAMINACEAE**
Spotted Touch-me-not	*Impatiens capensis*
Water-starwort Family	**CALLITRICHACEAE**
Vernal Water-starwort	*Callitriche verna*
Crowberry Family	**EMPETRACEAE**
Crowberry	*Empetrum nigrum*
Buckthorn Family	**RHAMNACEAE**
Alder-leaved Buckthorn	*Rhamnus alnifolia*
Rockrose Family	**CISTACEAE**
Sand Heather	*Hudsonia tomentosa*
Violet Family	**VIOLACEAE**
Early Blue Violet	*Viola adunca*
Western Canada Violet	*V. canadensis*
Marsh Violet	*V. palustris*
Kidnet-leaved Violet	*V. renifolia*
Oleaster Family	**ELAEAGNACEAE**
Wolf Willow	*Elaeagnus commutata*
Canadian Buffaloberry	*Shepherdia canadensis*
Evening Primrose Family	**ONAGRACEAE**
Small Enchanter's Nightshade	*Circaea alpina*
Fireweed	*Epilobium angustifolium*
Northern Willowherb	*E. ciliatum*
Purple-leaved Willowherb	*E. glandulosum*
Narrow-leaved Willowherb	*E. leptophyllum*
Mare's-tail Family	**HIPPURIDACEAE**
Common Mare's-tail	*Hippuris vulgaris*
Ginseng Family	**ARALIACEAE**
Wild Sarasparilla	*Aralia nudicaulis*
Carrot Family	**UMBELLIFERAE**
Bulb-bearing Waterhemlock	*Cicuta bulbifera*
Water-hemlock	*C. maculata*
Cow Parsnip	*Heracleum lanatum*

Common Name	*Scientific Name*
Water Parsnip	*Sium suave*
Dogwood Family	**CORNACEAE**
Bunchberry	*Cornus canadensis*
Red-osier Dogwood	*C. stolonifera*
Wintergreen Family	**PYROLACEAE**
One-flowered Wintergreen	*Moneses uniflora*
One-sided Wintergreen	*Orthilia secunda*
Common Pink Wintergreen	*Pyrola asarifolia*
Greenish-flowered Wintergreen	*P. chlorantha*
Indian-pipe Family	**MONOTROPACEAE**
Indian Pipe	*Monotropa uniflora*
Heath Family	**ERICACEAE**
Bog Rosemary	*Andromeda polifolia*
Alpine Bearberry	*Arctostaphylos rubra*
Common Bearberry	*A. uva-ursi*
Leather-leaf	*Chamaedaphne calyculata*
Creeping Snowberry	*Gaultheria hispidula*
Northern Bog-laurel	*Kalmia polifolia*
Common Labrador Tea	*Ledum groenlandicum*
Northern Labrador Tea	*L. palustre*
Small Bog Cranberry	*Oxycoccus microcarpus*
Bog Cranberry	*O. quadripetalus*
Dwarf Blueberry	*Vaccinium caespitosum*
Blueberry	*V. myrtilloides*
Bog Cranberry	*V. vitis-idaea*
Primrose Family	**PRIMULACEAE**
Shooting Star	*Dodecatheon pulchellum*
Tufted Loosestrife	*Lysimachia thyrsiflora*
Northern Starflower	*Trientalis borealis*
Arctic Starflower	*T. europaea*
Gentian Family	**GENTIANACEAE**
Felwort	*Gentianella amarella*
Spurred Gentian	*Halenia deflexa*
Buck-bean Family	**MENYANTHACEAE**
Buck-bean	*Menyanthes trifoliata*
Dogbane Family	**APOCYNACEAE**
Spreading Dogbane	*Apocynum androsaemifolium*
Indian Hemp	*A. cannabinum*
Dogbane	*A. x medium*
Phlox Family	**POLEMONIACEAE**
Collomia	*Collomia linearis*
Jacob's-ladder	*Polemonium acutiflorum*
Borage Family	**BORAGINACEAE**
Beggar-ticks	*Lappula occidentalis*
Tall Mertensia	*Mertensia paniculata*
Mint Family	**LABIATAE**

Common Name	*Scientific Name*
Giant Hyssop	*Agastache foeniculum*
American Dragonhead	*Dracocephalum parviflorum*
Western Water Horehound	*Lycopus asper*
Northern Water Horehound	*L. uniflorus*
Wild Mint	*Mentha arvensis*
Marsh Skullcap	*Scutellaria galericulata*
Marsh Hedge Nettle	*Stachys palustris*
Figwort Family	**SCROPHULARIACEAE**
Purple Paint-brush	*Castilleja raupii*
Cow-wheat	*Melampyrum lineare*
Labrador Lousewort	*Pedicularis labradorica*
Swamp Lousewort	*P. parviflora*
Yellow Rattle	*Rhinanthus minor*
American Brooklime	*Veronica americana*
Hairy Speedwell	*V. peregrina*
Marsh Speedwell	*V. scutellata*
Bladderwort Family	**LENTIBULARIACEAE**
Common Butterwort	*Pinguicula vulgaris*
Common Bladderwort	*Utricularia vulgaris*
Madder Family	**RUBIACEAE**
Northern Bedstraw	*Galium boreale*
Labrador Bedstraw	*G. labradoricum*
Small Bedstraw	*G. trifidum*
Sweet-scented Bedstraw	*G. triflorum*
Honeysuckle Family	**CAPRIFOLIACEAE**
Twin-flower	*Linnaea borealis*
Fly Honeysuckle	*Lonicera caerulea*
Twining Honeysuckle	*L. dioica*
Bracted Honeysuckle	*L. involucrata*
Snowberry	*Symphoricarpos albus*
Buckbrush	*S. occidentalis*
Low-bush Cranberry	*Viburnum edule*
High-bush Cranberry	*V. opulus*
Moschatel Family	**ADOXACEAE**
Moschatel	*Adoxa moschatellina*
Valerian Family	**VALERIANACEAE**
Northern Valerian	*Valeriana dioica*
Bluebell Family	**CAMPANULACEAE**
Bluebell	*Campanula rotundifolia*
Lobelia Family	**LOBELIACEAE**
Kalm's Lobelia	*Lobela kalmii*
Composite Family	**COMPOSITAE**
Common Yarrow	*Achillea millefolium*
Many-flowered Yarrow	*A. sibirica*
Small-leaved Pussytoes	*Antennaria parvifolia*
Leafy Arnica	*Arnica chamissonis*

Common Name	*Scientific Name*
Biennial Sagewort	*Artemisia biennis*
Plains Wormwood	*A. campestris*
Dragonwort	*A. dracunculus*
Marsh Aster	*Aster borealis*
Fringed Aster	*A. ciliolatus*
Showy Aster	*A. conspicuus*
Creeping White Prairie Aster	*A. falcatus*
Western Willow Aster	*A. hesperius*
Smooth Aster	*A. laevis*
Purple-stemmed Aster	*A. puniceus*
Nodding Beggar-ticks	*Bidens cernua*
Northern Daisy Fleabane	*Erigeron acris*
Horseweed	*E. canadensis*
Philadelphia Fleabane	*E. philadelphicus*
Common Tall Sunflower	*Helianthus nuttallii*
Narrow-leaved Hawkweed	*Hieracium umbellatum*
Artic Coltsfoot	*Petasites frigidus*
Palmate-leaved Coltsfoot	*P. palmatus*
Arrow-leaved Coltsfoot	*P. sagittatus*
Vine-leaved Coltsfoot	*P. vitifolius*
Marsh Ragwort	*Senecio congestus*
Rayless Ragwort	*S. indecorus*
Balsam Groundsel	*S. pauperculus*
Canada Goldenrod	*Solidago canadensis*
Flat-topped Goldenrod	*S. graminifolia*
Northern Goldenrod	*S. multiradiata*
Mountain Goldenrod	*S. spathulata*
Perennial Sow Thistle	*Sonchus arvensis*
INVERTEBRATES	
chironomid midge larva	*Chironomus tentans*
amphipod	*Hyalella azteca*
oligocaete worm	*Lumbriculus variegatus*
stoneflies	Order *Plecoptera*
mayflies	Order *Ephemeroptera*
dragonflies and damselflies	Order *Odonata*
caddisflies	Order *Trichoptera*
water flea	*Daphnia magna*
water flea	*Ceriodaphnia dubia*
FISH	
Arctic grayling	*Thymallus arcticus*
brook stickleback	*Culaea inconstans*
bull trout	*Salvelinus confluentus*
burbot	*Lota lota*
cisco	*Coregonus artedi*
emerald shiner	*Notropis atherinoides*

Common Name	*Scientific Name*
fathead minnow	*Pimephales promelas*
finescale dace	*Phoxinus neogaeus*
flathead chub	*Platygobio gracilis*
goldeye	*Hiodon alosoides*
Iowa darter	*Etheostoma exile*
lake chub	*Couesius plumbeus*
lake whitefish	*Coregonus clupeaformis*
longnose dace	*Rhinichthys cataractae*
longnose sucker	*Catostomus catostomus*
mountain whitefish	*Prosopium williamsoni*
ninespine stickleback	*Pungitius pungitius*
northern pike	*Esox lucius*
northern redbelly dace	*Phoxinus eos*
pearl dace	*Margariscus margarita*
rainbow trout	*Oncorhynchus mykiss*
river shiner	*Notropis blennius*
shiner species	*Notropis sp.*
slimy sculpin	*Cottus cognatus*
spoonhead sculpin	*Cottus ricei*
spottail shiner	*Notropis hudsonius*
trout-perch	*Percopsis omiscomaycus*
walleye	*Stizostedion vitreum*
white sucker	*Catostomus commersoni*
yellow perch	*Perca flavescens*
REPTILES AND AMPHIBIANS	
red-sided garter snake	*Thamnophis sirtalis*
boreal chorus frog	*Pseudacris triseriata*
Canadian toad	*Bufo hemiophrys*
northern leopard frog	*Rana pipiens*
wood frog	*Rana sylvatica*
BIRDS	
alder flycatcher	*Empidonax alnorum*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*
American white pelican	*Pelecanus erythrorhynchos*
American wigeon	*Anas americana*
bald eagle	*Haliaeetus leucocephalus*
barn swallow	*Hirundo rustica*
bay-breasted warbler	*Dendroica castanea*
black-and-white warbler	*Mniotilta varia*
black-backed woodpecker	*Picoides arcticus*
black-billed magpie	*Pica pica*

Common Name	*Scientific Name*
black-capped chickadee	*Parus atricapillus*
black-throated green warbler	*Dendroica virens*
blackburnian warbler	*Dendroica fusca*
blackpoll warbler	*Dendroica striata*
blue-winged teal	*Anas discors*
boreal chickadee	*Parus hudsonicus*
boreal owl	*Aegolius funereus*
brown creeper	*Certhia americana*
brown-headed cowbird	*Molothrus ater*
bufflehead	*Bucephalus albeola*
Canada goose	*Branta canadensis*
Canada warbler	*Wilsonia canadensis*
canvasback	*Aythya valisineria*
Cape May warbler	*Dendroica tigrina*
cedar waxwing	*Bombycilla cedrorum*
chestnut-sided warbler	*Dendroica pensylvania*
chipping sparrow	*Spizella passerina*
clay-colored sparrow	*Spizella pallida*
common goldeneye	*Bucephala clangula*
common loon	*Gavia immer*
common raven	*Corvus corax*
common snipe	*Gallinago gallinago*
common yellowthroat	*Geothlypis trichas*
Connecticut warbler	*Oporonis agilis*
dark-eyed junco	*Junco hyemalis*
downy woodpecker	*Picoides pubescens*
evening grosbeak	*Coccothraustes vespertinus*
gadwall	*Anas strepera*
golden-crowned kinglet	*Regulus satrapa*
gray jay	*Perisoreus canadensis*
great blue heron	*Ardea herodias*
great gray owl	*Strix nebulosa*
great-horned owl	*Bubo virginianus*
greater yellowlegs	*Tringa melanoleuca*
green-winged teal	*Anas crecca*
hairy woodpecker	*Picoides villosus*
hermit thrush	*Catharus guttatus*
house wren	*Troglodytes aedon*
killdeer	*Charadrius vociferus*
least flycatcher	*Empidonax minimus*
LeConte's sparrow	*Ammodramus leconteii*
lesser scaup	*Aythya affinis*
lesser yellowlegs	*Tringa flavipes*
Lincoln's sparrow	*Melospiza lincolnii*
long-eared owl	*Asio otus*
magnolia warbler	*Dendroica magnolia*

Common Name	*Scientific Name*
mallard	*Anas platyrhynchos*
mourning warbler	*Oporornis philadelphia*
northern flicker	*Colaptes auratus*
northern harrier	*Circus cyaneus*
northern hawk owl	*Surnia ulula*
northern pintail	*Anas acuta*
northern shoveler	*Anas clypeata*
northern waterthrush	*Seiurus noveboracensis*
olive-sided flycatcher	*Contopus borealis*
orange-crowned warbler	*Vermivora celeta*
osprey	*Pandion haliaetus*
ovenbird	*Seiurus aurocapillus*
palm warbler	*Dendroica palmarum*
peregrine falcon	*Falco peregrinus*
Philadelphia vireo	*Vireo philadelphicus*
pileated woodpecker	*Dryocopus pileatus*
pine siskin	*Carduelis pinus*
red-breasted nuthatch	*Sitta canadensis*
red-eyed vireo	*Vireo olivaceus*
red-necked grebe	*Podiceps grisegena*
red-tailed hawk	*Buteo jamaicensis*
red-winged blackbird	*Agelaius phoeniceus*
redhead	*Aythya americana*
ring-necked duck	*Aythya collaris*
rose-breasted grosbeak	*Pheucticus ludovicianus*
Ross' goose	*Chen rossii*
ruby-crowned kinglet	*Regulus calendula*
ruffed grouse	*Bonasa umbellus*
sandhill crane	*Grus canadensis*
screech owl	*Otus kennicottii*
sharp-shinned hawk	*Accipiter striatus*
sharp-tailed grouse	*Tympanuchus phasianellus*
short-eared owl	*Asio flemmeus*
snow goose	*Chen caerulescens*
solitary sandpiper	*Tringa solitaria*
solitary vireo	*Vireo solitarius*
song sparrow	*Melospiza melodia*
spruce grouse	*Dendragapus canadensis*
Swainson's thrush	*Catharus ustulatus*
swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
three-toed woodpecker	*Picoides tridactylus*
western grebe	*Aechmophorus occidentalis*
western tanager	*Piranga ludoviciana*
western wood-pewee	*Contopus sordidulus*
white-throated sparrow	*Zonotrichia albicollis*

Common Name	*Scientific Name*
white-winged crossbill	*Loxia leucoptera*
willow ptarmigan	*Lagopus lagopus*
Wilson's warbler	*Wilsonia pusilla*
winter wren	*Troglodytes troglodytes*
yellow warbler	*Dendroica petechia*
yellow-bellied flycatcher	*Empidonax flaviventris*
yellow-bellied sapsucker	*Sphyrapicus varius*
yellow-rumped warbler	*Dendroica coronata*
MAMMALS	
beaver	*Castor canadensis*
black bear	*Ursus americanus*
buffalo	*Bison bison*
Canada lynx	*Lynx canadensis*
coyote	*Canis latrans*
deer mouse	*Peromyscus maniculatus*
elk	*Cervus elaphus*
ermine	*Mustela erminea*
fisher	*Martes pennanti*
gray wolf	*Canis lupus*
least weasel	*Mustela nivalis*
marten	*Martes americana*
meadow vole	*Microtus pennsylvanicus*
mink	*Mustela vison*
moose	*Alces alces*
mule deer	*Odocoileus hemionus*
muskrat	*Ondatra zibethicus*
porcupine	*Erethizon dorsatum*
red fox	*Vulpes vulpes*
red squirrel	*Tamiasciurus hudsonicus*
red-backed vole	*Clethrionomys gapperi*
river otter	*Lutra canadensis*
snowshoe hare	*Lepus americanus*
striped skunk	*Mephitis mephitis*
water shrew	*Sorex palustris*
white-tailed deer	*Odocoileus virginianus*
wolverine	*Gulo gulo*
woodland caribou	*Rangifer tarandus*

APPENDIX III

AIR QUALITY MODELLING DOCUMENTATION

III AIR QUALITY MODELLING DOCUMENTATION

III.1 INTRODUCTION

This technical Appendix provides documentation and support for the models selected, the dispersion modelling approach adopted, and the meteorological data used to generate the results that have been presented in the body of the Air Quality Impact Assessment for the Project Millennium EIA.

The reasoning for the overall modelling approach used in this assessment is a combination of accepted procedures and sound technical judgement, with consideration given to the practical limits established due to availability of information.

To the extent feasible, this Appendix includes the information on the modelling approach adopted to facilitate the review by independent parties and the replication of the modelling results. All efforts have been made to include a thorough justification for the completed modelling work.

III.2 MODEL SELECTION

The selection of an air quality model for use in evaluating the atmospheric emissions in the Athabasca oil sands region should be able to satisfy the following key conditions:

- The model should have the capability to evaluate the various regional source types.
- The model must be able to able to predict the necessary pollutant concentrations or required deposition rates.
- The technical basis of the dispersion model must be scientifically sound, and in keeping with the current understanding of the dispersal of contaminants in the atmosphere.
- The assumptions and formulations used in the model must be clearly set out, and should have undergone rigorous independent scrutiny by peers in the technical community.
- The model should be applied in situations for which it was developed. In the case of this assessment, the model should have the capability to evaluate both the regional and local effects of atmospheric emissions.
- The predictions made by the model should be consistent with historic observations made in the region.

A series of dispersion models were considered for use in the assessment. These ranged from the SCREEN3 model, which requires minimal inputs to run, to the more elaborate CALPUFF and CALGRID models, which are designed to run using extensive source, air quality and meteorological parameters. A brief review of the models considered for use in the evaluation is given in Table III-1.

III.2.1 SCREEN3

The SCREEN3 model is an easy-to-use Gaussian plume model that uses a predefined set of meteorological conditions to determine the worst case concentrations from a single source. SCREEN3 uses the Pasquill-Gifford dispersion coefficients to characterize atmospheric turbulence and the Briggs relationships to determine plume rise.

Table III-1 Comparison of the Principal Features of the Air Quality Models

Model	Strengths	Weaknesses
SCREEN3	U.S. EPA, 1997	
	• built in meteorological data • screening level evaluation of the maximum concentrations from single sources • considers the influence of terrain, building wakes and downwash	• multiple or complex sources • unrealistic predictions
ISCST3	U.S. EPA, 1997 (96113)	
	• evaluating maximum and average concentrations from complex sources • considers terrain, building wakes and downwash • allows simple deposition calculations • well established and accepted	• requires representative meteorological data set • not able to simulate chemical transformations • cannot deal with meteorological conditions which vary temporally or spatially
ISC3BE	BOVAR Environmental (Version 7)	
	• designed to replicate the monitored concentrations in the vicinity of the Suncor and Syncrude facilities • considers site specific observations in the modelling algorithms • similar strengths as ISCST3	• not open to scrutiny or review • similar limitations as ISCST3
CALPUFF	U.S. EPA and EARTH TECH, 1998 (Version 5; with NO, NO_2 Chemistry)	
	• evaluating maximum and average concentrations from complex sources • addresses building wakes and downwash • can use simplified meteorology or a 3-dimensional wind field • can simulate terrain in a manner similar to ISCST3 or using the CTDM Plus algorithms • allows full chemical transformation calculations • considers wet and dry deposition components • well researched and has strong backing from IWAQM, the U.S. Forestry Service and the U.S. EPA	• requires extensive computational capabilities • the data required to gain the full benefit of the model
CALGRID	U.S. EPA and EARTH TECH, 1998	
	• evaluating ozone chemical formation on a regional scale • addresses all of the technical strengths of CALPUFF	• requires the full implementation of the CALPUFF system • meteorological and digital terrain data requirements are typically beyond what is available • ozone transformation models place a premium on the characterization of the emissions and emission species from all anthropogenic and biogenic sources

The model is available on the U.S. EPA Office of Air Quality Planning and Standards (OAQPS) internet web site under the Technology Transfer Network (TTN) and specifically the Support Centre for Regulatory Air Quality Models (SCRAM). The internet address is http://www.epa.gov/scram001.

Due to the screening nature of the model, it is possible for SCREEN3 to significantly overpredict the worst case concentrations for some scenarios.

III.2.2 ISC3ST (Version 3)

The Industrial Source Complex Short Term Model, Version 3 (ISCST3) is a steady-state Gaussian plume model, recommended by the U.S. EPA for evaluating pollutant releases from a wide variety of sources associated with industrial source complexes. This model can account for: building downwash; area, line and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment.

The model assumes constant, uniform (steady-state) winds for each hour modelled. Therefore, the plumes are assumed to travel in a straight line for all downwind receptors. The model accepts user specific wind profiles (as discussed in more detail in Section III.3) or uses default wind profile exponents (Irwin 1979) for both rural and urban modelling situations. Vertical wind speed is assumed to be zero.

Plume rise is accounted for using the equations developed by Briggs (1969, 1971, 1975). The Briggs equations are also used to account for the stack top downwash. The effect of building wakes is addressed using either the formulations of Huber and Snyder (1976), or for lower stacks, the Schulman and Scire approach (Schulman and Hanna 1986).

Horizontal dispersion coefficients from Turner (1969), with no adjustments for surface roughness, are used in rural setting. The effect of an elevated capping layer is accounted for in the model with multiple reflections of the plume. Perfect reflection (i.e., no loss of pollutant due to scavenging nor increased dispersion due to windshear) is assumed at the ground.

For rolling terrain (terrain below stack height), plume centerline is assumed to remain horizontal at the height of final rise above source. The model evaluates concentrations in elevated terrain either by truncating elevations at the stack top, or using a plume height correction similar to the approach utilized in the COMPLEX I model.

The ISCST3 model acquires hourly meteorological (surface weather) data, including stability class, wind vector (direction towards which the wind is blowing), wind speed, temperature, and mixing height.

The ISCST3 model is one of the most widely applied dispersion models for evaluating industrial emissions. The model, documentation and source code is available on the U.S. EPA Office of Air Quality Planning and Standards (OAQPS) internet web site under the Technology Transfer

Network (TTN) and specifically the Support Centre for Regulatory Air Models (SCRAM). The internet address is http://www.epa.gov/scram001.

III.2.3 ISC3BE

The ISC3BE dispersion model is a modified version of the original ISCST3 model which was developed by BOVAR Environmental. Modifications were made to the original model code to tune maximum predicted concentrations and the number of times guidelines are exceeded to observed values at local monitoring stations (Conor Pacific 1998). The model changes were not subjected to rigourous independent review (as per guidance of the U.S. EPA). However, changes were made to the code to calibrate the model to observations made at the air monitoring locations in the oil sands region, along the Athabasca River valley.

The specific changes made to the ISCST3 model include:

- The vertical rise of the plume was adjusted to reflect the analysis of photographic plume rise data in the region by Davidson and Leavitt (1979). This was achieved by adjusting the plume rise coefficients used in the model and results in plumes which are 87% of the height estimated by ISCST3 during neutral and unstable conditions, and 69% as high during the stable hours.
- The Briggs (1973) vertical dispersion coefficients were used in the model instead of the Pasquill-Gifford values used by the U.S. EPA.
- The horizontal dispersion in the valley locations (for locations below 270 masl) was based on the scheme recommended by Briggs (1973). The ISC3BE model uses the default Briggs horizontal dispersion parameters for the unstable (A, B, and C) and neutral (D) conditions. However, during slightly stable (E) and highly stable (F) conditions, the horizontal dispersion parameters were set equal to those usually associated with neutral stability conditions.
- Two horizontal dispersion schemes were used in the ISC3BE for receptors outside of the valley (i.e., locations with elevations above 270 mASL). Within 10 km of the major sources, horizontal dispersion was based loosely on the scheme recommended by Briggs (1973). The ISC3BE model uses the same horizontal dispersion parameters for the unstable (A, B, and C) and neutral (D) conditions. During slightly slightly stable (E) conditions, the ISC3BE model uses horizontal dispersion parameters typically associated with slightly unstable (C) conditions. During the highly stable (F) conditions, ISC3BE uses the same horizontal dispersion parameters as during unstable (B) conditions. Outside of 10 km, the ISC3BE dispersion coefficients are further increased by a factor of $(distance/10)^{0.5}$. This is done to address the plume meander at increased distances (Conor Pacific 1998).

- The adjustments made within the ISC3BE model to address terrain conditions were based on the approach adopted by the ADEPT2 model originally developed by Alberta Environmental Protection. The ISC3BE model uses the following terrain coefficients: 0.8 during highly unstable (A) conditions; 0.7 during unstable (B) conditions; 0.6 during slightly unstable (C) conditions; and 0.5 during neutral (D), slightly stable (E) and highly stable (F) conditions.

III.2.4 CALPUFF

An Interagency Work Group for Air Quality Modelling (IWAQM) was formed in the United States with the objectives to review, identify and recommend candidate air quality modelling techniques that can be used to estimate pollutant concentrations on a regional scale. One of the efforts currently underway is to develop and test the feasibility of using the CALPUFF modelling system to address the IWAQM goals and objectives.

EARTH TECH (formerly Sigma Research Corporation) prepared a version of a Lagrangian puff modelling system based on CALPUFF for the IWAQM. The original design of the modelling system included (U.S EPA 1995b): the capability to treat time-varying point and area sources; suitability for modelling domains from tens of metres to hundreds of kilometres from a source; predictions for averaging times ranging from one-hour to one year; applicability to inert pollutants and those subject to linear removal and chemical conversion mechanisms; and applicability for rough or complex terrain situations.

The CALMET and CALPUFF models have been enhanced as part of work for IWAQM, U.S. EPA, the U.S. Forest Service, the Environmental Protection Authority of Victoria (Australia), and private industry in the U.S. and Australia. The improvements to CALMET included modifications to make it more suitable for regional applications. Some of the improvements to the CALPUFF system include new modules to treat buoyant rise and dispersion from area sources, buoyant line sources, volume sources, an improved treatment of complex terrain, additional model switches to facilitate its use in regulatory applications, and enhanced treatment of wind shear through puff splitting.

CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on pollutant transport, transformation and removal. CALPUFF can use the three dimensional meteorological fields developed by the CALMET or similar models, or simple, single station winds in a format consistent with the meteorological files used to drive the ISCST3 steady-state Gaussian models. The use of single station wind files does not allow CALPUFF to take advantage of its capabilities to treat spatially-variable meteorological fields.

Building downwash is handled using the Huber-Snyder and Schulman-Scire downwash models. The user has the ability to use either one or both schemes depending on the source and meteorological conditions.

CALPUFF includes the capability to use several schemes for computing the dispersion coefficients, including: the use of direct turbulence measurements (σ_v and σ_w); the use of similarity theory to estimate σ_v and σ_w from modeled surface heat and momentum fluxes; the use of Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients; or the dispersion equations based on the Complex Terrain Dispersion Model (CTDM).

The treatment of complex terrain by the CALPUFF varies depending on the meteorological data sets used in the model. If single-site (i.e. ISCST3) wind measurements are input, then a simple plume height adjustment approach is used similar to that for the COMPLEX I model. When more involved meteorological data and terrain characteristics are available, the model addresses terrain based on the approach used in the Complex Terrain Dispersion Model (CTDMPLUS) (Perry et al. 1989). Plume impingement on hills is evaluated using a dividing streamline to determine which pollutant material is deflected around the sides of a hill and which is advected over the hill.

Some of the key advantages of applying the CALPUFF model to the evaluation of air quality in the oil sands region are its capability to explicitly deal with chemical transformation, as well as wet and dry pollutant deposition. The latest version of CALPUFF developed by EARTH TECH includes options for parameterizing chemical transformation effects using a six species scheme (SO_2, SO_4, NO, NO_2, HNO_3, and NO_3) making use of background O_3 and NH_3. Wet deposition is addressed with an empirical scavenging coefficient approach. CALPUFF computes the depletion and wet deposition fluxes due to precipitation scavenging. Dry deposition of gases and particulate matter is undertaken as a function of geophysical parameters, meteorological conditions, and pollutant species.

III.2.5 CALGRID

The objective of the CALGRID model is the computation of ground-level ozone concentrations on typical air basin scales of 50 to 200 km. The CALGRID model is a companion model to CALPUFF with respect to meteorological and terrain characterization of the study area. The CALGRID model, however, uses a much more detailed chemical characterization of the ambient air flows. This characterization requires detailed emissions from biogenic (natural) and anthroprogenic (industrial) emissions for night time, daytime and seasonal changes that are used as parameters in up to 135 chemical reactions. The importance of non-linear

chemistry forces the CALGRID model to abandon conventional plume and puff methodology, that invoke superposition and thus imply linearity, and turn to a numerical time marching of a conservation equation over a number of grid points. The approach involves the time-integration of a partial differential equation (the advection-diffusion equation), taking into account emissions, depletion and chemical transformation. This is the same methodology used in other ground level ozone models, such as, the Urban Airshed Model (UAM).

III.3 MODEL CONFIGURATIONS

III.3.1 Meteorology

III.3.1.1 Tower Selection

Meteorological data for use in the dispersion modelling analysis were available from two possible locations in the region. The Mannix and Lower Camp monitoring stations (see Figure III-1), which have been operated by Suncor for an extended time period, record the necessary hourly data required in the modelling.

The Lower Camp monitoring station is situated in the Athabasca River valley, making it susceptible to local topographic effects. While a comparison of the wind directions and speeds collected at the upper levels of both stations show some agreement over time (BOVAR, 1996), the wind data from the Lower Camp is expected to be more representative of the local in-valley conditions. The Mannix station is located out of the river valley, and is likely to provide data more representative of the wind patterns over the RSA.

III.3.1.2 Anemometer Level Selection

Meteorological data are gathered at three levels at the Mannix station; at elevations of 20, 45 and 75 m above the base of the tower. Discussions with U.S. EPA personnel (Bailey 1998) and review of U.S. EPA guidance documents (U.S. EPA 1995) indicate that when available, wind speeds and directions gathered at the 75 m level are most appropriate for use in simulating plume dispersion because this height is closest to the plume height for the major sources. In addition, the wind parameters measured at the lowest level (i.e. 20 m height) are expected to be influenced by the local tree canopy (Conor Pacific, 1998) and, therefore, may not be representative of the winds over the entire RSA. The effect of the local tree canopy is not expected to be present for winds at the 75 m level.

For the purposes of this assessment, the dispersion modelling analysis was conducted using wind speeds and directions gathered at the 75 m level on the Mannix tower. These winds are deemed to be most appropriate for use in the dispersion modelling analysis as they are:

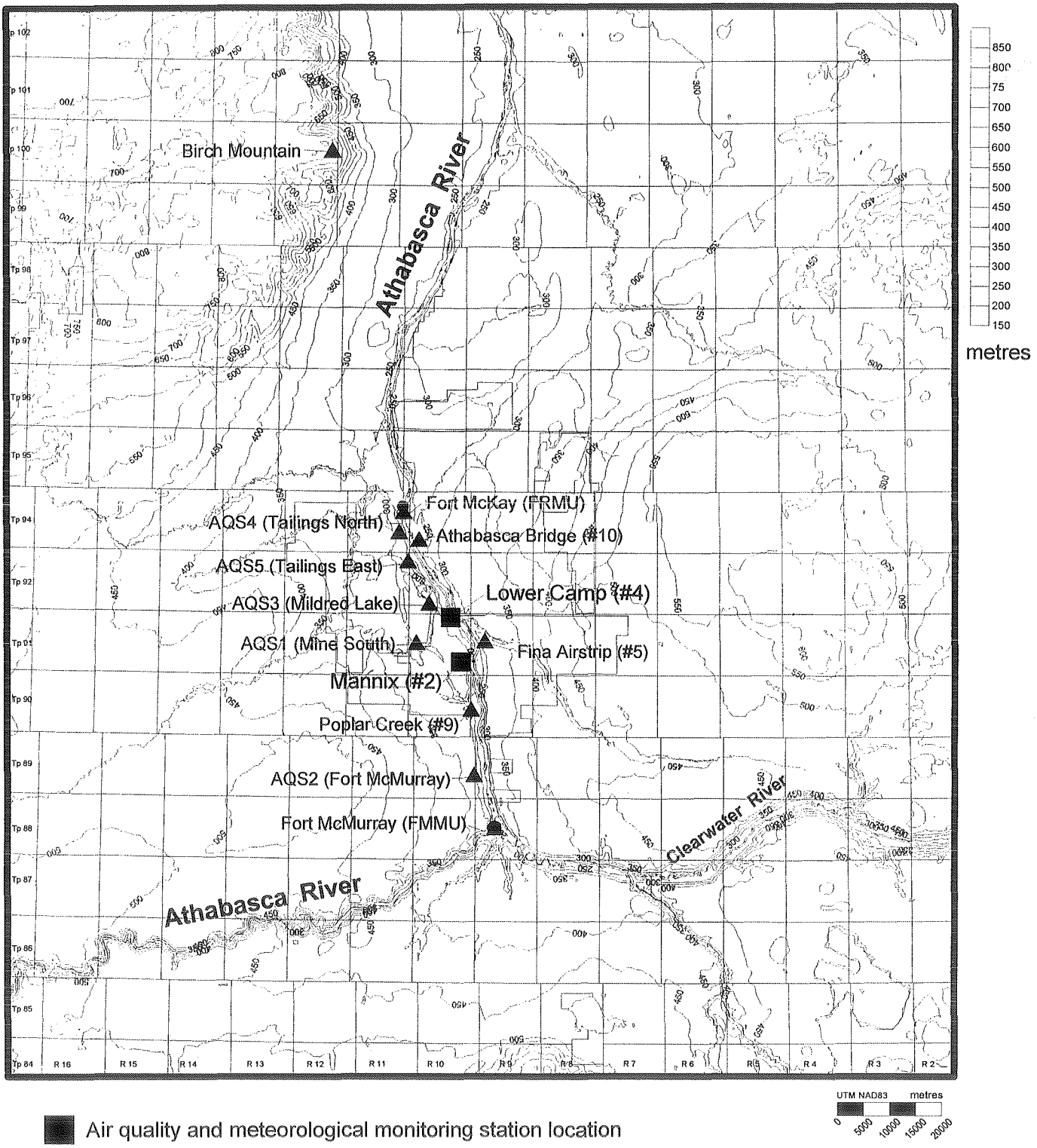


Figure III-1 **Locations of Meteorological and Continuous Air Quality Monitoring Stations**

- generally free from the strong river valley influence evident in the data gathered at the Lower Camp station;
- free of the local tree canopy effects which effect the winds at the 20 m level at the Mannix station;
- closest to the plume heights for the major emission sources being evaluated; and
- consistent with previous modelling completed in the region.

III.3.1.3 Data Period Selection

For the purposes of the air quality modelling analysis, it was necessary to select an extended period of meteorological data that would provide a representative cross section of the conditions to be expected in the region. The data period used for the modelling analysis spanned from November 1993 through to the end of October 1997. This data set covers a full four years of meteorological conditions and includes the most recent data available at the time the assessment was initiated.

III.3.1.4 Meteorological Data Parameters Utilized

Not all of the meteorological parameters required for use in the dispersion models can be monitored directly with electronic instruments. In these cases, the values were derived from the available measurements.

The wind speeds and directions used for the dispersion modelling analyses were taken from the data collected at the 75 m level on the Mannix tower. Since the models require that the user provide wind vector values, 180° were added to each reading. The methodology used in the models in the assessment cannot deal readily with wind speeds that are less than 1 m/s. In cases where the wind speeds were below this threshold, they were set to a minimum speed of 1 m/s. In situations when the wind speeds or directions were missing at the 75 m level, winds from lower levels on the Mannix tower were used. This is consistent with U.S. EPA guidance in meteorological processing for use with the air quality models.

One of the important characteristics required by the air quality models that is not available by direct measurement on-site is the mixing height (i.e., the depth of surface layer in which atmospheric mixing of emissions occurs). The mixing height was calculated based on local observations of wind speed and was set to a minimum height of 200 m. A minimum mixing height threshold of 200 m is a reasonable characterization of the meteorology for use in the air quality models based on the ways in which the dispersion models apply the mixing height. These include:

1. Wind speeds below 1 m/s have been truncated to 1 m/s because these calm conditions are not handled by the dispersion models. Mixing

heights are calculated based on the maximum of the mechanical or convective mixing heights. The mechanical mixing height is estimated by $Z_m = 200\ U$.

2. If a minimum mixing height is selected that is below the final rise height of the stack plume increased lofting can occur for point sources. Lofting prevents the plume from reaching the ground, and therefore the model can inadvertently underpredict long-term exposures. In addition, ground level area sources (e.g., pond emissions or fleet vehicle emissions) can become entrapped, and thereby create an arbitrary fumigation (uniform mixing of the pollutant between the ground and the mixing height, generally resulting in very high concentrations due to the restricted mixing) of the entire RSA. This is an unlikely and unreasonable assumption.

3. Low mixing heights can occur early in the morning when the sun begins to warm air near the ground surface. During this time, atmospheric stability classes change from Class F (or Class E) to Class D. During the change over to Class D (i.e., break up of the stable atmosphere), short periods in time may exist where the mixing height is less than 200 m. It is not reasonable that these low mixing heights would persist in time and spatial extent, because of the boundary layer mixing which would occur with Class D stability and a minimum wind speed of 1 m/s. Whereas on a local scale the observed mixing height could be low to the ground and the wind speeds very small, such that entrapment and fumigation could occur for a short time, the air quality models are not valid during these periods. It would not be reasonable to assume that these conditions would be applicable over the entire RSA.

A detailed discussion on the meteorological characterization in the region is presented in the supporting information document, entitled "Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region".

III.3.2 Terrain/Receptor Locations

III.3.2.1 Receptor Grids

The plume and puff dispersion models require a series of receptor locations at which the concentration and deposition values are calculated. The current analysis uses a series of nested grids of receptors, with the greatest density close to the major sources, and decreasing spacing at increased distances. The initial grid of receptors at a spacing of 1 km grid spans an area from 20 km east to 20 km west of the Suncor facility, and stretching from Fort McKay in the north to Fort McMurray in the south. A grid spaced at 5 km intervals covers an area a further 20 km in all directions. Finally, the balance of the RSA is covered with receptors spaced at 10 km

intervals. The relative spacing of the modelled receptor locations are illustrated in Figure III-2.

The selected receptor grid represents a compromise between computational speed and expected delineation of the maximum ground level concentrations and depositions over a study area. The resolution of the receptor grid is ideally selected so that one of the receptor grid points records the predicted overall maximum ground level concentration. The location of the maximum concentrations will depend on: the meteorological period selected for the model run; the number, location and parameters for the emission sources; the influence of the terrain on the individual plumes; and on the overlap of the plumes. Because of these complexities, the selection of the receptor grid can often be an iterative process, for which a successive pattern of greater and greater resolution receptor grids is applied. This kind of iteration is not feasible because of computational speed, but is also not necessary because the predicted ground level concentration from the models indicate gradual changes in the predited maximum concentrations. The selected grid spacing adequately captures the rate of change in these preditions and, therefore, the preditions will represent the maximum expected concentrations.

III.3.2.2 Additional Receptor Locations

In addition to the grid receptor locations, it is of value to determine the concentrations and depositions at specific locations of interest. These additional receptor locations include: the 12 continuous ambient monitoring locations operated by Suncor, Syncrude and AEP; the location of the discontinued monitoring station at Birch Mountain; Indian Reserves 201G and 201F which are located to the north of the RSA; as well as, the communities of Fort McMurray, Fort McKay, Embarras Portage and Fort Chipewyan.

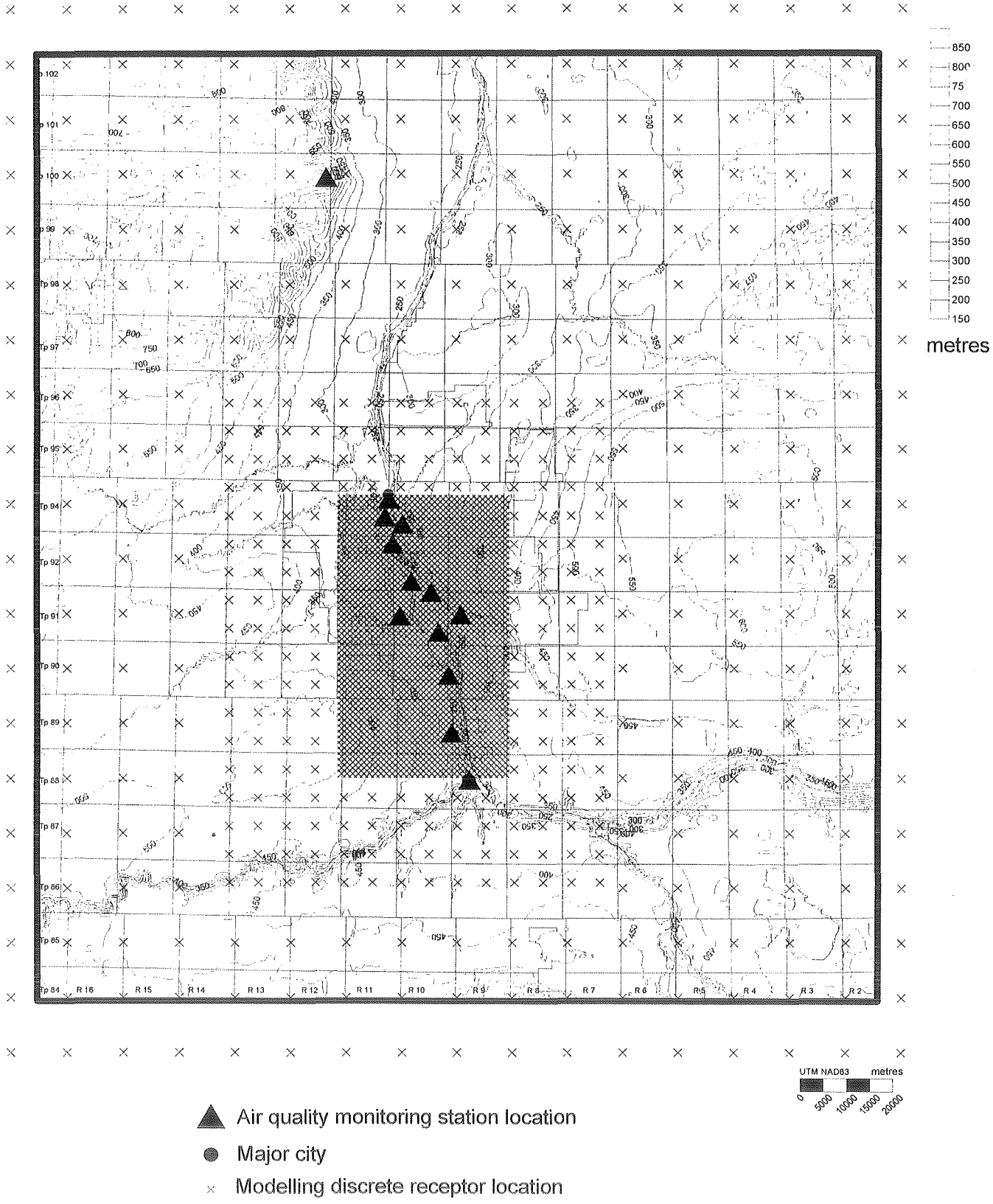


Figure III-2 Map of RSA with modelling discrete receptor locations

The location of these receptors and their relative location to the Suncor facility are provided in Table III-2. Distances are measured from the Suncor sulphur plant incinerator stack.

Table III-2 Location of Additional Modelling Receptors

Location	UTM NAD83 Easting	UTM NAD83 Northing	Elevation [mASL]	Distance [km]	Direction
Fort McMurray	476100	6287300	254	31.0	S
Fort McKay	461800	6337400	244	21.5	NNW
Fort Chipewyan	491137	6508225	218	191.4	N
IR 201G	476348	6418199	243	100.5	N
IR 201F	480280	6431901	243	114.4	N
Embarrass Portage	471676	6478680	234	160.8	N
Mannix	470600	6313700	334	4.2	S
Lower Camp	469300	6320800	245	3.3	NNW
Fina	474600	6316800	323	3.9	ESE
Poplar Creek	472400	6306000	245	12.0	S
Athabasca Bridge	464200	6333000	260	16.5	NNW
AQS1 (Mine South)	463800	6316600	306	7.2	W
AQS2 (Fort McMurray)	472900	6295700	339	22.3	S
AQS3 (Mildred Lake)	465800	6322800	319	7.1	NW
AQS4 (Tailings North)	461100	6334200	265	19.0	NNW
AQS5 (Tailings East)	462500	6329500	278	14.3	NW
Fort McMurray	476100	6287300	254	31.0	S
Fort McKay	461800	6337400	244	21.5	NNW
Birch Mountain	450800	6394700	795	79.4	NNW

III.3.3 Dispersion Parameters

The dispersion parameters used in this assessment vary from model to model. In the ISCST3 model, the horizontal and vertical terms cannot be adjusted and are based on rural coefficients from Turner (1969), with no adjustments for surface roughness.

In the ISC3BE model, the dispersion parameters used in the original model model were adjusted as described in Section III-2.3. While the rural control parameter was also selected for the ISC3BE model, the dispersion characteristics will differ from the original ISC3ST model.

CALPUFF was configured to use a rural setting with the use of Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients. At distances greater than approximately 10 km, however, the model assumes that the dispersion coefficients are a function of time rather than distance, and the horizontal dispersion formulations reflect these conditions. This is similar to the approach used in the ISC3BE .

III.3.4 Complex Terrain Coefficients

Air quality models (SCREEN3, ISC3ST, ISCBE and the way in which CALPUFF is used in this assessment) account for the influence of terrain height and how this affects the ground level concentrations from elevated plumes by defining three classifications:

1. **Simple terrain**: gently rolling terrain where the height of the hills is less than stack height.

2. **Intermediate terrain:** gently rolling terrain where the height of the hills can exceed stack height but is less than the height of the plume.

3. **Complex Terrain:** terrain where the height of the hills can exceed the height of the plume.

In general, the models account for terrain by adjusting the effective height of the plume. This can either increase or decrease the ground level concentrations depending on whether there is a hill or a valley present. The models can be configured to estimate concentrations in Complex Terrain by using a scheme used in the COMPLEX I model which is characterized by a plume half-height correction. The ISCBE model has incorporated these terrain correction algorithms to the ISCST code (the current U.S. EPA versions of ISCST3 now include the plume half-height correction algorithms) based on the approach adopted by the ADEPT2 model originally developed by AEP. Specifically, the ISCBE model uses the following terrain coefficients: 0.8 during very unstable (Class A) conditions; 0.7 during unstable (Class B) conditions; 0.6 during slightly stable (Class C) conditions; and 0.5 during neutral (Class D), stable (Class E) and very stable (Class F) conditions.

The methodology applied in the CALPUFF model can vary depending on the type of meteorological data sets used and on user preference. For the configuration of CALPUFF applied in this assessment, the simplistic plume half-height adjustment approach was selected so that the results could be readily compared with the ISCBE ground level concentration predictions.

III.3.5 Chemical Transformation Parameters

Only the CALPUFF model allows for the evaluation of chemical transformations explicitly in the model. The user can select from three transformation options: no chemical transformation; 24-hour cycles of transformation rates input directly by the user; and pseudo-first-order chemical reaction mechanism for the conversion of SO_2 to SO_4^{2-} and NO_x (as the total of NO + NO_2) to NO_2, which has been based on the transformation formulations implemented in the MESOPUFF II model.

The third option was utilized to simulate the chemical transformation associated with the atmospheric emissions in the region. The chemical processes include both gas and aqueous phase reactions. The gas phase reactions for both SO_x and NO_x involve free radical photochemistry and, therefore, are coupled to the oxidation of organic gases. Ozone and hydrogen peroxide are believed to be the principal oxidants for aqueous-phase oxidation of SO_2.

During the daylight hours, the gas phase chemical transformations make use of ambient ozone concentration and the radiation intensity as surrogates for the direct concentration of the photochemical radical concentrations. At night, the model uses the default oxidation rates of 0.2 and 2.0% for SO_2 and NO_x, respectively.

Single background ozone and ammonia concentrations of 22 ppb and 1.46 ppb, respectively, were used.

III.3.6 Deposition Parameters

The CALPUFF model was configured to calculate both wet and dry deposition of the modelled sulphur and nitrogen chemical species. The approach adopted in the CALPUFF model (U.S. EPA 1995b) to estimate wet removal is an empirically-based scavenging coefficient method. The scavenging coefficients depend on the characteristics of the pollutant and the nature of the precipitation. Table III-3 contains the values of the scavenging coefficients used for SO_2, SO, NO_x, HNO_3, and NO_3.

Table III-3 Wet Deposition Scavenging Coefficient Used in CALPUFF

Pollutant	Scavenging Coefficients [s^{-1}]	
	Liquid Precipitation	Frozen Precipitation
SO_2	3.0×10^{-5}	0
SO_4^{2-}	3.0×10^{-5}	3.0×10^{-5}
NO_X, NO, NO_2	0	0
HNO_3	6.0×10^{-5}	0
NO_3^-	10.0×10^{-5}	3.0×10^{-5}

Three methods can be used in CALPUFF for calculating the dry deposition of the modelled pollutants, namely: calculating no dry deposition; providing direct values of deposition velocities for each pollutant for a 24-hour cycle; and the use of the resistance model to determine spatial and temporal values for the gaseous and particulate deposition rates

The CALPUFF model was run using the third, and most comprehensive, of the dry deposition schemes available. In this model, the deposition flux (F) of any chemical is determined as the product of a deposition velocity and the ambient concentration of the species. The method used to calculate deposition velocity differs between gases and particles, as illustrated in the following equations:

$$v_{gas} = \frac{1}{(r_a + r_d + r_c)}$$

$$v_{part} = \frac{1}{(r_a + r_d + r_a \times r_d \times v_g)} \times v_g$$

In the above equations r_a, r_d and r_c refer to the atmospheric, deposition layer and canopy resistance terms, respectively. The v_g term in the particle deposition equation refers to the gravitational settling velocity.

In order to calculate the specific deposition velocities for each parameter, the user is required to input parameters regarding the chemical characteristics, the particle behavior and the canopy conditions. Tables III-4, III-5, and III-6 list the dry deposition parameters used in the CALPUFF analysis.

Table III-4 Chemical Characteristics Used for Calculating the Dry Deposition of Gases in CALPUFF

Parameter	SO_2	NO	NO_2	HNO_3
Diffusivity [cm^2/s]	0.12	0.13	0.17	0.16
α*	1000	1.0	1.0	1.0
Reactivity	8	2	8	18
Mosophyll resistance [s/cm]	0	25	5	0
Henry's Law Coefficient	0.04	18	3.5	0

Table III-5 Physical Characteristics Used for Calculating the Dry Deposition of Aerosols in CALPUFF

Parameter	SO_4^{2-}	NO_3^-
Geometric Mass Mean Diameter [μm]*	0.45	0.45
Geometric Standard Deviation [μm]**	2.00	2.00

*Ruijgrok, 1997
** CALPUFF default parameters

Table III-6 Leaf Area Index (LAI) Values Used for Calculating the Dry Deposition of Gases in CALPUFF

	Regional Study Area		Foliage Period		Non-Foliage Period	
Land Cover Classes	Area [ha]	Area [%]	LAI	Weighted LAI	LAI	Weighted LAI
Unclassified (no data)	65,199	2.7	4.5	0.12	3	0.08
Aspen (mixed decidious)	179,015	7.4	6.5	0.48	2	0.15
Mixedwood	310,110	12.8	8.5	1.09	5.5	0.70
White Spruce	132,249	5.4	8	0.44	7.5	0.41
Mixed Conifers (Sw, Pj)	22,149	0.9	7.5	0.07	7	0.06
Mixed Conifers (pine dominated)	20,283	0.8	7	0.06	6	0.05
Open Pine (lichen)	130,600	5.4	5.5	0.30	4.5	0.24
Pine Regeneration Shrub	103,266	4.3	4	0.17	3	0.13
Black Spruce and Tamarack	118,135	4.9	2.8	0.14	2.5	0.12
Wet Closed Conifer (Sb)	450,266	18.5	10	1.85	9	1.67
Wet Open Conifer (Sb)	175,217	7.2	6.8	0.49	5	0.36
Fens (shrub wetlands)	298,314	12.3	4	0.49	1	0.12
Graminoid Fens	234,033	9.6	2.5	0.24	1.8	0.17
Low Shrub Bog	63,871	2.6	1.8	0.05	0.8	0.02
Peat Bog	5,263	0.2	1	0.00	1	0.00
March (emergents)	11,757	0.5	0.3	0.00	0.1	0.00
Forestry Cutblocks	12,877	0.5	3.5	0.02	2.5	0.01
Natural or Human Disturbances	35,192	1.4	0	0.00	0	0.00
Water	60,900	2.5	0	0.00	0	0.00
TOTAL	**2,428,696**	**100.0**		**6.00**		**4.31**

Note: Annual average leaf area index based on 7 months of winter is 5.0.

III.3.7 SOURCE CHARACTERIZATIONS

III.3.7.1 Point Sources

The most significant stack emission sources associated with oil sands activities have been modelled as point source emissions. For these emissions, source specific values for the stack height and diameter, the release temperature and velocity as well as the pollutant release rate were required. For the purposes of calculating the short-term maximum concentrations, the stream day emissions rates were used in the modelling. The calendar day emission rates, however, have been used for determining the annual average concentrations as well as the PAI and deposition rates.

III.3.7.2 Area Sources

To incorporate all of the atmospheric releases in the dispersion modelling analysis, it was necessary to reduce the number of sources down to a value that could be handled by the models. The methodology adopted to reduce the number of sources was to group the vents, fugitive releases and minor stack emissions into single source groups that were modelled as area releases. For each area source modelled, emission rates and areal extents were input to the models. To simulate the true release behaviour of the grouped emissions, these area sources were also assigned an initial vertical dispersion term (σ_z).

The simulation of the tailings ponds and the open pit mine emission sources were handled in the same manner as the grouped facility emissions. In the case of the open pit mines, the initial vertical dispersion term (σ_z) was assumed to be similar to the average height of the vehicles (i.e., 10 m). For the tailings ponds, a nominal initial vertical dispersion term (σ_z) of 1.5 m was assumed to account for the mixing that occurs above these extensive surface areas.

III.3.7.3 Building Influences

For the purposes of the modelling analysis, the building wake effects were omitted as they were assumed to be negligible. This assumption is valid for the major point sources, which are sufficiently tall as to escape the building influences. The smaller point sources and vents have been modelled as area sources with an initial σ_z term which simulates the downwind effect of building wakes.

III.3.8 ISC3ST/ISC3BE Specific

To duplicate the dispersion modelling results presented in this assessment, it is essential that the specific control and output codes be replicated. Tables III-7, III-8 and III-9 list the control codes, the meteorological parameters, and the model output codes used.

Table III-7 ISCST3 and ISCBE7 Program Control Codes

Control Option	ISCST3 Model Options	ISCBE7 Model Options
Model Options Card (MODELOPT)	MSGPRO, CONC, RURAL, NOSMPL	MSGPRO, CONC, RURAL, NOCMPL
Averaging Time Periods (AVERTIME)	1, 24 ANNUAL 1, 8, ANNUAL (for CO)	1, 24 ANNUAL 1,8, ANNUAL (for CO)
Polutant Identification (POLLUTID)	SO_2, NO_X, CO, PM, VOC	SO_2, NO_X, CO, PM, VOC
Run or Do-Not-Run Flag (RUNORNOT)	RUN	RUN
Elevated Terrain Flag (TERRHGTS)	ELEV	ELEV

Table III-8 ISCST3 and ISCBE7 Meteorological Parameters

Control Option	ISCST3 Model Options	ISCBE7 Model Options
Anemometer Height (ANEMHGHT)	75 metres	75 metres
Wind Speed Categories (WINDCATS)	1.54 3.09 5.14 8.23 10.80	1.54 3.09 5.14 8.23 10.80
Stability Specific Temperature Profiles (DTHETADZ)	A 6*0.00 B 6*0.00 C 6*0.00 D 6*0.00 E 6*0.051 F 6*0.054	A 6*0.00 B 6*0.00 C 6*0.00 D 6*0.00 E 6*0.051 F 6*0.054
Stability Specific Wind Speed Profiles (WINDPROF)	A 6*0.28 B 6*0.28 C 6*0.30 D 6*0.44 E 6*0.59 F 6*0.46	A 6*0.28 B 6*0.28 C 6*0.30 D 6*0.44 E 6*0.59 F 6*0.46

Table III-9 ISCST3 and ISCBE7 Output Codes

Control Option	ISCST3 Model Options	ISCBE7 Model Options
Receptor Table Card (RECTABLE)	ALLAVE FIRST	ALLAVE FIRST
Maximums Table Card (MAXTABLE)	ALLAVE 50	ALLAVE 50
Output Plotfile Options (PLOTFILE)	1, ALL, FIRST, file 24, ALL, FIRST, file (an 8 hour averaging period is used for CO) ANNUAL, ALL, FIRST, file	1, ALL, FIRST, file 24, ALL, FIRST, file (an 8 hour averaging period is used for CO) ANNUAL, ALL, FIRST, file
Maximums Options (MAXFILE)	1, ALL, criteria, file 24, ALL, criteria, file (an 8 hour averaging period is used for CO) the criteria value used for each pollutant modelled corresponds to the applicable Alberta guideline	1, ALL, criteria, file 24, ALL, criteria, file (an 8 hour averaging period is used for CO) the criteria value used for each pollutant modelled corresponds to the applicable Alberta guideline

III.4 MODELLING EVALUATION

Atmospheric dispersion models are useful in predicting the likely maximum, areal extent and frequencies of various air concentrations. These dispersion models do have certain restrictions as discussed more fully in Section III-2. To determine how well the model predictions correspond with actual measurements, a series modelling runs were made using the ISC3BE dispersion model, real meterological data collected at the 75m level on the Mannix tower, and historic emission rates during each of the 1994, 1995, 1996 and 1997 calendar years. The results of the dispersion model were compared to the continuous ambient air quality data gathered at the 12 monitoring stations in the region. The modelling comparison will focus on the concentrations of SO_2 since it has long been used as an air pollution indicator in the oil sands region.

III.4.1 Historic SO_2 Emissions

Suncor has spent considerable effort in understanding and reducing SO_2 emissions. Over the last few years Suncor has substantially reduced total SO_2 emissions with the installation of the FGD unit, improvements in the Upgrader sulphur plant and in overall operational reliability. This approach has initially been directed toward the major sources of SO_2. At the same time, Suncor has been identifying and quantifying smaller SO_2 sources. These include the flaresand the upgrading furnace stacks. With success in reducing emissions from the largest sources, Suncor is now conducting a closer examination of emissions from smaller sources. As a result, more accurate estimates of total SO_2 emissions from the facility have been acquired.

Table III-10 provides a summary of the sulphur emissions from Suncor from 1994 to 1997. This time frame was selected to match available meteorological data for modelling purposes. Historically, Suncor's SO_2 emissions have been assessed based only on the powerhouse and incinerator stacks. As Table III-11 indicates, these two sources represented about 95% of the overall Suncor SO_2 emissions. These two sources plus the main stack at Syncrude (emissions of 208 t/d) represented the major area sources and formed the basis for historical SO_2 modelling efforts. In 1997, the FGD unit was commissioned and SO_2 emissions are expected to be reduced from approximately 250 t/d in 1994 to 65 t/d for the Baseline case (the Approved emission conditions used as the baseline for this EIA) from all sources and from approximately 240 t/d to 50 t/d from the historical main sources.

Table III-10 Summary of Historical SO_2 Suncor Emissions

Source	Suncor Emission Rates				
	1994 (t/sd)	1995 (t/sd)	1996 (t/sd)	1997 (t/sd)	Baseline (t/cd)
Powerhouse Stack	211	215	153	171	13.1
FGD Stack	-	-	-	10.8	18.0
Sulphur Incinerator	31	16	18	19.4	18.8
Upgrading furnaces	2.6	3.0	3.0	3.1	2.8
Continuous Flaring	7.8	8.7	9.1	9.3	12.6
Mine Fleet	-	-	-	-	0.04
Extraction	-	-	-	-	-
Tank Farms	-	-	-	-	-
Tailings Ponds	-	-	-	-	-
Mine Surface	-	-	-	-	-
Total	**252.4**	**242.6**	**183.1**	**213.6**	**65.3**

In order to get a good understanding of the historic perspective, considering all of the emission sources at Suncor, a series of dispersion modelling runs were conducted using the emission sources listed in the Table III-10, combined with the emissions from the Syncrude main stack. These results provide a true basis for evaluating the SO_2 dispersion modelling results presented throughout this EIA, since these analyses now include all known SO_2 emission sources.

III.4.2 Comparison of Modelled to Measured SO_2

The resultant SO_2 air concentrations predicted by the ISC3BE dispersion model, along with the corresponding ambient measurements at the twelve air quality monitoring stations in the region, have been summarized in Tables III-11 and III-12. Table III-11 summarizes the observed and predicted maximum hourly GLC and the number of times the Alberta Ambient Air Quality Guidelines (AAAQG) is exceeded for each of the past 4 years. Table III-12 lists the 1st, 5th and 10th highest SO_2 concentrations observed at the monitoring stations as well as predicted using the ISC3BE dispersion model.

The modelling for the historical review was based on SO_2 emission rates listed in Table III-10. The SO_2 emission sources at Suncor include the powerhouse, incinerator, continuous flaring and furnace stacks (containing mercaptans). Emission rates for the principal sources were based on data previously reported in Suncor's annual air reports. Other rates were prorated based on 1997 production levels. Syncrude main stack emission rates were assumed constant over the 4 year assessment based on 1997 rates. Two scenarios were presented for 1997 based on whether the FGD was operational during its commissioning phase. The "Powerhouse Case" (worst case) listed assumes the Powerhouse is 100% operational over the year, while the "FGD Case" (best case) that assumes the FGD is 100% operational through the year. It would be expected that measured concentrations will fall between these two extremes.

Table III-11 Summary of Predicted and Observed SO_2 Concentrations

Station	1994	1995	1996	1997[a]	Baseline
Mannix Location					
Predicted Concentration, Predicted ($\mu g/m^3$)	707	695	569	588 / 447	524
SO_2 Concentration, Observed ($\mu g/m^3$)	1101	1272	725	535	n/a
Maximum Number of Exceedances, Predicted	39	20	10	12 / 0	2
Maximum Number of Exceedances, Observed	21	20	10	1	n/a
Lower Camp Location					
Predicted Concentration ($\mu g/m^3$)	544	438	346	390 / 394	370
SO_2 Concentration, Observed ($\mu g/m^3$)	839	1363	1506	381	n/a
Maximum Number of Exceedances, Predicted	5	0	0	0	0
Maximum Number of Exceedances, Observed	6	5	3	0	n/a
Fina Location					
Predicted Concentration ($\mu g/m^3$)	558	482	450	487 / 309	405
SO_2 Concentration, Observed ($\mu g/m^3$)	736	1175	1583	630	n/a
Maximum Number of Exceedances, Predicted	22	4	1	4 / 0	0
Maximum Number of Exceedances, Observed	16	21	11	3	n/a
Poplar Creek Location					
Predicted Concentration ($\mu g/m^3$)	400	418	324	278 / 169	252
SO_2 Concentration, Observed ($\mu g/m^3$)	958	622	392	n/a	n/a
Maximum Number of Exceedances, Predicted	0	0	0	0	0
Maximum Number of Exceedances, Observed	4	4	3	0	n/a
Athabasca Bridge Location					
Predicted Concentration ($\mu g/m^3$)	489	431	249	333 / 226	248
SO_2 Concentration, Observed ($\mu g/m^3$)	802	630	450	392	n/a
Maximum Number of Exceedances, Predicted	1	0	0	0	0
Maximum Number of Exceedances, Observed	6	2	0	0	n/a
AQS1 Location					
Predicted Concentration ($\mu g/m^3$)	563	489	517	469/ 325	361
SO_2 Concentration, Observed ($\mu g/m^3$)	1046	752	482	220	n/a
Maximum Number of Exceedances, Predicted	6	3	2	1 / 0	0
Maximum Number of Exceedances, Observed	7	3	1	0	n/a
AQS2 Location					
Predicted Concentration ($\mu g/m^3$)	526	488	424	352 / 169	243
SO_2 Concentration, Observed ($\mu g/m^3$)	545	625	418	289	n/a
Maximum Number of Exceedances, Predicted	3	2	0	0	0
Maximum Number of Exceedances, Observed	5	6	0	0	n/a
AQS3 Location					
Predicted Concentration ($\mu g/m^3$)	769	658	486	622 / 410	412
SO_2 Concentration, Observed ($\mu g/m^3$)	1072	675	559	442	n/a
Maximum Number of Exceedances, Predicted	12	16	3	5 / 0	0
Maximum Number of Exceedances, Observed	8	5	2	0	n/a
AQS4 Location					
Predicted Concentration ($\mu g/m^3$)	433	338	294	354 / 190	222
SO_2 Concentration, Observed ($\mu g/m^3$)	686	651	728	315	n/a
Maximum Number of Exceedances, Predicted	0	0	0	0	0
Maximum Number of Exceedances, Observed	3	3	2	0	n/a
AQS5 Location					
Predicted Concentration ($\mu g/m^3$)	398	341	312	262 / 262	292
SO_2 Concentration, Observed ($\mu g/m^3$)	469	386	588	357	n/a
Maximum Number of Exceedances, Predicted	0	0	0	0	0
Maximum Number of Exceedances, Observed	1	0	2	0	n/a
Fort McMurray (FMMU) Location					
Predicted Concentration ($\mu g/m^3$)	396	368	253	227 / 138	199
SO_2 Concentration, Observed ($\mu g/m^3$)	400	455	257	177	n/a
Maximum Number of Exceedances, Predicted	0	0	0	0	0
Maximum Number of Exceedances, Observed	0	1	0	0	n/a
Fort McKay (FRMU) Location					
Predicted Concentration ($\mu g/m^3$)	416	357	193	313 / 191	201
SO_2 Concentration, Observed ($\mu g/m^3$)	649	611	394	296	n/a
Maximum Number of Exceedances, Predicted	0	0	0	0	0
Maximum Number of Exceedances, Observed	2	2	0	0	n/a

[a] Concentrations provided are for the Powerhouse case / FGD case.

Table III-12 Highest Observed and Predicted SO_2 Concentrations

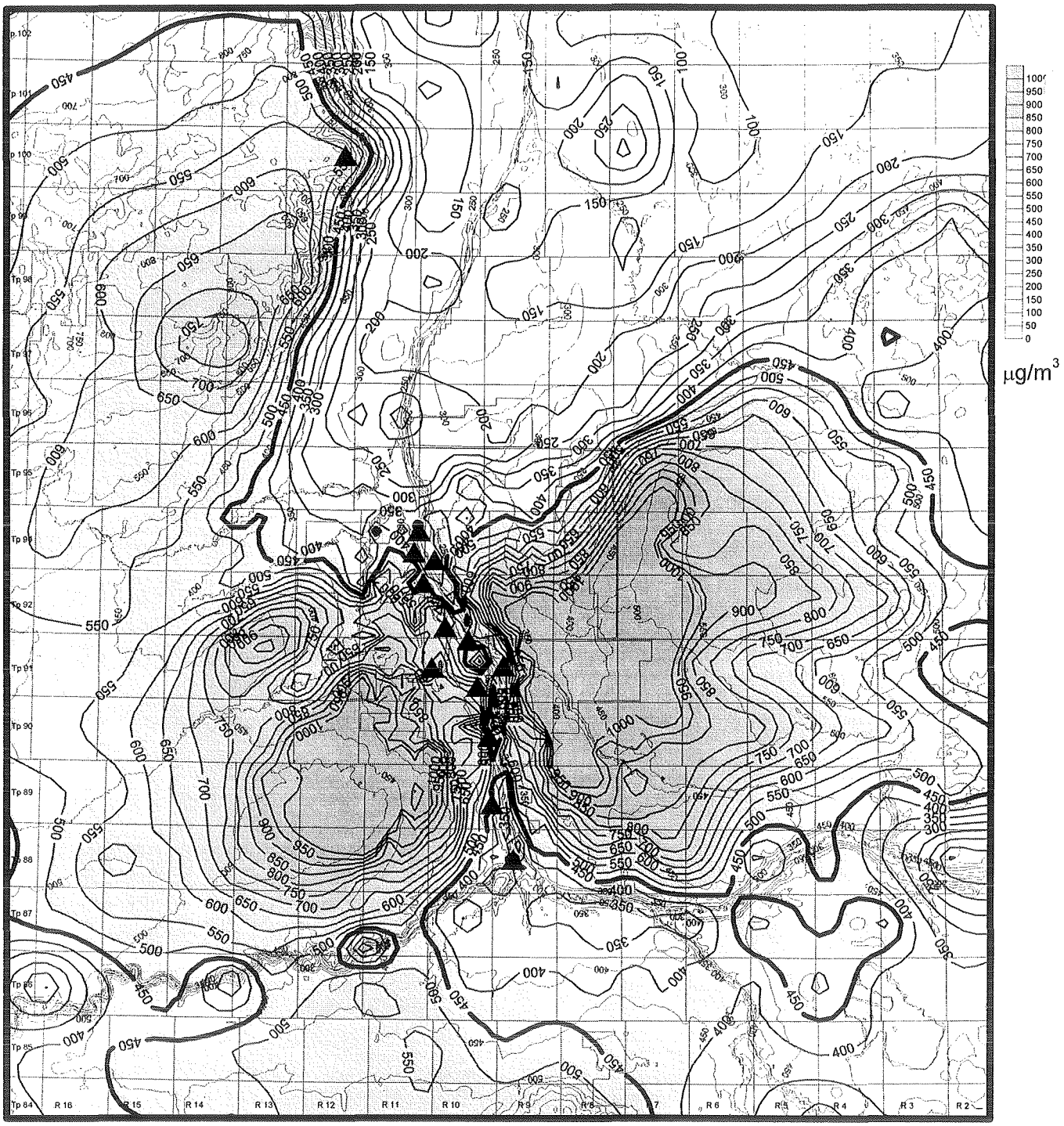
Station	1994[a]	1995[a]	1996[a]	1997[a] Powerhouse	1997[a] FGD
Mannix Location					
1st highest concentration (µg/m³)	1101 / 707	1272 / 695	725 / 570	535 / 588	535 / 447
5th highest concentration (µg/m³)	765 / 648	1123 / 657	596 / 461	326 / 511	326 / 348
10th highest concentration (µg/m³)	627 / 597	1117 / 548	519 / 451	283 / 456	283 / 300
Lower Camp Location					
1st highest concentration (µg/m³)	839 / 544	1363 / 438	1506 / 347	381 / 391	381 / 394
5th highest concentration (µg/m³)	508 / 451	926 / 309	551 / 330	273 / 359	273 / 282
10th highest concentration (µg/m³)	302 / 413	646 / 276	394 / 278	212 / 345	212 / 262
Fina Location					
1st highest concentration (µg/m³)	736 / 558	1175 / 483	1583 / 450	630 / 487	630 / 309
5th highest concentration (µg/m³)	601 / 517	858 / 437	715 / 409	392 / 449	392 / 287
10th highest concentration (µg/m³)	521 / 498	651 / 392	559 / 377	275 / 428	275 / 279
Poplar Creek Location					
1st highest concentration (µg/m³)	958 / 400	622 / 419	392 / 325	1549 / 278	1549 / 169
5th highest concentration (µg/m³)	445 / 334	508 / 315	278 / 208	249 / 230	249 / 148
10th highest concentration (µg/m³)	357 / 256	492 / 278	228 / 191	199 / 212	199 / 126
Athabasca Bridge Location					
1st highest concentration (µg/m³)	802 / 489	630 / 431	450 / 249	392 / 333	392 / 226
5th highest concentration (µg/m³)	484 / 349	429 / 311	379 / 202	246 / 287	246 / 170
10th highest concentration (µg/m³)	315 / 308	418 / 280	294 / 194	204 / 236	204 / 157
AQS1 Location					
1st highest concentration (µg/m³)	1046 / 563	752 / 489	482 / 517	220 / 469	220 / 325
5th highest concentration (µg/m³)	524 / 474	450 / 324	392 / 266	167 / 331	167 / 204
10th highest concentration (µg/m³)	376 / 374	344 / 302	217 / 253	138 / 303	138 / 172
AQS2 Location					
1st highest concentration (µg/m³)	545 / 526	625 / 488	418 / 424	289 / 352	289 / 169
5th highest concentration (µg/m³)	458 / 409	514 / 397	302 / 315	159 / 280	159 / 116
10th highest concentration (µg/m³)	371 / 393	379 / 322	183 / 266	135 / 249	135 / 103
AQS3 Location					
1st highest concentration (µg/m³)	1072 / 769	675 / 658	559 / 486	442 / 622	442 / 410
5th highest concentration (µg/m³)	516 / 572	540 / 586	397 / 297	334 / 487	334 / 288
10th highest concentration (µg/m³)	424 / 466	373 / 520	315 / 241	183 / 409	183 / 253
AQS4 Location					
1st highest conventration (µg/m³)	686 / 433	651 / 338	728 / 294	315 / 354	315 / 190
5th highest conventration (µg/m³)	379 / 388	365 / 320	331 / 263	251 / 296	251 / 171
10th highest conventration (µg/m³)	307 / 281	302 / 278	262 / 200	191 / 234	191 / 162
AQS5 Location					
1st highest concentration (µg/m³)	469 / 398	386 / 342	588 / 312	357 / 262	357 / 262
5th highest concentration (µg/m³)	188 / 324	278 / 267	304 / 242	228 / 232	228 / 187
10th highest concentration (µg/m³)	154 / 271	185 / 225	251 / 208	151 / 199	151 / 174
Fort McMurray (FMMU) Location					
1st highest concentration (µg/m³)	400 / 396	455 / 369	257 / 253	177 / 227	177 / 138
5th highest concentration (µg/m³)	318 / 298	328 / 232	193 / 122	106 / 206	106 / 102
10th highest concentration (µg/m³)	270 / 233	273 / 195	164 / 111	98 / 168	98 / 97
Fort McKay (FRMU) Location					
1st highest concentration (µg/m³)	649 / 416	611 / 357	394 / 193	296 / 313	296 / 191
5th highest concentration (µg/m³)	318 / 268	373 / 258	294 / 169	188 / 227	188 / 169
10th highest concentration (µg/m³)	225 / 235	302 / 222	254 / 163	164 / 206	164 / 141

[a] Concentrations provided are for the Observed / Predicted

A review of the data presented in Tables III-11 and III-12 indicates that the observed maximum hourly concentrations at the monitoring stations are typically under-predicted by the ISCBE model. On average the ISCBE model maximum GLC predictions are 80% of the observed extreme concentrations at the monitoring locations. The emission rates for the model

prediction were based on stream day rates, which does not necessarily reflect hourly fluctuations in production levels or unpredictable upset conditions. These variations may be captured in the ambient monitoring data, hence the maximum observed concentrations at the monitoring stations could exceed the maximum hourly predicted concentrations. It can be seen in Table III-12 that by the 10^{th} highest values, the observed and predicted SO2 concentrations are in much closer agreement.

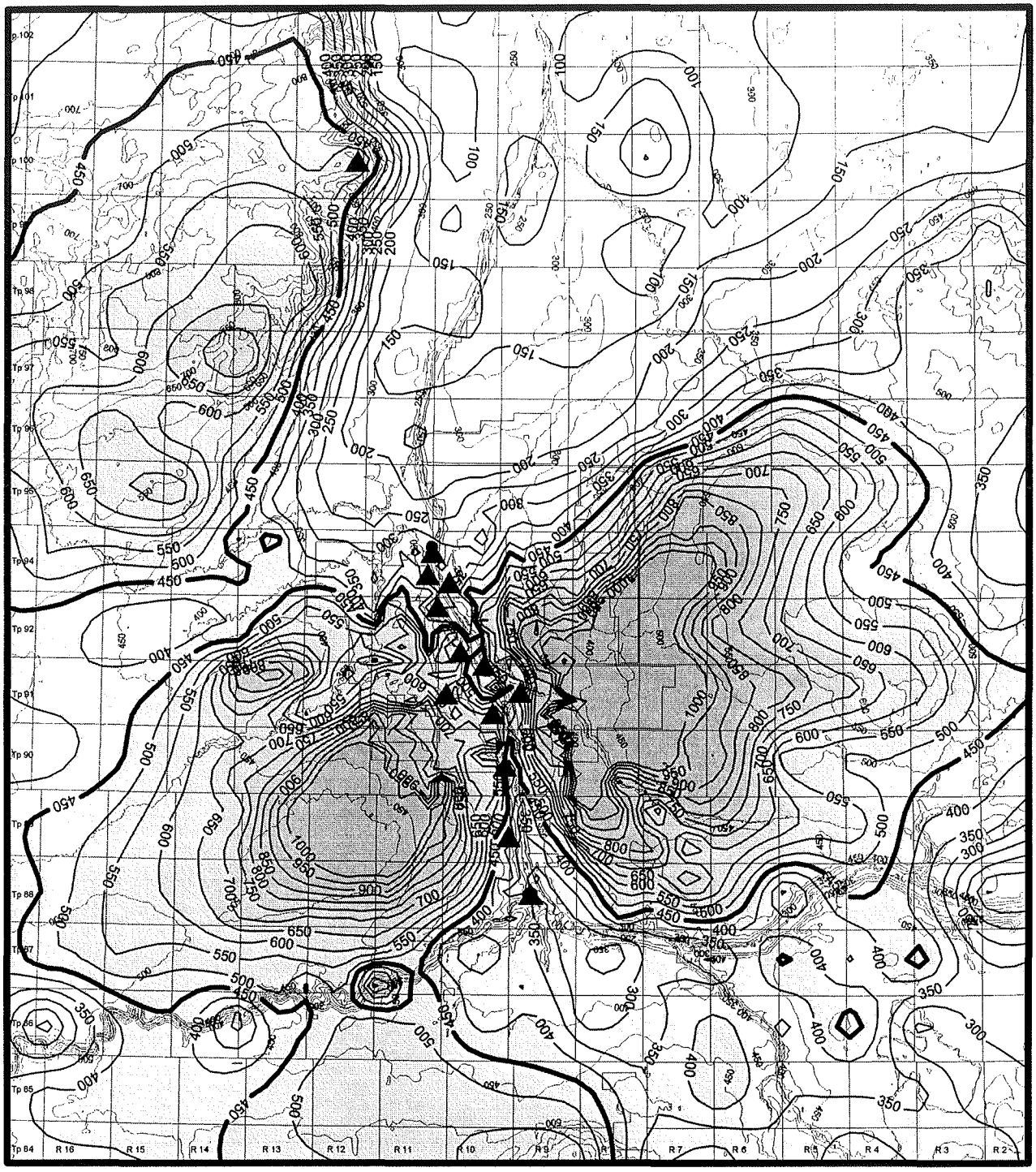
The predicted maximum SO_2 concentrations, assuming all emission sources for 1994 through 1997 are presented in Figures III-3 to III-7. Figure III-3, representing the 1994 concentrations, indicates a significant amount of the RSA would have had maximum values in excess of the Alberta guideline of 450 ($\mu g/m^3$). In 1995 (Figure III-4) and 1996 (Figure III-5) the areal extent of the readings in excess of the guideline are reduced substantially. These plots show the effect of the SO_2 reduction activities implemented by Suncor, most notably the Superclaus technology installed in the upgrader. The two figures for 1997 (Figures III-6 and III-7) indicate the extremes for the operation depending on whether the boiler emissions were going through the FGD unit or directly up the Powerhouse stack.



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	211
FGD	-
Incinerator	31
Flaring	8.3
Other Sources, Suncor	2.8
Syncrude (total)	208
Other Emissions (total)	-
TOTAL	461.1

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	1642
Exceedences / Year [#]	80

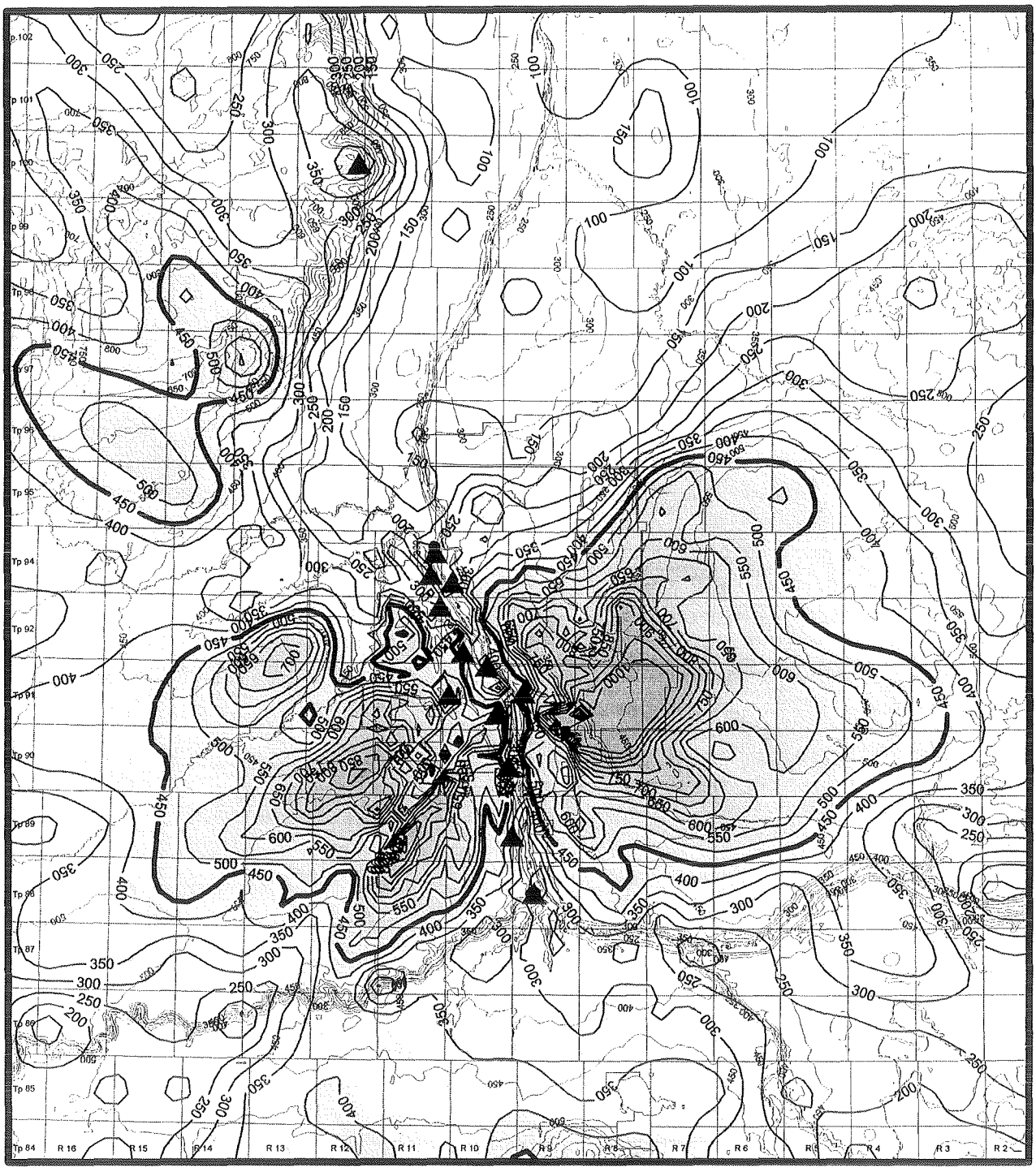
Figure III-3 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1994



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	215
FGD	-
Incinerator	16
Flaring	8.9
Other Sources, Suncor	3.0
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	451.9

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	1446
Exceedences / Year [#]	43

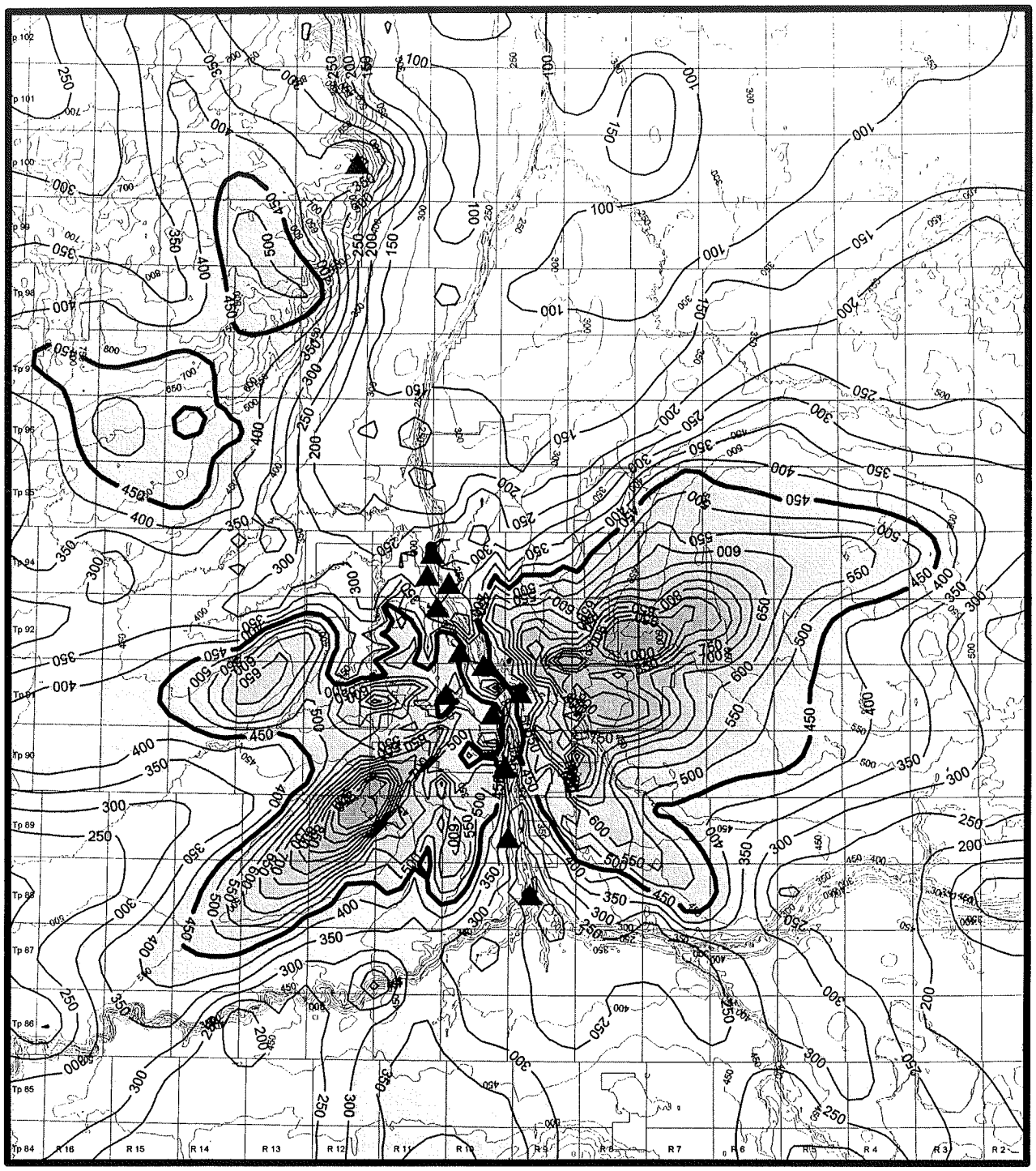
Figure III-4 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1995



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	153
FGD	-
Incinerator	18
Flaring	9.1
Other Sources, Suncor	3.0
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	392.1

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m^3]	450
Maximum [µg/m^3]	1246
Exceedences / Year [#]	32

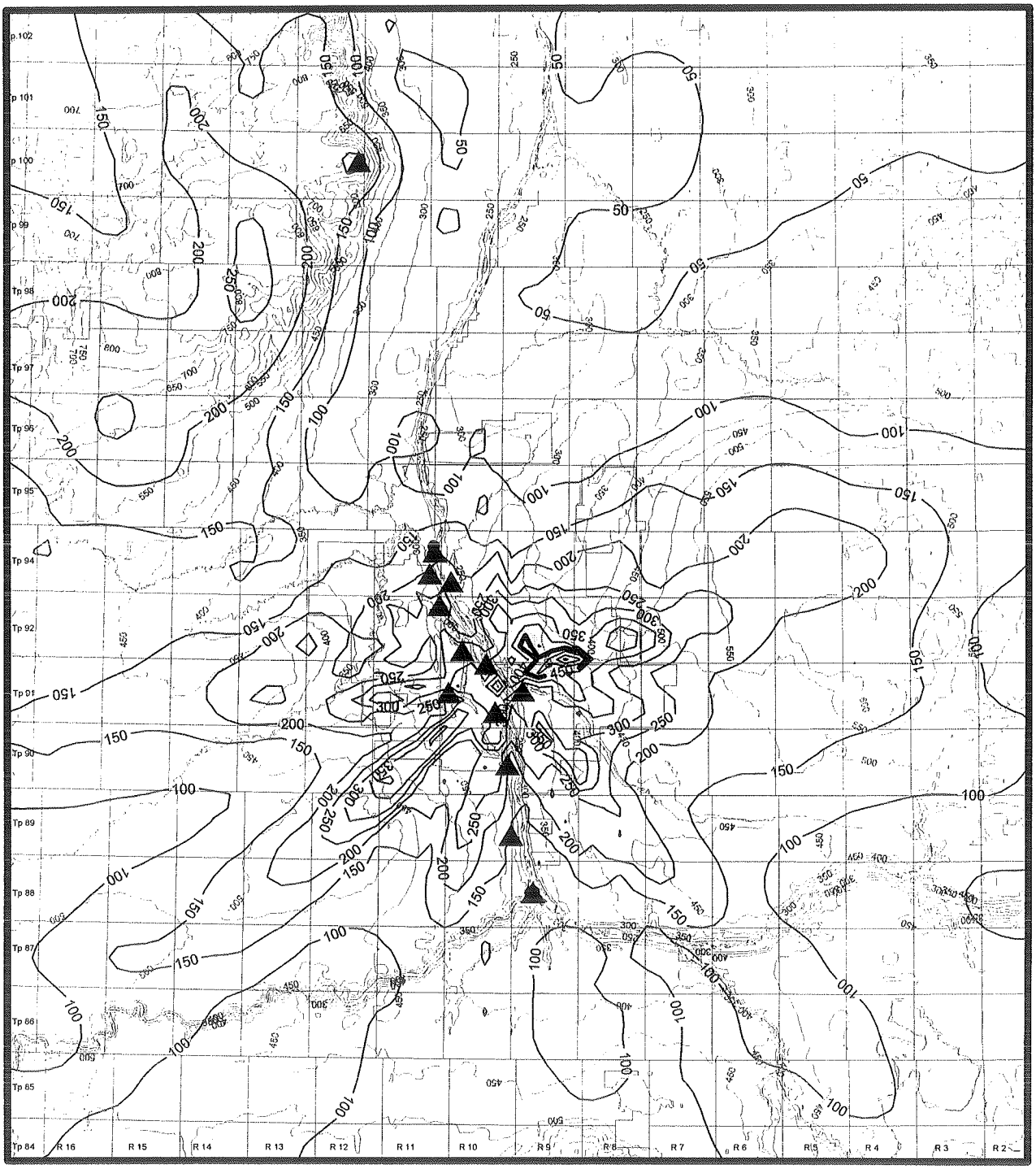
Figure III-5 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1996



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	171
FGD	-
Incinerator	19.1
Flaring	9.3
Other Sources, Suncor	3.1
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	411.5

Model Description	
Development	1997 "Powerhouse"
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m^3]	450
Maximum [µg/m^3]	1250
Exceedences / Year [#]	49

Figure III-6 Predicted SO_2 Concentrations in 1997 Using all Emission Sources for the "Powerhouse Case"



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	-
FGD	10.8
Incinerator	19.1
Flaring	7.3
Other Sources, Suncor	3.1
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	249.3

Model Description	
Development	1997 "FGD"
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m^3]	450
Maximum [µg/m^3]	648
Exceedences / Year [#]	2

Figure III-7 Predicted SO_2 Concentrations in 1997 Using all Emission Sources for the "FGD Case"

III.5 DISPERSION MODEL COMPARISONS

III.5.1 Comparison to SO_2 Monitoring

Continuous ambient air quality data have been gathered at a series of monitoring stations across the study region. Due to the nature of the industrial activity in the oil sands, the emissions and resultant air concentrations of SO_2 have been used as an indicator for an extended period of time. To evaluate the relative performance of the dispersion models considered in the assessment, predictions of the ambient SO_2 concentrations for the period 1 November 1993 through to the end of October 1997 were made at these stations. The model results were then compared to the ambient measurements for the same period of time. With the exception of the SCREEN3 model, models were compared by considering the following:

- A comparison of the number of predicted and measured hours of exceedence of the Alberta Guidelines;
- A review of the overall statistics of the measured and predicted results;
- A comparison of the measured and predicted concentrations when the winds were transporting the plume over the station (i.e., the concentrations that were predicted or measured were greater than zero);
- A comparison of the 1^{st}, 5^{th} and 10^{th} highest concentrations predicted by the models with the observed concentrations;
- A comparison of the frequency histograms for the measured and predicted non-zero hours; and
- A screening level performance test of the functional bias of each model, as recommended by the U.S. EPA for evaluating the performance of dispersion models.

The SCREEN3 model is not capable of calculating the hourly concentrations that correspond to the specific meteorological conditions observed over the 4 year evaluation period. For this model, a comparison of the highest concentrations predicted at each of the monitoring stations as a result of the key emission sources was performed.

III.5.1.1 Monitoring Data

The ambient SO_2 monitoring data from the 12 continuous stations illustrated in Figure III-1 are summarized in the Table III-13.

Table III-13 Monitored SO_2 Exceedances and Highest Values

Station	Exceedances		Highest [µg/m³]			Statistics [µg/m³]			
	>450 µg/m³	>900 µg/m³	1st	5th	10th	μ_p	i_p	μ_t	γ
Mannix	27	4	1257	1110	1105	22.3	2.77	17.5	0.79
Lower Camp	16	2	1490	1026	809	19.6	2.22	17.2	0.87
Fina	31	2	1566	1021	804	21.6	3.02	13.4	0.62
Poplar Creek	11	1	1532	610	503	16.0	2.73	10.7	0.67
Athabasca Bridge	2	0	793	573	445	15.5	2.82	9.0	0.58
AQS1	3	1	1034	644	477	18.8	2.32	6.0	0.32
AQS2	3	0	618	539	463	16.4	2.09	7.8	0.48
AQS3	4	0	1061	555	534	19.1	2.14	10.7	0.56
AQS4	2	0	720	592	435	16.7	2.22	7.0	0.42
AQS5	1	0	581	354	306	13.4	2.09	4.6	0.34
Fort McMurray	0	0	450	361	314	10.0	2.17	5.9	0.59
Fort McKay	1	0	642	437	372	8.9	2.37	8.7	0.98

μ_p the average concentration, excluding zeroes
μ_t the average concentration, including zeroes
i_p the standard deviation (excluding zeroes), normalized by μ_p
γ the fraction of the time the station experienced a non-zero concentration

III.5.1.2 SCREEN3

The SCREEN3 dispersion model was run using the existing SO_2 emission characteristics from the major point sources in the region. The model was run assuming simple terrain up to the stack top elevation. Receptors located above the stack top were assumed to be level with the top of the stack. The results of the dispersion modelling, which are presented in Table III-14, demonstrates that the SCREEN3 model is poor at predicting the extreme maximum observations. However, it is reasonable at estimating the 5th highest monitoring results. The reason for this is largely due to the possible variations in the hour-to-hour emissions from the facility which is not captured in the modelling, but which may be captured in the observations.

Table III-14 Predicted SO2 Concentrations Using the SCREEN3 Model

	Maximum SCREEN3 Predicted SO2 [µg/m^3]					
	Syncrude	Suncor				
	Main Stack	Powerhouse	Incinerator	HC Flare	FGD Stack	Total
Mannix	170.5	204.0	217.6	1142.0	62.7	1796.8
Lower Camp	235.9	212.4	212.4	515.8	60.3	1000.9
Fina	163.9	201.5	219.7	1267.0	64.4	1916.5
Poplar Creek	144.1	114.2	112.8	224.4	32.2	627.7
Athabasca Bridge	173.1	101.2	86.2	167.5	24.8	552.7
AQS1 (Mine South)	238.6	156.3	153.5	503.6	45.8	859.2
AQS2 (Fort McMurray)	111.2	186.5	165.3	292.0	33.0	788.0
AQS3 (Mildred Lake)	349.8	160.7	160.8	586.7	48.1	956.3
AQS4 (Tailings North)	161.1	92.1	76.9	146.3	22.1	498.4
AQS5 (Tailings East)	227.7	112.8	100.1	208.7	28.9	678.2
Fort McMurray	87.7	62.3	56.3	87.6	14.2	308.1
Fort McKay	156.9	82.8	68.4	126.8	19.6	454.6

III.5.1.3 ISCST3

The ISCST3 dispersion model was run using the existing major SO_2 emission characteristics from the point sources in the region. All of the dispersion modelling control codes and meteorological codes are the same as listed in Table III-7, III-8 and III-9. The results of the dispersion models are tabulated below.

Table III-15 ISCST3 Predicted SO_2 Concentrations

Station	Exceedances		Highest [$\mu g/m^3$]			Statistics [$\mu g/m^3$]			
	>450 $\mu g/m^3$	>900 $\mu g/m^3$	1st	5th	10th	μ_p	i_p	μ_t	γ
Mannix	65	4	970	957	952	124.1	1.13	21.7	0.17
Lower Camp	3	0	521	521	497	32.0	1.84	9.4	0.29
Fina	11	0	815	803	704	72.0	1.46	13.5	0.19
Poplar Creek	0	0	140	139	138	23.2	1.19	4.0	0.17
Athabasca Bridge	0	0	141	141	140	22.9	1.02	6.3	0.28
AQS1	0	0	400	392	392	19.6	2.51	3.3	0.17
AQS2	0	0	319	318	311	31.0	1.52	4.6	0.15
AQS3	4	0	528	524	495	36.8	1.87	7.5	0.20
AQS4	0	0	148	147	147	21.0	1.10	5.3	0.25
AQS5	0	0	200	193	193	23.6	1.31	5.9	0.25
Fort McMurray	0	0	108	108	108	14.7	1.18	2.0	0.14
Fort McKay	0	0	111	105	105	19.7	0.93	5.0	0.25

μ_p the average concentration, excluding zeroes
μ_t the average concentration, including zeroes
i_p the standard deviation (excluding zeroes), normalized by μ_p
γ the fraction of the time the station experience a non-zero concentration

The correlation between observed 1st, 5th and 10th highest values and those predicted using the ISCST3 model can be compared by examining Tables III-13 and III-15. The results suggest that the ISCST3 model is underpredicts the concentrations for these events. This may be due, in part, to the fact that the modelling cannot deal readily with fluctuations in emissions or in upset conditions which may contribute to the highest observations. However, the average number of annual exceedances of the Alberta Guideline for SO_2 (450 $\mu g/m^{3)}$ were comparable between the modelling estimate (84 events) and the observations (101) over the period from 1994 through 1997.

III.5.1.4 ISCBE

The ISC3BE dispersion model was run using the input conditions and codes as listed in Tables III-7, III-8 and III-9. The dispersion modelling results, which are summarized in Table III-16, illustrates that the ISC3BE model does a better job than the ISCST3 model at predicting the magnitude and variability of the average concentrations observed. The performance in estimating the number of hours in excess of the 450 $\mu g/m^3$ guideline is comparable to the ISCST3 model. ISC3BE does perform better at predicting the highest concentrations, but does not estimate the extreme values observed. This may be due to variability in the emissions conditions which could not be readily simulated in the modelling.

Table III-16 ISC3BE Predicted SO_2 Concentrations

Station	Exceedances		Highest [$\mu g/m^3$]			Statistics [$\mu g/m^3$]			
	>450 $\mu g/m^3$	>450 $\mu g/m^3$	1st	5th	10th	μ_p	i_p	μ_t	γ
Mannix	37	1	1009	910	823	71.9	1.72	20.9	0.29
Lower Camp	5	0	656	572	540	29.5	2.14	13.1	0.44
Fina	12	0	892	789	706	34.5	2.52	12.4	0.36
Poplar Creek	0	0	400	367	318	22.5	1.91	4.2	0.19
Athabasca Bridge	0	0	455	354	295	18.4	2.07	7.0	0.38
AQS1	3	0	655	535	508	11.7	3.75	3.4	0.29
AQS2	0	0	417	371	333	16.5	2.12	4.0	0.24
AQS3	8	0	709	631	560	16.6	3.30	7.0	0.42
AQS4	0	0	408	305	275	18.8	1.97	6.1	0.33
AQS5	0	0	358	336	277	14.1	2.32	6.3	0.45
Fort McMurray	0	0	349	248	212	13.9	2.03	1.9	0.13
Fort McKay	0	0	361	297	245	17.7	1.88	5.7	0.32

μ_p the average concentration, excluding zeroes
μ_t the average concentration, including zeroes
i_p the standard deviation (excluding zeroes), normalized by μ_p
γ the fraction of the time the station experience a non-zero concentration

III.5.1.5 CALPUFF

The CALPUFF dispersion model was run using the existing major SO_2 emission characteristics and the modelling parameters listed in Table III-10. The resulting SO_2 predictions, which are summarized in Table III-17, show similar strengths and weaknesses as observed for the ISC3BE model. The model does a poor job at estimating the extreme events, however, it does reasonably well in replicating the average concentrations and the number of hours when the plumes pass over the station (γ). The failure to simulate the highest observed values may be due to the steady emission rates used in the modelling, as opposed to the variable emissions which could be observed at the monitoring sites.

Table III-17 CALPUFF Predicted SO_2 Concentrations

Station	Exceedances		Highest [$\mu g/m^3$]			Statistics [$\mu g/m^3$]			
	>450 $\mu g/m^3$	>450 $\mu g/m^3$	1st	5th	10th	μ_p	i_p	μ_t	γ
Mannix	22	0	911	771	711	21.2	3.25	16.9	0.80
Lower Camp	5	0	716	662	595	10.5	3.57	8.8	0.83
Fina	9	0	1587	645	595	12.0	4.17	9.6	0.80
Poplar Creek	0	0	387	216	165	4.7	3.20	3.7	0.79
Athabasca Bridge	0	0	420	188	164	7.0	2.45	5.5	0.79
AQS1	1	0	869	423	341	4.2	5.05	3.4	0.80
AQS2	0	0	638	262	217	4.7	3.16	3.6	0.77
AQS3	4	0	790	571	505	7.5	4.39	6.0	0.81
AQS4	0	0	268	170	148	6.3	2.50	4.9	0.78
AQS5	0	0	308	234	207	6.5	2.94	5.1	0.80
Fort McMurray	0	0	110	86	77	2.7	2.59	2.0	0.75
Fort McKay	0	0	140	129	126	5.9	2.27	4.5	0.76

μ_p the average concentration, excluding zeroes
μ_t the average concentration, including zeroes
i_p the standard deviation (excluding zeroes), normalized by μ_p
γ the fraction of the time the station experience a non-zero concentration

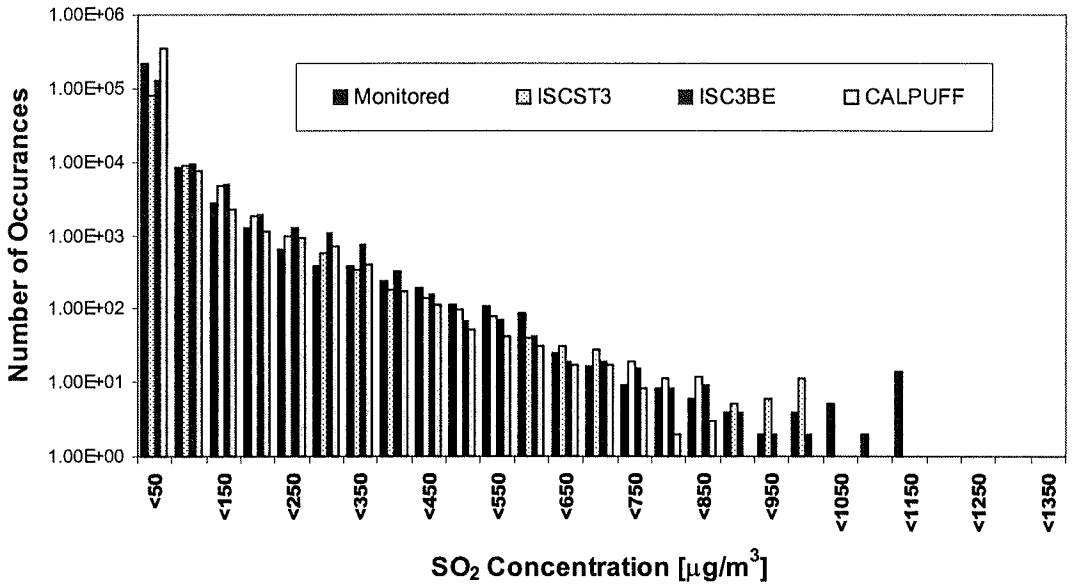
III.5.1.6 Comparison of Model Performance

An overall comparison of the performance of the dispersion models considered in the evaluation is summarized graphically in Figures III-8 and Figure III-9.

The histogram in Figure III-8 presents the relative frequencies at which different concentrations were predicted and observed. This figure illustrates that the models are unable to simulate the extreme concentrations. Throughout most of the range of concentrations, the predicted and measured frequencies compare reasonably well. In the upper range of the model predictions (i.e. 800 to 1000 $\mu g/m^3$) the ISC3BE model appears to do the best job of replicating observations. In this range, the

CALPUFF model appears to under estimate the frequencies, while the opposite is true for ISCST3.

Figure III-8 Frequency Histograms of Observed and Predicted SO_2



One of the evaluation methods recommended by the U.S. EPA (1992) for determining how well a dispersion model performs is to calculate the functional bias of the means and standard deviations. These can then be plotted to illustrate how well a model worked.

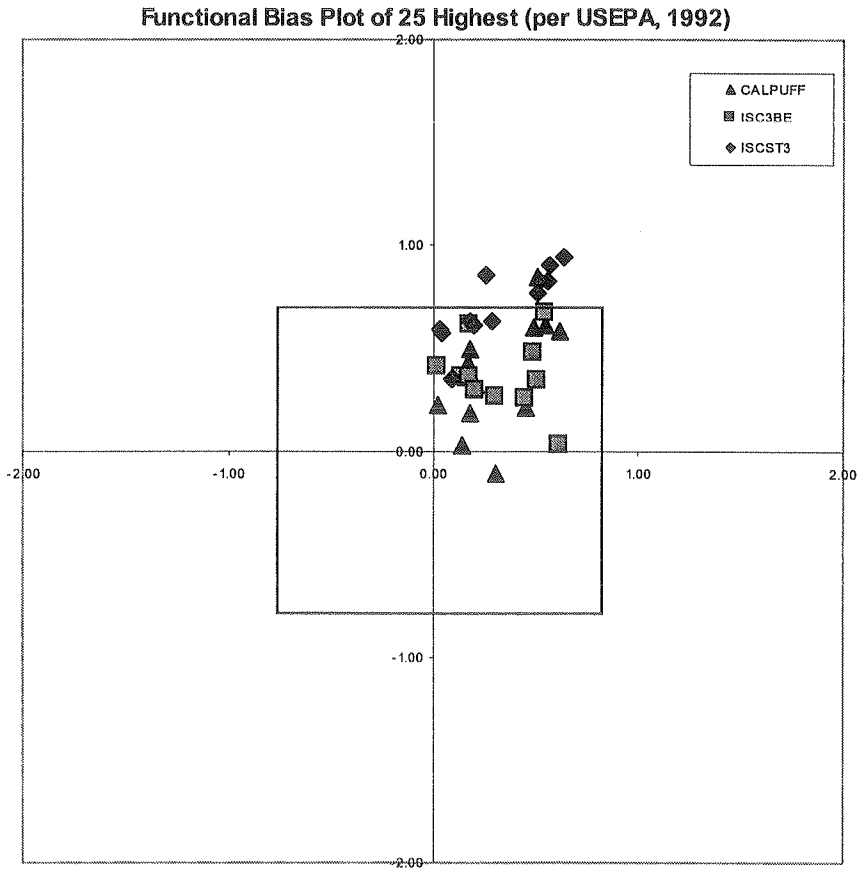
The functional bias is usually calculated on a subset of the modelling period and is calculated in the following manner.

$$FB = 2 \times \left(\frac{OB - PR}{OB + PR} \right)$$

In the above formula, the *OB* term refers to the observed means or standard deviations and the *PR* term refers to the predicted values. Once determined, the values are plotted on a graph using the FB_{means} on the X axis and the FB_{stdev} on the Y axis. A box is typically placed on the plot enclosing the area of the graph where the model predictions were within a factor of two (corresponding to a FB= -0.67 to +0.67).

The functional bias plots using the 25 highest values for all three models is presented in Figure III-9. In general, it can be seen that the ISC3BE and CALPUFF models outperform the ISCST3 model for simulating the concentrations at the 12 monitoring stations in the Oil Sands Region. The ISC3BE and CALPUFF models appear to perform equally well in the region, with CALPUFF performing better at some locations, while ISC3BE performs better at others.

Figure III-9 Functional Bias Plots of the Predicted and Measured SO_2 Concentrations



On the basis of the Functional Bias test, the performance of the ISCST3 model would be considered unsuitable for modelling in the oil sands region. On the same basis, there would be no clear indication as to which of the ISC3BE or CALPUFF models would be preferred as they both performed equally well.

III.5.2 Comparison to NO_x Monitoring

One of the sources of ambient air quality information available for validating the dispersion model performance is available adjacent to the Syncrude north mine (Conor Pacific, 1998). These data were collected over the period from 4 April 1997 to 22 January 1998. Although the hourly monitoring and meteorological observation were not made available in time for the assessment, the maxima observed at the monitoring location have been published. The overall maximum of the observed NO_x concentrations was in the 1520 to 1640 $\mu g/m^3$ range (Conor Pacific, 1998).

These data were used to evaluate the performance of the dispersion models used in the assessment to characterize the large area of the open pit area source.

A series of modelling scenarios were conducted with varying source configurations. The following configuration was used for test modelling of the mine exhausts from the open pits:

- one single area source emitting equally over the surface
  - for the evaluation of NO_x emissions from the north mine at Syncrude a rectangular area 2.2 by 1.2 km was used
  - the average emission rates used to simulate the vehicle exhausts was $2.5 * 10^{-5}$ $g/m^2/s$
- the source height was set equal to 0 m (for the SCREEN3 model the user is not able to enter an initial vertical dispersion term, therefore, several source heights were used in lieu of this ability)
- an initial vertical dispersion coefficient (σ_{zo}) of 10 m

The Open Pit Source configuration available in the ISCST3 and ISC3BE models was not utilized as this source type is not available in CALPUFF, and the desire was to simulate all sources in a similar manner with all of the models used. In addition, the Open Pit algorithms in the ISC3 family of models have been developed to address the retention of particulate matter generated in open pit mines, rather than the gaseous emissions considered in the modelling analysis.

III.5.2.1 SCREEN3

The SCREEN3 model was run using an area source configuration equal to the full size of the north pit, and at source heights of 0 m, 5 m and 10 m, in lieu of using an initial vertical dispersion term of 10 m. The maximum concentrations predicted at a distance of 100 m (the separation of the monitoring station from the edge of the north mine) were: 5617 $\mu g/m^3$ using a source height of 0 m; 2022 $\mu g/m^3$ using a source height of 5 m; and

1186 $\mu g/m^3$ using a source height of 10 m. The 5 m source height scenario is likely the most comparable to the true modelling case using an initial vertical coefficient of 10 m.

III.5.2.2 ISCST3

The ISCST3 dispersion modelling analysis of the open pit mine emissions was run using a full 4 years of meteorological data (the wind directions were forced to correspond with the centre-line of the receptor grid used) . The modelling results using the ISCST3 model give maximum concentrations in the range of 2200 to 2600 $\mu g/m^3$ range.

III.5.2.3 ISCBE

The ISC3BE dispersion model was run using the identical input characteristics as the ISCST3 modelling analysis, discussed above, with the exception of the complex terrain flag which was set to NOCMPL. Four years of meteorological data with the wind directions forced to correspond with the centre-line of the receptor grid. The modelling results yield the maximum concentration in the range of 2200 to 2600 $\mu g/m^3$ range.

III.5.2.4 CALPUFF

The CALPUFF dispersion model was run to simulate the maximum NO_x emissions predicted from the Syncrude north mine using a meteorological file with a full 4 years of data (the wind directions were forced to correspond with the centre-line of the receptor grid) and the source characteristics outlined at the beginning of this section. The CALPUFF model estimate a maximum ground level concentration 1000 to 1150 $\mu g/m^3$ range.

III.5.2.5 Model Comparison

Table III-18 summarizes the dispersion modelling comparison for simulating the mine fleet emissions adjacent to the open pit mines. Generally, the performance of the models were comparable, and in the range of the observed values. This confirms the suitability of the source characteristics selected for use in the assessment.

Table III-18 Comparison of Dispersion Models for Simulating Mine Pit Vehicle Emissions

Model	Range of Predicted Maximums		Observed
SCREEN3	2022 $\mu g/m^3$	—	1520 to 1640 $\mu g/m^3$
ISCST3	2200 $\mu g/m^3$	2600 $\mu g/m^3$	1520 to 1640 $\mu g/m^3$
ISC3BE	2200 $\mu g/m^3$	2600 $\mu g/m^3$	1520 to 1640 $\mu g/m^3$
CALPUFF	1000 $\mu g/m^3$	1150 $\mu g/m^3$	1520 to 1640 $\mu g/m^3$

III.5.3 Comparison to VOC Monitoring

The tailings pond areas of the Suncor facility have been the focus of a number of investigations on emissions of VOCs. This data was utilized as an additional check on the performance of the selected models at simulating the emissions in the immediate vicinity of the tailings areas.

As with the simulation of the NO_x emissions from the north mine at Syncrude, a series of modelling scenarios were conducted under varying source configurations. The results of these trials was the selection of the following configuration for modelling the tailings emissions.

- one single area source 1157 m on a side, emitting equally over the entire surface at a rate of $0.49 * 10^{-6}$ g/m^2/s
- the source height was set equal to 0 m (for the SCREEN3 model the user is not able to enter an initial vertical dispersion term, therefore, several source heights were used in lieu of this ability)
- an initial vertical dispersion coefficient (σ_{zo}) of 1.4 m

III.5.3.1 SCREEN3

The SCREEN3 model was run using an area source configuration equal to the full size of the tailings pond area, and source release heights of 0 m, 0.7 m and 1.4 m. These source release heights were used in lieu of using an initial vertical dispersion term of 1.4 m. The model predicts maximum concentrations of 97 $\mu g/m^3$ at a source height of 0 m; 67 $\mu g/m^3$ at a source height of 0.7 m; and 55 $\mu g/m^3$ at a source height of 1.4 m.

III.5.3.2 ISC3

The ISCST3 dispersion modelling of the pond VOC releases was run using 4 years of meteorological data, with the wind directions forced to correspond with the centre-line of the receptor grid. The model predicts maximum concentrations in the range of 35 to 55 $\mu g/m^3$ range.

III.5.3.3 ISCBE

The ISCST3 dispersion modelling of the pond VOC releases was run using 4 years of meteorological data, with the wind directions forced to correspond with the centre-line of the receptor grid. The modelling results give maximum concentrations in the range of 35 to 65 $\mu g/m^3$.

III.5.3.4 CALPUFF

The dispersion modelling of the VOC releases from the tailings pond areas of Suncor was done using the same 4 years of meteorological data (with the forced wind directions) and source characteristics as used in the ISC3 models. The modelling results yield maximum concentration in the range of 20 to 25 $\mu g/m^3$ range.

III.5.3.5 Model Comparison

Table III-19 summarizes the dispersion model results for simulating the VOC releases from the tailings ponds. Generally, the performance of the models were comparable, and in the range of the observed values. This confirms the suitability of the source characteristics selected for use in the assessment.

Table III-19 Comparison of Dispersion Models for Simulating VOC Releases from the Tailings Pond Areas

Model	Range of Maximum Predictions		Observed
SCREEN3	67 $\mu g/m^3$	—	<50 $\mu g/m^3$
ISCST3	35 $\mu g/m^3$	55 $\mu g/m^3$	<50 $\mu g/m^3$
ISC3BE	35 $\mu g/m^3$	65 $\mu g/m^3$	<50 $\mu g/m^3$
CALPUFF	20 $\mu g/m^3$	25 $\mu g/m^3$	<50 $\mu g/m^3$

III.6 CALCULATION OF NO_2 FROM NO_X

The ambient concentrations of nitrogen dioxide (NO_2) are of the greatest interest when modelling emissions of NO_x. However, the majority of models are not able to perform the necessary chemical transformations to calculate the NO_2 values directly.

Using the observed data in the vicinity of the Syncrude north mine pit, Conor Pacific (1998) established a ratio between the measured NO_x and NO_2 concentrations. In general, it was noted that the NO_2 accounted for nearly 80% of the measure NO_x when the NO_x concentrations were relatively low (i.e. <0.05 ppm). At relatively large NO_x concentrations (i.e. >0.5 ppm) the NO_2 concentrations were about 13% of the NO_x concentrations.

Conor-Pacific (1998) suggested an empirical formulation to calculate the ambient NO_2 concentrations, given a predicted value of NO_x. This formulation is listed below.

$$NO_2 = 0.10 \times NO_X^{0.392}$$

III.7 BACKGROUND PAI IN NORTHEASTERN ALBERTA

III.7.1 Definition of Background

Background air quality for this assessment refers to the characteristics of the air flow entering the 148 x 169 km study area. The use of the term background, will represent biogenic (natural) sources and anthropogenic (industrial) sources outside the study area. This definition of background is different from that used in Cheng, et al., (1997) in the assessment of total potential acid input in Alberta. The modelling domain for that western Canadian modelling study was much larger and the background in that assessment represented biogenic sources contributions to air mass inflows only. Therefore, the numerical values for background in this study will be much greater.

III.7.2 Calculation Approach

Hourly concentrations, dry deposition and wet deposition values are calculated by CALPUFF (U.S. EPA 1995b) for each of SO_2, NO, NO_2, SO_4^{2+}, HNO_3 and NO_3^-. The maximum hourly, daily and annual average SO_4 and NOx air concentrations are calculated by post processing of the CALPUFF output files.

Total sulphate equivalent deposition rate, $[SO_4^{2-}]_{dep}$, is calculated from the annual average sulphur species deposition rate predictions as follows:

$$\left[SO_4^{2-}\right]_{dep,equiv} = 1.5\left[SO_2\right]_{dep} + 1.0\left[SO_4^{2-}\right]_{dep}$$

Total nitrate equivalent deposition rate, $[NO_3]_{dep}$ is calculated from the annual average nitrogen species deposition rate predictions as follows:

$$\left[NO_3^-\right]_{dep,equiv} = 2.07\left[NO\right]_{dep} + 1.35\left[NO_2\right]_{dep} + 0.98\left[HNO_3\right]_{dep} + 1.0\left[NO_3^-\right]_{dep}$$

where all values are expressed in [kg/ha/a] and the leading constants are the respective ratios of molecular mass to the reference parameter. The above equations are applied to both wet and dry deposition.

The potential acid input (PAI) is calculated from the sulphur and nitrogen deposition rates from anthroprogenic sources within the RSA in addition to background PAI:

$$PAI = \frac{\left[SO_4^{2-}\right]_{dep,equiv}}{48} + \frac{\left[NO_3^{-}\right]_{dep,equiv}}{62} + PAI_{back}$$

Where the background PAI (PAI_{back})accounts for SO_4^{2-} equivalent, NO_3^- equivalent and total base cations associated with the airflow into the study area (wet and dry).

Specifically, the background PAI will be given by:

$$PAI_{back} = \frac{\left[SO_4^{2-}\right]_{dep,equiv,back}}{48} + \frac{\left[NO_3^{-}\right]_{dep,equiv,back}}{62} - \left(\frac{\left[Ca^{2+}\right]_{dep,back}}{20} + \frac{\left[Mg^{2+}\right]_{dep,back}}{24} + \frac{\left[K^{+}\right]_{dep,back}}{39} \right)$$

where all values are expressed in [kg/ha/a] and the leading constants are the respective ratios of molecular mass to the reference parameter. The above values o account for wet and dry deposition values for each component.

III.7.3 Wet PAI

Precipitation data from Fort Chipewyan, Fort Vermilion, High Prairie, Cold Lake, Cree Lake and Snare Rapids were reviewed. Data from Fort McMurray were not used since this site is expected to be significantly influenced by the oil sands sources. The selected sites surround the study area. On this basis, the average wet PAI is list in Table III-20. The data in Table III-20 are provided by two different agencies and the data for some sites are incomplete. Different time periods are also represented. However, these values are considered to be a good indication of wet PAI for air flow entering the region.

Table III-20 Wet Background PAI From Selected Sites in Northeastern Alberta

Location	PAI [kg/ha/a]
Fort Chipewyan	0.02
Fort Vermilion	0.02
High Prairie	0.03
Cold Lake	0.06
Cree Lake	0.07
Snare Rapids	0.04
Average	0.04

III.7.4 Dry PAI (Sulphur Compound Contribution)

The primary contributors are SO_2 and SO_4^{2-}. There are limited locations where reliable annual average concentration measurements are collected. Available data is listed in Table III-21. The SO_2 air concentration of 1.2 [$\mu g/m^3$] is much larger than the Environment Canada value of 0.25 [$\mu g/m^3$] assumed for the Cheng et al. (1997) Western Canadian modelling study. The value in the Table III-21 is assumed to be more applicable to the Oil Sands study area.

Table III-21 Background SO_2 and SO_4^{2-} Concentrations Applicable to the Study Area

Site	SO_2		SO_4^{-2}
	($\mu g/m^3$)	(ppb)	($\mu g/m^3$)
Hightower Ridge (1986)	1.1	0.41	0.58
Fortress Mountain (1985 to 1987)	1.4	0.51	0.51
Cree Lake (1988 to 1995)	1.2	0.45	0.99
Average	1.2	0.46	0.69

III.7.5 Dry PAI (Nitrogen Compound Contribution)

Nitrate equivalent includes NO, NO_2, HNO_3, NH_4^+ and NO_3^-. Background values for some of these components are available from the same sites as the sulphate data, as listed in Table III-22. The average values were adopted for our study area. We do not have direct measurements for NO and NO_2. Ridley (1991) suggests that NO and NO_2 are typically 10% of total nitrate equivalent and the tabulated values above have not been accounted for this.

Table III-22 Background HNO_3, NH_4^+ and NO_3^- Concentrations Applicable to the Study Area

Site	HNO_3		NH_4^+	NO_3^-
	($\mu g/m^3$)	(ppb)	($\mu g/m^3$)	($\mu g/m^3$)
Hightower Ridge (1986)	0.10	0.27	0.18	0.09
Fortress Mountain (1985 to 1987)	0.11	0.31	—	0.13
Cree Lake (1988 to 1995)	0.06	0.15	0.20	0.05
Average	0.10	0.23	0.19	0.09

III.7.6 Dry PAI (Base Cations)

We do not have a good data set for base rations. Therefore, we adopted the ECIAEP approach and inferred these values from precipitation chemistry. We adopted the approach given by Draaijers (AE 31, 24 pp. 4139 to 4157).

$$C_{air} = \frac{C_{prec}\rho}{188\, e^{0.227\,MMD}}$$

where: C_{air} = air concentration, [$\mu g/m^3$]
C_{prec} = precipitation concentration, [mg/L]
ρ = density of air, 1200 [g/m^3]
MMD = Mass Mean Diameter, [μm]

MMD values were adopted from Draaijers (1997): 5.7 μm for Mg^{2+}, 6.3 μm for Ca^{2+}, and 4.1 μm for K^{+}. Therefore, the following relationships can be used to predict air concentration from the observed precipitation chemistry water concentrations:

$$C_{air}(Mg^{2+}) = 1.75\, C_{prec}(Mg^{2+})$$
$$C_{air}(Ca^{2+}) = 1.53\, C_{prec}(Ca^{2+})$$
$$C_{air}(K^{2+}) = 2.52\, C_{prec}(K^{2+})$$

The relationships in the above equations have been applied to the observed precipitation data listed in Table 27. The low Cree Lake, Snare Rapids and Fort Smith values are likely representative of air flow from the north and west, while the other sites account for air flow from southern Alberta which appears to have a greater base cation content. This approach is consistent with those values presented in Shell (1997), median values are provided for the Fort Chipewyan and Fort McMurray data. The median value will be less influenced by short term high concentrations in the data set which may be representative of emission sources close to the monitoring site.

Legge and Kruppa (1990, page 151) list Ca^{+}, Mg^{2+} and K^{+} observed at Birch Mountain (1976) and Fort Smith (1970) as listed in Table 27 (based on air flow from the Arctic and Pacific).

A summary of base cation concentrations for selected sites are listed in Table III-23. The average values have been applied as being representative of base cation concentrations for the regional airshed

Table III-23 Background Base Cation Concentrations Applicable to the Study Area

	Ca^{2+}		Mg^{2+}		K^{+}	
	[mg/L]	[μg/m^3]	[mg/L]	[μg/m^3]	[mg/L]	[μg/m^3]
Cree Lake (1983 to 1992)	0.068	0.10	0.015	0.026	0.028	0.071
Snare Rapids (1989 to 1996)	0.047	0.07	0.010	0.018	0.023	0.058
Fort Chipewyan (1992 to 1996)	0.258	0.39	0.076	0.063	0.082	0.207
Fort McMurray (1992 to 1996)	0.237	0.36	0.058	0.102	0.034	0.086
Fort Vermillian (1990 to 1993)	0.160	0.25	0.020	0.035	0.090	0.227
High Prairie (1990 to 1993)	0.210	0.32	0.030	0.053	0.110	0.277
Cold Lake (1990 to 1993)	0.140	0.21	0.030	0.053	0.050	0.126
Birch Mountain (1976)	–	0.026	–	0.021	–	0.024
Fort Smith (1970)	–	0.033	–	–	–	0.044

III.7.7 PAI (Conversion From Concentrations to Deposition)

The ambient air concentration [μg/m^3] data can be converted to a deposition [kg/ha/a] using a deposition velocity V_d [cm/s] from:

$$Dep = Conc \times V_d \times 3.15$$

Where the constant 3.15 is a unit conversion factor to convert to [kg/ha/a].

The selection of appropriate deposition velocities provides a challenge as the resulting PAI will be very dependent on this selection. For this assessment, five sets of deposition velocities were used to illustrate the sensitivity:

- Bates (1996) developed a set of deposition velocities for Vegreville. SO_4^{2-} and cation deposition velocities were assumed to be the same since the diameters were assumed to he the same. This, however, is not the case as most of the sulphate is in the fine fraction and most of the base cations are in the coarse fraction.
- Values taken from Cheng (1993) assumed summer stability D conditions (forest and woodland).
- Ruijgrok (AE 31, 3 pp. 399-415; 1997) estimates dry deposition values over a forest from SO_4^{2-}, NO_3^- and base cations. These values are larger than those reported elsewhere in the literature.
- Modified Bates values assuming the base cation depositions velocities are 4.4 times those for SO_4^{2-} based on the Ruijgrok study (4.4 * 0.14 = 0.616).
- Stability weighted Cheng (1993) deposition velocities.

The associated deposition velocities, total deposition and PAI are summarized in Tables III-24 and III-25. The results in the table indicate that the deposition velocity has a considerable effect on the calculated background PAI. Base cation deposition rates range from 0.007 to 0.271 keq/ha/a and dry PAI ranges from -0.116 to 0.072 keq/ha/a. The Bates' (1997) deposition velocities likely underestimate cation deposition. Similarly, the Ruijgrok deposition velocities are likely on the high side. The Cheng and modified Bates provide similar base cation depositions but differ for non-cation values.

Table 24 Calculation of Background PAI Based on Varying Dry Deposition Velocity Schemes

		Bates (1996)			Cheng (1993)			Ruijgrok, PM (1997)		
		V_d	Deposition		V_d	Deposition		V_d	Deposition	
	[μg/m³]	[cm/s]	[kg/ha/y]	[keq/ha/y]	[cm/s]	[kg/ha/a]	[keq/ha/a]	[cm/s]	[kg/ha/a]	[keq/ha/a]
SO_2	1.20	0.37	1.40	0.043	0.35	1.32	0.041	0.37	1.40	0.043
SO_4^{2-}	0.69	0.14	0.30	0.006	0.5	1.09	0.023	1.15	2.50	0.053
NH_4	0.19	0.14	0.08	0.005	0.5	0.30	0.016	1.15	0.69	0.036
HNO_3	0.23	1.33	0.96	0.015	1.4	1.02	0.016	1.33	0.96	0.015
NO_3^-	0.09	0.26	0.07	0.001	0.5	0.14	0.002	1.15	0.33	0.005
Ca^{2+}	0.20	0.14	0.09	0.004	0.5	0.31	0.016	5.1	3.17	0.158
Mg^{2+}	0.05	0.14	0.02	0.002	0.5	0.07	0.006	5.1	0.74	0.061
K^+	0.12	0.14	0.05	0.001	0.5	0.20	0.005	5.1	1.99	0.052
Background dry PAI				**0.064**			**0.072**			**-0.1**
Base Cations				**0.007**			**0.027**			**0.2**
Wet Plus Dry PAI				**0.10**			**0.11**			**-0.08**

Table 25 Additional Calculations of Background PAI Based on Varying Dry Deposition Velocity Schemes

		ModifiedBates			Cheng (1993) Slab Weighted		
		V_d	Deposition		V_d	Deposition	
	[μg/m³]	[cm/s]	[kg/ha/y]	[keq/ha/y]	[cm/s]	[kg/ha/y]	[keq/ha/y]
SO_2	1.20	0.37	1.40	0.043	0.327	1.24	0.038
SO_4^{2-}	0.69	0.14	0.30	0.006	0.37	0.81	0.017
NH_4	0.19	0.14	0.08	0.005	0.37	0.22	0.012
HNO_3	0.23	1.33	0.96	0.015	1.327	0.96	0.015
NO_3^-	0.09	0.26	0.07	0.001	0.37	0.11	0.002
Ca^{2+}	0.20	0.616	0.38	0.019	0.37	0.23	0.011
Mg^{2+}	0.05	0.616	0.09	0.007	0.37	0.05	0.004
K^+	0.12	0.616	0.24	0.006	0.37	0.14	0.004
Background dry PAI				**0.038**			**0.065**
Base Cations				**0.033**			**0.020**
Wet Plus Dry PAI				**0.08**			**0.10**

The total PAI assuming Bates, Cheng and modified Cheng is 0.10 keq/ha/a. The Ruijgrok value is 0.09 due to extremely high deposition velocities associated with base cations. A Monte Carlo variability assessment based on the ranges of data provided, indicates a mean total PAI of between 0.09 and 0.10 keq/ha/a based on 10,000 simulations. The range in the estimates is approximately 0.0 to 0.26 keq/ha/a.

III.7.7.1 Conclusions

Based on the available data, the following background PAI appears representative of the Oil Sands region:

PAI Component	PAI Value [keq/ha/y]
Wet PAI	0.04
Dry PAI	0.06
Total PAI	0.10

III.8 CONCLUSIONS

SCREEN3 is a screening level model suitable for evaluating worst case concentrations from individual sources. The number of sources and scope of the area make this model unsuitable for use.

ISCST3 is the work-horse dispersion model of the U.S. EPA which can deal with the large numbers of complex sources present in the study area. The model, however, does not have the sophisticated chemistry required to deal fully with the wet and dry deposition issues. When compared to the ISC3BE model, ISCST3 does not do as good a job at simulating concentrations within Athabasca River valley.

ISC3BE has been refined to more closely replicate the concentrations observed in the region. The model is not open to peer scrutiny, however, and has not been calibrated outside of the immediate river valley. In addition, ISC3BE does not have the sophisticated chemistry required to deal fully with the wet and dry deposition issues. The ISC3BE model does have a history of application in the region, and will be used by some parties as a yardstick for evaluating any changes in air emissions.

CALPUFF is potentially the most accurate model for simulating all of the required concentration and deposition values needed in the assessment. To get the full benefit of this model, however, a full 3-dimensional meteorological and terrain data set would be required. When run using the meteorological data from a single station, and run using the ISC3BE terrain coefficients, the CALPUFF model performs comparably to the ISC3BE at simulating the measured concentrations along the Athabasca River valley. The CALPUFF model is also the only model evaluated that has the sophisticated chemistry required to deal fully with the wet and dry deposition issues.

CALGRID is the next progression from the CALPUFF model, designed to deal with photochemical transformations. At this time, the sophisticated emissions characterizations and 3-dimensional meteorological and terrain data sets required to run the model have not been fully implemented.

III.9 RECOMMENDATIONS

ISC3BE should be applied to determine the short and long term concentrations of non-reactive chemicals in the region. The model estimates will provide a good reference with respect to historic studies in the region, and provide confirmation of the CALPUFF model predictions.

CALPUFF will be run to simulate the atmospheric deposition and PAI values in the region. In addition, the model will be run to calculate the short and long term concentrations of all of the contaminants considered in the assessment. Since the 3-dimensional meteorological and terrain data required to run the model in full implementation has yet to be fully developed, CALPUFF will be run using meteorological data from a single station. When these data are available, the CALPUFF model can be readily applied to more accurately simulate dispersion in the region.

CALGRID model development is currently proceeding as part of an independent working group. When the sophisticated emissions characterizations and 3-dimensional meteorological and terrain data sets required to run the model have been fully developed, it will be applied to predict the behaviour of the photochemical species in the region.

APPENDIX IV

Hydrogeology Calculations

&

Technical Appendix

IV METHODS USED TO DETERMINE THE IMPACTS TO THE GROUNDWATER FLOW REGIME

IV.1 INTRODUCTION

The impacts to groundwater of the development and reclamation of the proposed Millennium Mine have been evaluated on the basis of changes to:

- Direction of groundwater flow;
- Rate of groundwater discharge to surface water bodies; and
- Groundwater quality.

Groundwater diversions expected to result from the Project Millennium mine development and the associated estimation methods are summarized below. The hydraulic conductivities used in this analysis are presented in the following table.

Medium	Regional Hydraulic Conductivity Low (m/sec)	Regional Hydraulic Conductivity High (m/sec)	Regional Hydraulic Conductivity Mean (m/sec)	Local Hydraulic Conductivity Low (m/sec)	Local Hydraulic Conductivity High (m/sec)	Local Hydraulic Conductivity Mean (m/sec)	Hydraulic Conductivity Applied (m/sec)	Hydraulic Conductivity Applied (m/day)	Source
Peat	7.50E-08	3.80E-04	NA	NA	NA	NA	7.50E-08	6.48E-03	Boelter, 1965
Regional Sand	1.10E-08	9.20E-05	1.10E-05	4.00E-05	NA	NA	NA		Klohn-Crippen, 1996
Regional Sand and Gravel	7.00E-06	1.00E-03	3.80E-04	NA	NA	NA	NA		Klohn-Crippen, 1996
Sand and Gravel, North Extremity of LSA	NA	NA	NA	3.70E-06	4.00E-07	3.70E-06	3.70E-06	3.2E-01	Klohn-Crippen, 1996
Sand and Gravel, Central to LSA	NA	NA	NA	NA	3.70E-04	NA	3.70E-04	3.2E+01	Klohn-Crippen, 1998
Till	5.30E-08	6.80E-07	1.40E-07	NA	NA	NA	1.40E-07	1.2E-02	Klohn-Crippen, 1998
Oilsand	3.50E-09	3.20E-07	1.50E-07	NA	NA	NA	2.00E-08	1.7E-03	Shell Muskeg River Mine Project EIA, 1998
Basal Aquifer	1.50E-07	2.40E-04	4.20E-05	8.60E-08	2.20E-05	4.10E-06	4.10E-06	3.5E-01	Klohn-Crippen, 1996
Devonian	4.00E-11	3.00E-05	5.10E-07	NA	NA	5.80E-06	NA		Klohn-Crippen, 1996
CT	NA	NA	NA	NA	NA	NA	1.00E-09	8.64E-05	AGRA, 1996
MFT	NA	NA	NA	NA	NA	NA	4.00E-07	3.46E-02	Shell Muskeg River Mine Project EIA, 1998
Sand Dyke	NA	NA	NA	NA	NA	NA	1.00E-06	8.64E-02	Shell Muskeg River Mine Project EIA, 1998
Overburden Dyke	NA	NA	NA	NA	NA	NA	1.00E-07	8.64E-03	Shell Muskeg River Mine Project EIA, 1998

Hydraulic Conductivity For Peat
Dense decomposed herbaceous peat: 7.5E-8m/sec (Boelter, 1965)
- Undecomposed moss peat with many large pores: 3.8E-4 m/sec
Organic soils: 7.1E-5 m/sec to 8.6E-6 m/sec (Irwin, 1966)

The following processes were assessed for the Millennium EIA:

1. Muskeg de-watering
2. Surficial sand and gravel groundwater discharge
3. Surficial sand and gravel de-watering
4. Bedrock de-pressurization
5. Seepage of consolidated tailings (CT) water from the CT ponds
6. Seepage of water from pond 8A which will contain mature fine tailings (MFT)
7. Seepage of surficial sand and gravel into the end pit lake
8. Seepage of bedrock groundwater into end pit lake
9. Seepage of water from the end pit lake into the bedrock

IV.2 MUSKEG DE-WATERING

The flow system in the peat layer is considered to be part of the surface flow system for the EIA. However, the radius of influence of de-watering the peat was estimated as a part of the hydrogeology impact analysis. The radius of influence of de-watering the peat was estimated using a trench de-watering equation.

The de-watering equation for flow from an unconfined aquifer to one side of a dewatering ditch of unit length is given by the following equation described by Driscoll (1989).

$$\frac{Q}{x} = \frac{K\,(H^{2} - h^{2})}{2\,L\,o}$$

where:

K = Hydraulic Conductivity (m/day)

H = Saturated thickness before pumping (m)

h = Depth of water in well (ditch) while pumping (m)

Lo = Distance from point of greatest drawdown to point of no drawdown (m)

x = Unit length; the length of the trench (m) across the width of the basin

Q = Discharge rate (m3/day), the muskeg discharge across the width of the basin

Hydraulic conductivity for peat has been determined as follows:

- Dense decomposed herbaceous peat: 7.5E-8m/sec (6.4E-3 m/day) (Boelter, 1965)
- Undecomposed moss peat with many large pores: 3.8E-4 m/sec (32.8 m/day)
- Organic soils: 7.1E-5 m/sec to 8.6E-6 m/sec (Irwin, 1966) (6.13 to .74 m/day)

The flow within the muskeg layer is determined using an adaptation of Darcy's Law:

$Q = KbiL$

where:

K = the hydraulic conductivity of the muskeg (m/day)

b = the thickness of the muskeg (m)

L = the width the of the catchment (m)

i = the horizontal hydraulic gradient in the muskeg

Q = the discharge through the area defined by the width and the depth of the flow system (m^3/day)

K (m/day)	b (m)	L (m)	i i	Q (m^3/day)
4.32	0.8	2800	0.002	1.9E+01
4.32	1.5	2800	0.002	3.6E+01

Using the flows determined above the radius of influence of a trench stretching across the entire width of the Leggett Creek catchment is calculated for a range of thicknesses as follows:

K (m/day)	b (m)	H (m)	h (m)	Q (m^3/day)	x (m)	Lo/x (m)	Lo (m)
4.32E+00	0.8	0.8	0.1	1.94E+01	2800	0.0703	196.9
4.32E+00	1.5	1.5	0.1	3.63E+01	2800	0.1333	373.3

(Terrestrial assessment has determined that the muskeg is .8 to 1.5 m thick.)

This calculation determines the volumes pumped from a trench in order to create a radius of drawdown out to a distance of Lo. The application presented above assumes complete capture of the muskeg flow.

IV.3 SURFICIAL SAND AND GRAVEL GROUNDWATER DISCHARGE ESTIMATE

Surficial sand and gravel groundwater discharge to surface water was estimated using Darcy's Law. The area over which the discharge occurs is equivalent to the outcrop (subcrop) area of the sand and gravel along the deeply incised creek valleys. Alluvial deposits and organic cover prevented direct observation of the outcrop areas in the field. Therefore the area and thickness distribution of the sand and gravel incised by the creek valleys was estimated from a combination of the baseline sand and gravel isopach map and the ground surface topography map.

Estimates of the capture zones of the creek valleys were required to determine whether any groundwater from the surficial sand and gravel discharges directly to the Athabasca River Valley along a seepage face. It has not been possible to map the potentiometric surface at a high enough resolution to determine the discharge directly. Therefore the baseline capture zones of incised creek valleys were estimated using trench de-watering equations.

The trench de-watering equation for the unconfined case (Driscoll, 1989) was used for a range of thicknesses and assuming an average hydraulic conductivity as follows:

Creek	K	H	h	Q	x	Lo/x	Lo
	(m/sec)	(m)	(m)	(m^3/sec)	(m)	(m)	(m)
Leggett	3.70E-06	2	0.1	2.10E-05	1,400	0.35	492
Leggett	3.70E-06	4	0.1	2.10E-05	1,400	1.41	1,972
Wood	3.70E-06	2	0.1	4.15E-05	2,800	0.18	498
Wood	3.70E-06	4	0.1	4.15E-05	2,800	0.71	1,996
McLean	3.70E-06	6	0.1	9.30E-05	2,100	0.72	1,503

The discharge (Q) in the previous calculations is the baseline discharge determined through application of Darcy's Law.

For the case of the confined aquifer :

$$\frac{Q}{x} = \frac{K\, b\, (H - h)}{L_o}$$

where:

b = Aquifer thickness (m)

Creek	K (m/sec)	b (m)	H (m)	h (m)	Q (m^3/sec)	x (m)	Lo/x (m)	Lo (m)
Leggett	3.70E-06	2	2	0.1	2.10E-05	1400	0.67	937
Leggett	3.70E-06	4	4	0.1	2.10E-05	1400	2.75	3848
Wood	3.70E-06	2	2	0.1	4.15E-05	2800	0.34	949
Wood	3.70E-06	4	4	0.1	4.15E-05	2800	1.39	3894
McLean	3.70E-06	6	6	0.1	9.30E-03	2100	0.01	30

The later case of the confined aquifer is more consistent with the terrestrial mapping that has been completed to date at the site. The confined case is also more consistent with the vertical hydraulic gradients that have been measured at locations instrumented with stand pipe piezometers.

IV.4 SURFICIAL SAND AND GRAVEL DE-WATERING

Groundwater will be extracted from the surficial sand and gravel in the mine development area to result in the following:

- to remove the water from storage in the area to be mined so that the overburden may be stripped;
- to retain water levels along the boundary of the mine development area to a level suitable to guarantee pit wall stability during construction and operations.

In order to determine the effects of these activities the volume of water that would be removed and discharged to the environment was assessed, and the radius of influence of the drawdown was estimated. Since this groundwater would be released to the environment, there would be no net loss in the discharge. However, the groundwater would be directed to a new discharge point due to the pumping and estimates of the relative increases and decreases in discharge were required. Drawdown caused by groundwater withdrawal will induce a downward vertical gradient across overlying confining layers. This could result in the lowering of water levels in the muskeg thereby stressing the vegetation.

The volume of water to be removed from storage was determined by assessing the volume of the sand and gravel deposit and assuming unconfined conditions in the vicinity of stripping. A storage coefficient of 0.15 was assumed. The volume was determined for an area to be stripped during the interval of time between snapshots. This total volume for the interval was divided by the duration of the interval to arrive at an average annual discharge in units of L/sec. The results of this analysis are presented in the following table.

Surficial Sand and Gravel Groundwater Removed from Storage
(does not include the deep confined aquifer material which is assumed to be negligible)

Explanation:
For each snapshot, the area and thickness of surficial aquifer was determined per pond
The aquifer total volume was then calculated
The water from storage is the aquifer volume multiplied by the storage coefficient giving the total volume removed over the time span of the snapshot
This volume was divided by the time span to give L/Yr. The discharge was further divided by the number of seconds in a year to give L/sec/Yr.

Snapshot	Pond (Pit)	Aquifer Area (m^2)	Aquifer Thickness (m)	Aquifer Volume (m^3)	Aquifer Volume (L)	Storage Coefficient	Water Volume Per Snapshot (L/time span)	Water Volume Per 1 Year (L/Yr)	Discharge Per Sec Per 1 Year (L/sec)	Total (L/sec)	Destination
2005	Pond 8	490000	2	9.8E+05	9.8E+08	0.15	1.5E+08	2.9E+07	0.9		Shipyard Creek
2005	Pond 8	1347500	3	4.0E+06	4.0E+09	0.15	6.1E+08	1.2E+08	3.8		Shipyard Creek
2005	Pond 8	1470000	2	2.9E+06	2.9E+09	0.15	4.4E+08	8.8E+07	2.8	7.6	Shipyard Creek
2007	Pond 9	1347500	3	4.0E+06	4.0E+09	0.15	6.1E+08	3.0E+08	9.6		Shipyard Creek
2007	Pond 9	1102500	2	2.2E+06	2.2E+09	0.15	3.3E+08	1.7E+08	5.2	14.9	Shipyard Creek
2012	Pond 9	1102500	2	2.2E+06	2.2E+09	0.15	3.3E+08	6.6E+07	2.1	2.1	Shipyard Creek
2012	Pond 10	1102500	1.5	1.7E+06	1.7E+09	0.15	2.5E+08	5.0E+07	1.6	3.7	Shipyard Creek
2018	Pond 10	367500	1.5	5.5E+05	5.5E+08	0.15	8.3E+07	1.4E+07	0.4		Shipyard Creek
2018	Pond 10	980000	2	2.0E+06	2.0E+09	0.15	2.9E+08	4.9E+07	1.6		Shipyard Creek
2018	Pond 10	490000	1	4.9E+05	4.9E+08	0.15	7.4E+07	1.2E+07	0.4	2.4	Shipyard Creek
2018	Pond 11	490000	1	4.9E+05	4.9E+08	0.15	7.4E+07	1.2E+07	0.4		McLean Creek
2018	Pond 11	612500	2	1.2E+06	1.2E+09	0.15	1.8E+08	3.1E+07	1.0	1.4	McLean Creek
2025	Pond 11	980000	2	2.0E+06	2.0E+09	0.15	2.9E+08	4.2E+07	1.3		McLean Creek
2025	Pond 11	2450000	5	1.2E+07	1.2E+10	0.15	1.8E+09	2.6E+08	8.3	9.7	McLean Creek
2025	Pond 12	2940000	5	1.5E+07	1.5E+10	0.15	2.2E+09	3.2E+08	10.0	10.0	McLean Creek
2030	Pond 12	6737500	5	3.4E+07	3.4E+10	0.15	5.1E+09	1.0E+09	32.0	32.0	McLean Creek
Closure	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	NA
Far Future	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	NA

The radius of influence of dewatering the surficial sand and gravel was determined based on the following assumptions:

- At greater distances away from the area of the stripping the sand and gravel behaves as a confined aquifer.
- Direct discharge from the surficial aquifer to the Athabasca Basin is negligible because the capture zones of the incised valleys overlap. All groundwater in the surficial deposits discharges to McLean Creek, Wood Creek, Leggett Creek, and Shipyard Creek.
- The hydraulic conductivity of the surficial sand and gravel is 3.7E-6 m/sec.
- The hydraulic head is at or slightly above the ground surface. Therefore the horizontal component of the hydraulic gradient in the surficial sand and gravel is equal to the slope of the ground.

Over approximately 90 percent of the Local Study Area the sand and gravel is less than 10 meters deep and may be de-watered using trenches. Locally however, the sand and gravel is thick enough to require water well pumping. Using the assumptions and constraints presented above, a Theis analysis was conducted to determine a range in the radius of influence of pumping the sand and gravel deposits. The radius from the center of pumping to where the drawdown would be 0.1 m was estimated as follows:

$Q_{storage}$ (L/sec)	=	10.5 average per year
$Q_{recharge}$(L/sec)	=	4.5 average per year

Using only the recharge component of the groundwater flow:

Q_{total} (L/sec)	=	4.5 total average per year
Q_{total} (m^3/sec)	=	0.0045 total average per year
Q_{total} (m^3/min)	=	0.27 total average per year
Total Volume (m^3)	=	141912 for one year
Total Volume (m^3)	=	709560 for five years
Q (m^3/yr)	=	236520 Volume per year over three years
Q (m^3/day)	=	648

and assuming confined conditions for a conservative estimate of radius of influence at late time:

Q (m^3/day)	=	650
K (m/sec)	=	3.70E-06

K (m/day)	=	3.20E-01
b (m)	=	5
S		0.005000
t (days)	=	1095
ho-h (m)	=	0.1
r (m)	=	unknown

The Theis solution is as follows:

$$ho\text{-}h = \frac{Q\,W(u)}{4\pi T}$$

W(u)	=	0.003089
(u)	=	4 (From Freeze and Cherry 1979; page 318)

$$u = \frac{r^2 S}{4Tt}$$

r^2	=	5600794
r	=	2367 m

Assuming an average hydraulic conductivity and calculating the radius of influence for a range of values for thickness and duration of pumping:

K (m/day)	t (day)	b (m)	W(u)	u	r^2	r (m)
3.20E-01	365	5	0.00309	4.0	1866931	1366
3.20E-01	1095	5	0.00309	4.0	5600794	2367
3.20E-01	365	2	0.00124	5.0	933466	966
3.20E-01	1095	2	0.00124	5.0	2800397	1673

Groundwater pumping will induce a vertical gradient causing leakage from the muskeg to the underlying sand and gravel. Leakage will only occur after the drop in head has propagated through the low permeability material at the base of the muskeg. The time for this to occur is determined through an analytical solution by Terzaghi (1925) which depends on characterization of the muskeg properties. The muskeg properties are not known, therefore groundwater migration times were estimated by applying Darcy's Law and assuming a muskeg porosity of 0.50. These migration times are an approximation of the time for the muskeg to be impacted by groundwater withdrawal from the underlying sand and gravel. Assuming leakage has commenced, typical times for one pore volume of water to leak through the low permeability layer for various degrees of drawdown are calculated as follows:

b (m)	K (m/sec)	Drawdown (m)	i	n	q (m^3/sec)	Velocity (m/sec)	Velocity (m/day)	Time (days)
	7.5E-08	0.1	0.1	0.5	7.5E-09	1.5E-08	1.3E-03	770
	7.5E-08	0.5	0.5	0.5	3.75E-08	7.5E-08	6.5E-03	154
	7.5E-08	1.0	1.0	0.5	7.5E-08	1.5E-07	1.3E-02	77

The times listed in the previous table are less than the duration of the life of one pit. Therefore, leakage from the muskeg to the underlying sand and gravel is expected. This is especially true for the prolonged de-watering effect expected due to the seepage of groundwater into the end pit lake after mine closure.

IV.5 BEDROCK GROUNDWATER DISCHARGE TO SURFACE FLOW

Bedrock groundwater discharge to surface flow was estimated using Darcy's Law. The bedrock flow system is unrelated to the surface flow system for the smaller creeks however the discharge was reported for each of the surface flow catchment area discharges for the sake of consistency of reporting and comparison of results. This flow alternately increases and decreases due to pumping and seepage at various times in the proposed mine development. Pumping is required to lower the hydraulic head in the bedrock to a level below the planned elevation of the pit floor. The de-pressurization of the bedrock produces two effects that required evaluation:

- Capture of recharge by pumping was estimated using an adaptation of Darcy's Law to determine the reduction of the baseflow to adjacent streams and to provide an estimate of the volume of groundwater that would be conveyed to the mine process stream.
- The reduction of hydraulic head in the area of the mine development would exert drawdown out to a radius of influence beyond the area of the mine development. An estimation of the radius was required for the impact analysis.

The volume of groundwater removed during depressurization of the bedrock relates entirely to capture of the recharge water. There is no water removed from storage. A Theis analytical approach was used incorporating the following assumptions;

- The hydraulic conductivity of the Basal Aquifer and the Upper Devonian are similar;
- The head in the basal Aquifer and the Upper Devonian are similar, so they act as one unit;
- The head in the bedrock would be lowered to about 2 meters beneath the planned pit floor elevation;
- All de-watered bedrock water is redirected to mine process; and
- The aquifer is confined.

$Q_{storage}$ (L/sec): = 0 average per year

$Q_{capture}$ (L/sec) = 2.2386 average per year

Q (L/sec)	=	2.2386 total average per year	
Q (m^3/sec)	=	0.002239 total average per year	
Q (m^3/min)	=	0.134316 total average per year	
Total Volume (m^3)	=	70596.49 for one year	
Total Volume (m^3)	=	352982.4 for five years	
Q (m^3/yr)	=	117660.8 Volume per year over three years	
Q (m^3/day)	=	322.3584 Volume per day average year over three years	
Q (m^3/day)	=	325	
K (m/sec)	=	4.10E-06	1.50E-07
K (m/day)	=	3.54E-01	1.30E-02
b (m)	=	26	
S	=	0.0005	
t (days)	=	1095	
ho-h (m)	=	0.1	
r (m)	=	Unknown	

The Theis solution is as follows:

$$ho\text{-}h = \frac{W(u)}{4\pi T}$$

W(u)	=	0.035594
(u)	=	2.5 (From Freeze and Cherry 1979; page 318)

$$u = \frac{r^2 S}{4Tt}$$

r^2	=	202E+08
r	=	14202

For a range in values of the hydraulic conductivity the thickness and the duration of pumping, the radius of influence is estimated as follows:

K (m/day)	t (day)	b (m)	W(u)	u	r^2	r (m)
3.54E-01	365	26	0.03557	2.2	59126496	7689
3.54E-01	1095	26	0.03557	2.2	177379488	13318
3.54E-01	365	50	0.06840	1.8	93031200	9645
3.54E-01	1095	50	0.06840	1.8	279093600	16706
1.30E-02	365	26	0.00131	5.0	4934800	2221
1.30E-02	1095	26	0.00131	5.0	14804400	3848
1.30E-02	365	50	0.00251	4.4	8351200	2890
1.30E-02	1095	50	0.00251	4.4	25053600	5005

IV.5.1 Seepage from the Consolidated Tailings Ponds

Consolidated tailings will be placed in the mine pits, as a component of the mine reclamation. The process of producing CT is relatively new, and the long-term behavior and composition of the material has not been well documented yet. The expected benefit of placing CT in the mined pits is that the tailings will provide a stable, weight-bearing, dry surface, that will be re-vegetated with trees.

Seepage from the CT ponds will be via two flow paths;

- Horizontal seepage may be expected through the dykes. This seepage will be collected in a toe ditch and will be either pumped back into the pond or will be conveyed to the mine process water stream.
- Vertical seepage from the CT ponds will contribute to flow in the bedrock.

The rate of seepage contributing to each flow path is a function of the hydraulic conductivity of the CT, the dyke, and the bedrock. Horizontal seepage through the overburden dyke for each pond was estimated assuming the pond was full of water and using the Darcy flux equation described in previous sections. This provides a conservative over estimate of the seepage because it does not account for the reduction of hydraulic conductivity of the CT as it consolidates.

Vertical seepage was also determined using the analytical approach. In this case it was assumed that the pond is full of consolidated tailings. The rate of vertical seepage from the ponds will be a function of the hydraulic conductivity of the CT, the vertical hydraulic gradient between the CT and the underlying bedrock aquifers, and the area of the ponds. The equation used to calculate the seepage rate is:

$Q = K\ i\ A$

where;

Q = seepage rate

K = the hydraulic conductivity of the aquifer, m/s

i = the hydraulic gradient in the aquifer, m/m

A = area of the pond, m^2

The hydraulic conductivity of the CT has been estimated to be 1×10^{-9} m/s (AGRA 1996). The vertical hydraulic gradient in the ponds is difficult to predict, because it is not known what the elevation of the phreatic surface within the CT will be. However, as the hyraulic conductivity of the CT is quite low (10^{-9} m/s is similar to what is measured in clayey deposits), it is anticipated that the phreatic surface within the CT will be very close to

ground level. Therefore, the vertical hydraulic gradient in the CT has been calculated using the estimated elevation of the top of the ponds.

The seepage will ultimately discharge with the groundwater into the Athabasca River, the Steepbank River, and Shipyard Lake. The exact proportions of the CT contribution to each of these water bodies will depend on a number of factors, including preferential pathways in the bedrock, the final elevation of the bottom of the pond, variability in the composition of the CT and pumping of the bedrock in adjacent pit areas.

A finite element numerical model (SEEP/W) was used to test the sensitivity of the seepage to hydraulic conductivities for a typical pond in the mine development area. The results of this numerical approach were compared to the analytical approach used to determine the horizontal seepages for the impact analysis.

Pond	Filling Material	Ponding Height (mAMSL)	Analysis Method	Vertical Seepage (L/sec)
11	CT	335	SEEP/W	8.6
11	CT	340	Darcy	4.4
7	CT	335	SEEP/W	4.0
7	CT	335	Darcy	3.5

In summary, the SEEP/W analysis determined that all of the seepage will flow through the bedrock. This analysis is based on the assumption that all of the oilsand is mined out and the CT is in direct contact with the bedrock. The analytical approach determined horizontal seepage through the dyke assuming that the pond was filled with water and vertical seepage assuming that the pond was filled with CT. Therefore, the horizontal seepage determination from the analytical approach is over-estimated. All of this seepage would normally discharge to a drainage ditch and would be conveyed to the mine process stream.

In addition, the analysis of vertical seepage of CT to the bedrock is very sensitive to the hydraulic head in the bedrock. The current EIA is based on the head distribution for the bedrock used in the Steepbank EIA. More recent data from the bedrock indicates that the head may be 25 to 45 meters lower than what has been assumed for the Steepbank EIA. This is based on one reading at one additional pneumatic monitoring location in the eastern half of the local study area. The geology of these locations has not yet been determined and so the level of confidence in the head at the new location is low. The hydraulic conductivity and head of the bedrock is variable from place to place. Estimates of vertical seepage have been made with a low level of confidence given the high variability in the bedrock and the limited extent of the data, both spatially and temporally. The overall impact of the bedrock groundwater discharge to surface water is however very small. Groundwater discharge to the Athabasca River comprises less than 1% of

the total flow. Therefore, even with large relative variations in the outcome of CT seepage analyses, the overall impact to surface flow will remain low.

IV.6 SEEPAGE FROM POND 8A

For Pond 8A, the dykes will be constructed using a combination of an overburden starter dyke and upstream dyke construction using tailings sand. The pond will retain manufactured fine tails (MFT) during the operating life of the mine. The numerical approach (SEEP/W) was used to determine the MFT seepage assuming that the pond is full of water. The simulation was run for two scenarios. In the first scenario the pond overlies a low permeability layer (muskeg or till). In the second scenario the pond directly overlies a sand and gravel deposit.

The analytical approach (using Darcy's equation) was used to determine the seepage assuming that the pond is full of water and assuming that there is a low permeability muskeg layer beneath the pond. Pond 8A will be filled with mature fine tailings during operations. Therefore the seepage estimates should be considered as conservative over-estimates. It is assumed that all of the seepage from Pond 8A will be collected and fed into the mine process water stream. This will include vertical seepage that contributes to groundwater and flows along the buried valleys of the former Leggett Creek and Wood Creek respectively.

As with the CT seepage analysis, it was found that very little seepage flows through the dyke. Flow is predominantly through the bottom of the pond into the drift deposits. The analysis is very sensitive to the presence of a low permeability layer such as a till deposit or a dense herbaceous peat layer. Terrestrial mapping has shown that the area at the base of the proposed pond consists of shallow fen, shallow bog, and glaciofluvial sediments at the surface. Only one borehole has been logged in detail for the drift deposits and instrumented with a stand pipe piezometer in the area of Pond 8A (L19-P98-OB4). This borehole penetrated 0.90 meters of muskeg followed by 4.3 meters of medium and coarse grain sand with fine to medium grain gravel.

Pond	Filling Material	Ponding Height (mAMSL)	Low k Layer Present	Analysis Method	Vertical Seepage (L/sec)
8A	Water	365	no	SEEP/W	1270.0
8A	Water	365	no	na	na
8A	Water	365	yes	SEEP/W	590.0
8A	Water	365	yes	Darcy	425.0

IV.6.1 Seepage of Surficial Groundwater to the End Pit Lake

After mine closure the surficial sand and gravel groundwater will discharge to the end pit lake. Trench de-watering equations were used to estimate the

radius of influence of this permanent de-watering process. An estimate of the radius of influence is important to assess the potential geotechnical impacts and potential impacts to the overlying muskeg flow system and vegetation. Assuming that the muskeg is of constant thickness and hydraulic conductivity throughout the local study area, the calculations presented under the muskeg dewatering section also apply here. Therefore, the radius of influence would be 200 to 400 meters.

The radius of influence of the End Pit Lake on the surficial sand and gravel is determined using the trench de-watering equation for the confined aquifer case:

$$\frac{Q}{x} = \frac{K\,b\,(H - h)}{L\,o}$$

where:

b = Aquifer thickness

The baseline discharge through the sand and gravel adjacent to the perimeter of the end pit lake is estimated in the following table. A range has been estimated because there is limited data south east of the local study area.

K (m/day)	b (m)	L (m)	i	Q (m^3/day)
3.20E-01	2	2800	0.002	3.6E+00
3.20E-01	3	2800	0.002	5.4E+00
3.20E-01	4	2800	0.002	7.2E+00
3.20E-01	5	2800	0.002	9.0E+00
3.20E-01	6	2800	0.002	1.1E+01

Using the values presented above the influence of End Pit Lake on the surficial sand and gravel is estimated as follows:

K (m/day)	b (m)	H (m)	h (m)	Q (m^3/day)	x (m)	Lo/x (m)	Lo (m)
3.2E-01	2	2	0.1	3.6E+00	2800	0.34	950
3.2E-01	3	3	0.1	5.4E+00	2800	0.52	1450
3.2E-01	4	4	0.1	7.2E+00	2800	0.70	1950
3.2E-01	5	5	0.1	9.0E+00	2800	0.88	2450
3.2E-01	6	6	0.1	1.1E+01	2800	1.05	2950

IV.6.2 Bedrock Groundwater Seepage to the End Pit Lake

After mine closure, when the hydraulic gradient is directed upward, groundwater will seep from the bedrock into the end pit lake. An adaptation of Darcy's Law was applied to estimate the rate of the seepage from the

bedrock to the end pit lake. This seepage causes a temporary reduction in the baseflow of bedrock groundwater to the surface flow regime. Later in time when the end pit lake is full, the vertical gradient is vertically downward and the lake will recharge the bedrock.

IV.6.3 End Pit Lake Seepage to the Bedrock

An equation for injection by a well was applied to determine the contribution to the groundwater flow system in the bedrock due to the elevation of the fluid in the end pit lake being maintained at a level of 340 m which is above the level of the hydraulic head in the bedrock under baseline conditions.

The following assumptions were applied:

- The end pit lake is in direct contact with the bedrock
- The bedrock is isotropic and homogeneous.
- All of the recharging water ends up in the Athabasca River
- Theis ideal conditions for a confined aquifer are assumed
- The end pit lake is surrounded with overburden having a lower hydraulic conductivity than the bedrock

The equation for injection of water by a well is:

$$Q_r = \frac{Kb\,(h_w - H_o)}{0366\,\log(r_o / r_w)}$$

where:

Q_r = Rate of injection (m^3/day)

K = Hydraulic conductivity of the receiving aquifer (m/day)

b = aquifer thickness (m)

h_w = elevation while recharging (mamsl)

H_O = Baseline groundwater elevation for the bedrock (mamsl)

r_o = radius of influence (m)

r_w = radius of the injection well (m)

For a range in the hydraulic conductivity of the bedrock the seepage rate is estimated as follows:

K (m/day)	b (m)	hw (mamsl)	Ho (mamsl)	r_o (m)	r_w (m)	Q (m^3/day)	Q (L/sec)
3.5E-01	26	340	240	4000	300	2237.0	25.9
7.7E-02	26	340	240	4000	300	485.6	5.6
1.3E-02	26	340	240	4000	300	81.8	0.9

APPENDIX V

Water Quality Modelling Results

and

Model Assumptions

V-1 SURFACE WATER QUALITY

V-1.1 Operational and Reclamation Waters

The Oil Sands Water Release Technical Working Group (OSWRTWG), a consortium of industry and government experts, was established in 1995 to examine the issue of releases of waters from oil sands operations to the Athabasca River. Water releases were classified into two groups: operational and reclamation waters.

Operational waters are:

- discharged from a channel or outfall;
- discharged over the life of the project or a shorter time frame;
- controllable;
- treatable in a managed treatment system;
- amenable to comparing with ambient water quality guidelines; and
- potentially of concern with respect to regional off-site impacts.

The only operational waters to be released from the Project are muskeg and overburden dewatering waters. These waters are also the main sources of natural surface water in the region, since the drainage basins of the small streams are largely made up of areas covered with muskeg.

OSWRTWG (1996) described reclamation waters as:

- non-point source diffuse waters, which may be directed through wetlands, streams or lakes prior to discharge to surface waters;
- released at slow rates over large areas for extended periods of time;
- non-controllable;
- non-treatable (but may be altered through natural systems or constructed wetlands);
- not amenable to conventional end-of-pipe approval requirements; and
- primarily an on-site water management system and a component of a maintenance free reclamation landscape.

Table V-1 summarizes the water quality associated with Suncor and Syncrude's operational and reclamation waters.

Table V-1 Suncor/Syncrude Operational and Reclamation Waters (Page 1 of 3)

Substance (mg/L)	South Mine Drainage[a]	Mid-Plant Drainage[b]	North Mine Drainage[b]	Future Drainage	TID Seepage[b]	Sewage Effluent[c]
Water Quality Code[k]	A	B	C	D	E	F
Aluminum - Total	0.04	0.1	0.07	0.07	1.2	0.51
Ammonia - Total	0.082	19	0.03	0.082	6.0	9
Antimony - Total	-	-	-	-	-	-
Arsenic - Total	0.0005	0.0007	0.0002	0.0005	0.003	0.004
Barium - Total	0.08	0.09	0.12	0.12	0.10	0.06
Benzo(a)anthracene grp	ND	ND	ND	ND	ND	-
Benzo(a)pyrene grp	ND	ND	ND	ND	ND	-
Beryllium-Total	0.003	0.003	0.003	0.003	0.002	0.002
Biochemical Oxygen Demand	0.9	1.1	0.7	0.9	9.6	15.9
Boron - Total	0.22	0.38	0.19	0.22	1.9	0.50
Cadmium - Total	ND	ND	0.002	0.002	0.004	ND
Calcium	82	285	97	97	25	50
Chloride	40	190	36	40	17	106
Chromium - Total	0.005	0.01	0.002	0.005	0.002	0.006
Conductivity	602	1332	747	747	1328	937
Copper - Total	0.004	0.027	0.009	0.009	0.006	0.005
Dissolved Organic Carbon	11	112	15	15	43	48
Iron - Total	0.11	0.45	0.30	0.30	2.2	1.1
Lead - Total	ND	ND	ND	ND	ND	ND
Magnesium	21	79	30	30	9	16
Manganese - Total	0.068	2.2	0.11	0.11	0.14	0.43
Mercury - Total	0.0003	0.00011	0.00008	0.0003	ND	ND
Molybdenum - Total	ND	0.10	ND	ND	0.004	0.045
Naphthenic Acids	4	11	4	4	55	ND
Nickel - Total	0.005	0.60	ND	0.005	ND	0.008
Nitrate	ND	0.53	0.014	ND	0.26	8
Phenolics - Total	0.008	0.04	0.078	0.078	0.004	0.018
Selenium - Total	ND	0.0002	ND	ND	0.0002	ND
Silver - Total	0.002	0.002	ND	0.002	ND	ND
Sodium	33	340	30	33	322	57
Strontium	0.17	0.49	0.28	0.28	0.28	0.34
Sulphate	128	1250	142	142	32	57
Total Dissolved Solids	383	2390	518	518	910	560
Total PAHs	ND	ND	ND	ND	0.0023	-
Acute toxicity (TUa)	ND	ND	ND	ND	2.3	1.3
Chronic toxicity (TUc)	ND	1.4	8.3	8.3	6.3	2.8
Vanadium - Total	0.005	0.021	0.005	0.005	0.01	0.011
Zinc - Total	0.004	0.063	0.016	0.016	-	0.021

NOTE: ND = non-detectable; - = no data.

[a] Golder (1996d) and NAQUADAT Station 20AL07DA1014
[b] Golder (1996d)
[c] Golder (1996d) and NAQUADAT Station 20AL07DA1005
[d] Subset of data published in Golder (1998a)
[e] Golder (1996d) and NAQUADAT Station 20AL07DA1000/1001
[f] Golder (1996d) and NAQUADAT Station 20AL07DA1013
[g] Klohn-Crippen (1996a) and Klohn-Crippen (1998a)
[h] Unpublished Syncrude data
[i] Combination of TID water (Golder 1996d) + Syncrude tailings sand seepage (Bovar 1996e)
[j] Golder (1996c)
[k] Water Quality codes correspond to symbols used in Figures V-2 to V-10

Table V-1 Suncor/Syncrude Operational and Reclamation Waters (Page 2 of 3)

Substance (mg/L)	CT Seepage[d]	Wastewater[e]	Cooling Pond E[f]	Gypsum (FGD)[b]	Pond 1/1A[b]	Basal Aquifer[g]
Water Quality Code[k]	G	H	I	K	L	M
Aluminum - Total	1.9	0.72	1.2	-	0.88	0.01
Ammonia - Total	6.3	25	0.22	-	20	-
Antimony - Total	0.0018	0.002	-	-	0.0006	-
Arsenic - Total	0.007	0.0018	0.0014	-	0.0036	0.0002
Barium - Total	0.16	0.10	0.082	0.13	0.77	0.55
Benzo(a)anthracene grp	0.0016	0.00029	ND	ND	0.0001	ND
Benzo(a)pyrene grp	0.00048	0.00014	ND	-	-	ND
Beryllium-Total	0.006	0.002	0.002	-	-	0.001
Biochemical Oxygen Demand	8	11.2	2.5	-	-	-
Boron - Total	3.7	0.15	0.07	1.2	2.3	4.1
Cadmium - Total	0.0066	0.006	0.001	-	-	ND
Calcium	157	69	55	-	43	74
Chloride	67	354	18	-	33	4090
Chromium - Total	0.023	0.009	0.004	-	0.028	ND
Conductivity	2402	825	245	1374	-	14326
Copper - Total	0.022	0.055	0.029	0.01	-	0.001
Dissolved Organic Carbon	65	35	15	-	-	5.4
Iron - Total	1.0	1.8	2.3	0.35	23	0.26
Lead - Total	0.02	0.015	ND	-	-	ND
Magnesium	28	18	16	18	-	80.5
Manganese - Total	0.065	0.12	0.069	1.4	1.8	0.19
Mercury - Total	0.00005	0.0003	0.00006	ND	0.0004	ND
Molybdenum - Total	1.4	0.55	ND	2.2	0.071	ND
Naphthenic Acids	100	ND	ND		95	21
Nickel - Total	0.030	0.15	0.005	0.50	0.055	0.013
Nitrate	0.05	1.09	0.12	-	-	0.008
Phenolics - Total	0.015	0.017	0.009	-	-	-
Selenium - Total	0.0036	0.0059	0.0002	-	-	ND
Silver - Total	0.002	0.002	ND	-	-	0.0002
Sodium	510	246	23	16600	-	3200
Strontium	2.1	0.29	0.21	-	0.77	4.0
Sulphate	1270	116	49	-	118	0.7
Total Dissolved Solids	1780	570	190	-	1250	8546
Total PAHs	0.032	0.0037	ND	0.0053	0.003	0.002
Acute toxicity (TUa)	2.7	ND	ND	-	-	-
Chronic toxicity (TUc)	7.2	4.0	2.9	-	14	-
Vanadium - Total	0.17	1.1	0.006	0.13	0.05	ND
Zinc - Total	0.08	0.12	0.024	0.12	0.007	0.002

NOTE: ND = non-detectable; - = no data

[a] Golder (1996d) and NAQUADAT Station 20AL07DA1014
[b] Golder (1996d)
[c] Golder (1996d) and NAQUADAT Station 20AL07DA1005
[d] Subset of data published in Golder (1998a)
[e] Golder (1996d) and NAQUADAT Station 20AL07DA1000/1001
[f] Golder (1996d) and NAQUADAT Station 20AL07DA1013
[g] Klohn-Crippen (1996a) and Klohn-Crippen (1998a)
[h] Unpublished Syncrude data
[i] Combination of TID water (Golder 1996d) + Syncrude tailings sand seepage (Bovar 1996e)
[j] Golder (1996c)
[k] Water Quality codes correspond to symbols used in Figures V-2 to V-10

Table V-1 Suncor/Syncrude Operational and Reclamation Waters (Page 3 of 3)

Substance (mg/L)	Muskeg Drainage[h]	Overburden[g]	Tailings Sand Seepage[i]	Surface Drainage[j]
Water Quality Code[k]	N	O	P	Q
Aluminum - Total	0.53	0.5	1.2	0.21
Ammonia - Total	0.91	-	2.0	0.02
Antimony - Total	0.0005	-	ND	ND
Arsenic - Total	0.02	0.004	0.003	0.0004
Barium - Total	0.2	0.21	0.10	0.035
Benzo(a)anthracene grp	ND	ND	0.00099	-
Benzo(a)pyrene grp	ND	ND	0.00008	-
Beryllium-Total	0.001	0.004	0.002	ND
Biochemical Oxygen Demand	6.7	-	-	-
Boron - Total	0.04	0.08	1.9	0.1
Cadmium - Total	ND	0.004	0.004	ND
Calcium	106	80	70	50
Chloride	ND	14	17	9.6
Chromium - Total	0.023	0.013	0.002	ND
Conductivity	614	1048	2500	328
Copper - Total	0.01	0.01	0.006	0.002
Dissolved Organic Carbon	10.9	12	43	22.5
Iron - Total	6.1	0.5	2.2	0.8
Lead - Total	0.0019	0.0007	ND	ND
Magnesium	13	22	25	13
Manganese - Total	0.80	0.59	0.21	0.05
Mercury - Total	ND	ND	ND	ND
Molybdenum - Total	0.003	0.011	0.018	ND
Naphthenic Acids	ND	7	70	ND
Nickel - Total	ND	0.03	ND	ND
Nitrate	0.016	0.38	0.06	0.005
Phenolics - Total	ND	-	0.004	0.002
Selenium - Total	0.012	0.0004	0.0002	ND
Silver - Total	ND	0.003	ND	ND
Sodium	5.8	200	600	15
Strontium	0.17	0.3	0.28	0.15
Sulphate	3.1	115	200	8.1
Total Dissolved Solids	334	638	1007	190
Total PAHs	ND	0.0009	0.0011	-
Acute toxicity (TUa)	-	-	2.3	-
Chronic toxicity (TUc)	-	-	6.3	-
Vanadium - Total	0.005	0.012	0.01	ND
Zinc - Total	0.204	0.04	0.058	0.03

NOTE: ND = non-detectable; - = no data

[a] Golder (1996d) and NAQUADAT Station 20AL07DA1014
[b] Golder (1996d)
[c] Golder (1996d) and NAQUADAT Station 20AL07DA1005
[d] Subset of data published in Golder (1998a)
[e] Golder (1996d) and NAQUADAT Station 20AL07DA1000/1001
[f] Golder (1996d) and NAQUADAT Station 20AL07DA1013
[g] Klohn-Crippen (1996a) and Klohn-Crippen (1998a)
[h] Unpublished Syncrude data
[i] Combination of TID water (Golder 1996d) + Syncrude tailings sand seepage (Bovar 1996e)
[j] Golder (1996c)
[k] Water Quality codes correspond to symbols used in Figures V-2 to V-10

V-1.2 Water Quality Guidelines

Table V-2 summarizes the water quality guidelines used for assessing projected water quality impacts associated with Project Millennium.

Table V-2 Guidelines

Substance (mg/L)	Acute	Chronic	HHC	HHNC	Source[a]
Aluminum - Total		0.1			CCME
Ammonia - Low Winter Flow	16	2.1			USEPA
- Open-Water Flow	10	1.9			USEPA
Antimony - Total				0.014	USEPA
Arsenic - Total	0.36	0.01	0.000018		USEPA, ASWQG
Barium - Total		1		1	USEPA, ASWQG
Benzo(a)anthracene group			0.0000028		USEPA
Benzo(a)pyrene group			0.0000028		USEPA
Beryllium-Total	0.13	0.0053			USEPA
Boron - Total		0.5			ASWQG
Cadmium - Total	0.0074	0.0018			USEPA*
Chloride	860	230			USEPA
Chromium (VI)	0.016	0.011			USEPA
Copper - Total	0.027	0.007			ASWQG*
Iron - Total		1		0.3	ASWQG, USEPA
Lead - Total	0.17	0.007			USEPA*
Manganese - Total				0.05	ASWQG, USEPA
Mercury - Total	0.0024	0.000012		0.00014	USEPA
Molybdenum - Total		1			BCMOE
Nickel - Total	2.3	0.25		0.61	USEPA*
Nitrate		10		10	CCME, USEPA
Phenolics - Total		0.005			ASWQG
Silver - Total	0.01	0.05			USEPA, ASWQG *
Toxicity - acute	0.3				USEPA
Toxicity - chronic		1.0			USEPA
Vanadium - Total		10			BCMOE
Zinc - Total	0.19	0.05			USEPA*, ASWQG

[a] USEPA = United States Environmental Protection Agency
CCME = Canadian Council of Ministers of the Environment
ASWQG = Alberta Surface Water Quality Guidelines
BCMOE = British Columbia Ministry of the Environment
* guideline specified for hardness of 175 mg/L $CaCO_3$

V-1.3 Water Quality Screening Assumptions

V-1.3.1 Thermal Regime of McLean Creek

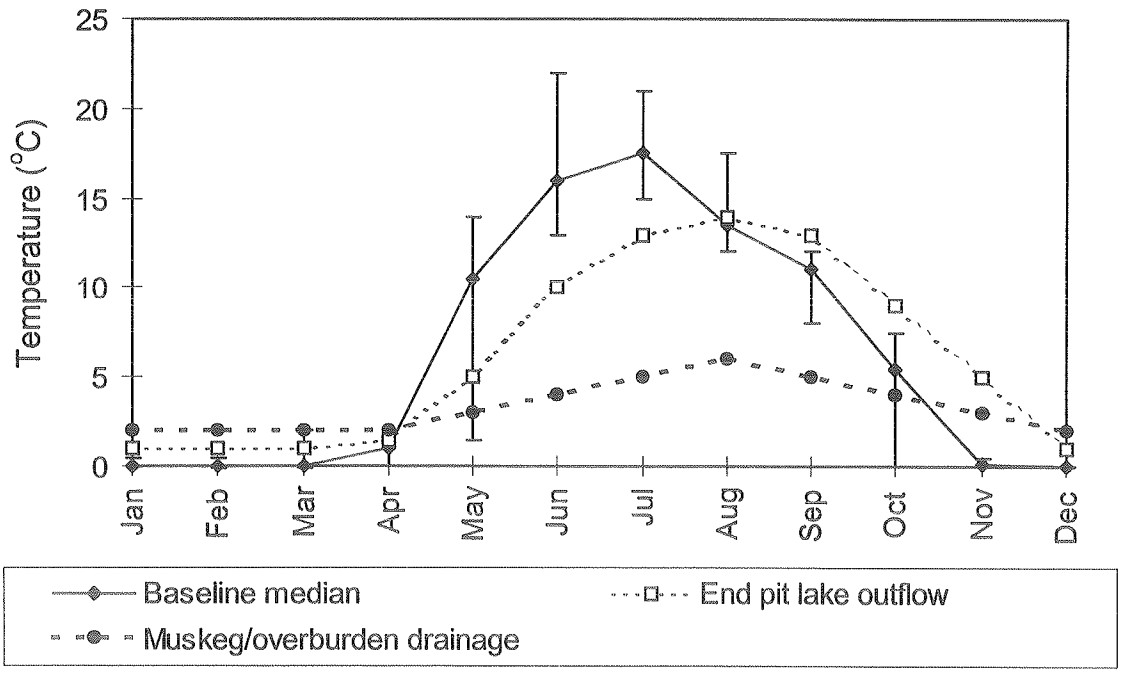
The following assumptions were used when assessing potential temperature variations in McLean Creek resulting from Project operations:

- The temperature of shallow groundwater in the vicinity of the oil sands area varies from 2 to 4°C in the winter, and from 2 to 6°C in the summer (T. Dabrowski, Komex International Limited, pers. comm.). Using this information as a starting point, monthly mean temperatures were estimated for muskeg and overburden drainage waters, assuming the water heats up 1°C per month beginning in May at 2°C, reaching a

peak of 6°C in August, and then cooling again at the same rate to 2°C by November (Figure V-1).

- Grab sample data taken from Lake Athabasca, Christina Lake and Gregoire Lake (Mitchell and Prepas 1990) were used to approximate the surface temperature of the EPL during the open water period on a monthly basis (April through October). To be conservative, these temperatures were scaled down by up to 5°C from April to August and scaled up (maximum 5°C) from September to November to obtain monthly mean temperatures that would occur in a large, deep lake. This was based on the expectation that the EPL would seasonally warm up and cool down over a longer period of time than smaller water bodies. During the ice cover period, near-surface temperature was estimated as 1°C. The resulting monthly mean EPL temperatures are compared with monthly median temperatures assigned to McLean Creek.
- There will be complete mixing of the incoming and receiving waters.
- The temperature of muskeg, overburden and EPL drainage waters will not change during travel to McLean Creek.

Figure V-1 Assumed Monthly Median Water Temperature of Muskeg and Overburden Drainage Waters and EPL Water, and the Assumed Baseline Thermal Regime of McLean Creek.



Error bars show the natural temperature range.

V-1.3.2 Seepages

The potential influence of Project seepage waters on surrounding surface waters was assessed using the following assumptions and boundary conditions:

- Potential seepages include tailings sand and CT seepage. During operations, tailings sand seepage will be collected in perimeter ditches and recycled to the tailings pond. At closure, these waters will be directed to wetlands systems which drain to the Athabasca River and the EPL. The wetland systems would have a one year retention period, and organic compounds will experience some decay during this time.
- CT seepages from the Project are expected to flow the Athabasca River and Shipyard Lake at rates outlined in Section C2.2. However, travel time to Shipyard Lake is projected to be over 700 years (Section C2.2.). CT seepage chemistry may change dramatically during this time. As a result, CT seepages destined for Shipyard Lake were not incorporated into the Shipyard Lake model, but CT seepages to the Athabasca River were modelled.
- Shipyard Lake, McLean Creek and the Athabasca River all receive natural Basal and surficial aquifer seepage. The flows were incorporated into the appropriate models at the rates specified in Section C.2.2.
- The Muskeg River Mine EIA (Shell 1998) indicated that Syncrude would alter the design of their Aurora Mines to include perimeter ditching around their tailings ponds. This feature was assumed to be in place when modelling water quality in the Athabasca River;

V-1.3.3 CT Consolidation

The potential influence of CT flux waters on surrounding surface waters was assessed using the following assumptions and boundary conditions:

- CT deposits take 20 years for complete consolidation;
- consolidation starts when CT is no longer added to the in-pit deposit, and continues at a constant rate over the 20 year period;
- all CT flux water produced after 2033 will be directed to the EPL;
- CT flux waters were assigned representative, worst-case CT chemistry, detailed in Table V-1;
- for Ponds 8 to 11, CT flux water volumes were calculated based on a total consolidation of 15 m over the entire area of the pond
- for CT placed within the EPL, flux waters were assumed to represent 17% of the original deposit, which is the average ratio observed in Ponds 8 to 11; and,

- CT water quality was assumed to remain constant during movement through reclamation wetlands.

V-1.3.4 MFT Consolidation

The potential influence of CT flux waters on surrounding surface waters was assessed using the following assumptions and boundary conditions:

- gypsum treated MFT placed into the EPL in 2033 is similar in character to aged MFT;
- MFT placed into the EPL will continue to consolidate at 0.0074 units/y for the first 20 years, and at a rate of 0.0046 units/y after that (from EMA 1993); and
- MFT porewater produced through consolidation has the same chemistry as TID water, which is described in Table V-1.

V-1.3.5 McLean Creek

The small streams model used to assess water quality in McLean Creek made use of the following assumptions:

- operational and reclamation discharges released from the Project Site mix completely with the receiving waterbody;
- Project releases flow year-round at constant rates;
- natural Basal and surficial aquifer seepage occurs year-round at a constant rate;
- surface runoff is non-existent during extreme low flow conditions (hence, the only flows in McLean Creek under these conditions are natural Basal and surficial aquifer seepages and Project releases);
- EPL discharge is also non-existent during extreme low flow conditions, since it is dependent on surface inflow (this is only relevant in the far future scenario when the EPL discharges to McLean Creek);
- there is no chemical decay occurring in the receiving waterbody;
- chemicals released into McLean Creek remain in the water column; and
- chemical precipitation, settling and sediment partitioning do not occur.

V-1.3.6 Shipyard Lake

The following assumptions and boundary conditions were incorporated into the Shipyard Lake model:

- Shipyard Lake has an open-water surface area of 19 ha, and an average depth of 1.6 m;

- lake is flooded with Athabasca River water once every 5 years (a conservative approach, since the lake has been observed to flood every 3 to 5 years);
- Basal and surficial aquifer seepage rates, as well as muskeg and overburden dewatering flows, match those described in Section C2.2;
- average annual precipitation is equal to 398 mm (Klohn-Crippen 1996c);
- average annual evaporation and evapotranspiration is equal to 572 mm (Klohn-Crippen 1996c); and,
- lake will begin to receive drainage waters from the reclamation landscape in 2039;
- 0.1 m^3/s of Athabasca River water is added to Shipyard Lake from 2020 to 2033 to supplement reduced surface flows resulting from Project operations; and,
- other than muskeg and overburden dewatering waters, Shipyard Lake will not receive any reclamation or operational waters from the Project.

V-1.3.7 End Pit Lake

The following assumptions and boundary conditions were incorporated into the EPL model:

- total volume of Pond 12 is 1140 Mm^3;
- by the end of operation in 2033, Pond 12 will contain:
  - 710 Mm^3 of overburden,
  - 55 Mm^3 of unconsolidated CT,
  - 38 Mm^3 of gypsum treated MFT,
  - 12 Mm^3 of fine tails or MFT cap water, and
  - 50 Mm^3 of process water;
- liquids will begin to flow into the EPL in 2034;
- inflows into the EPL include CT flux water, runoff from reclaimed areas and surface drainage from the Wood and Leggett creeks drainage basins;
- precipitation and evaporation are equal to 4.9 and 5.8 Mm^3/yr, respectively;
- the EPL was modelled as one large completely mixed pond;
- ammonia, organic compounds and their associated acute and chronic toxicity decay at rates specified in Table V-3; and
- inflows will be controlled to produce a non-chronically toxic lake by the time it started to discharge to the Athabasca River.

Table V-3 Summary of Decay Rates Used for Water Quality Modelling

Substance	Wetlands (1/year)	EPL and Tailings Ponds (1/year)	Source
Ammonia - Total	8.54	8.54	Golder (1996d)
Benzo(a)anthracene group	0.37	0.37	BOVAR (1996e)
Benzo(a)pyrene group	0.48	0.48	BOVAR (1996e)
Naphthenic Acids	2.66	1.83	EVS (1996) (wetlands), EMA (1993) (EPL)
Toxicity - acute	0.77	0.77	Presentation material from M. MacKinnon, Syncrude Canada, 1997
Toxicity - chronic	1.67	1.67	Presentation material from M. MacKinnon, Syncrude Canada, 1997

V-1.3.8 Athabasca River

The dispersion model used to assess water quality in the Athabasca River took into account operational and reclamation water releases from the Project, as well as existing oil sands operations. Background water quality for low winter flows and mean open-water flows was characterized just upstream of Fort McMurray using data from NAQUADAT stations 00AL07CC0500/0600. The contribution of upstream pulp mills and municipalities were thus accounted for as background.

Operational flows from existing oil sands operations were simulated based on representative, worst-case concentrations and long-term average flows reported for each existing release water. Substances included in this analysis were ones that were both detectable (in one or more release waters) and for which an established guideline exists (Table V-2). The quality of future CT reclamation waters were based on existing data from both Suncor and Syncrude.

The following assumptions were used to predict Athabasca River water quality:

- complete, instantaneous vertical mixing;
- constant turbulence and dispersion coefficients across the width of the river;
- mass reaching the river banks is reflected back into the river;
- operational and reclamation releases from existing operators, occur year-round; and
- chemicals released into the Athabasca River remain in the water column; chemical precipitation, decay, settling and sediment partitioning do not occur.

V-1.4 The Use of Aquatic Toxicity Tests as the Basis for Impact Predictions

V-1.4.1 Approach

Prediction of acute or chronic effects on aquatic organisms focused on reclamation waters. The only operational waters to be released from the Project are those from dewatering of muskeg and overburden materials; thus, operational waters represent shallow groundwater, which is not expected to be toxic. Reclamation waters include consolidated tailings (CT) release water via seepage and direct discharge from the EPL after closure, and tailings sand seepage waters. Results of previous toxicity tests indicate that these waters are potentially toxic to aquatic organisms.

Results of aquatic toxicity tests of presently available oil sands reclamation waters were used in combination with water quality modelling to predict potential acute and chronic effects on aquatic organisms in receiving waters. The general procedure used is outlined below.

1. Select representative reclamation waters for use in the impact analysis.

2. Select toxicity data representing the acute and chronic effects on the most sensitive test organisms caused by exposure to representative samples of the above reclamation waters.

3. Based the toxicity data selected in Step 2, assign levels of acute and chronic toxicity to each representative reclamation water in the form of acute and chronic Toxic Units (TUa and TUc, respectively).

4. Use water quality models to predict the level of toxicity (as TUa and TUc) in receiving waters. (TUs are treated during modelling as concentrations of water quality parameters.)

5. Compare predicted TUs with regulatory guidelines for whole effluent toxicity to evaluate the potential for impacts.

This approach is dependent on a number of assumptions. The most important assumption is that it is valid to extrapolate from laboratory toxicity data to effects on native fauna in the field. Sufficient research has been carried out to show that toxicity tests are usually predictive of effects on natural aquatic communities (Environment Canada 1996). This statement is based upon a review of laboratory-to-field validation studies that compare toxicity tests results with results from field studies of fish, invertebrates and aquatic plants. Therefore, extrapolation from toxicity test results to natural populations and communities is acceptable, provided the uncertainty inherent in such extrapolations is recognized and addressed through appropriate follow-up monitoring programs.

Background information on aquatic toxicity tests and details of the procedure outlined above are provided in the following sections.

V-1.4.2 Aquatic Toxicity Tests

Aquatic toxicity tests are used to detect and evaluate the potential toxicological effects of chemicals on aquatic organisms. Since these effects are not necessarily harmful, a principal function of these tests is to identify chemicals or whole effluents that can have adverse effects at relatively low exposure concentrations. These tests provide a database that can be used to assess the risk associated with a situation in which the chemical agent, the organism and the exposure conditions are defined. In the case of the Project, the "chemical agents" are reclamation waters; the "organisms" are the KIR fish species; and the "exposure conditions" are defined by the water quality modelling.

Aquatic toxicity tests consist of exposure of test organisms to a number of dilutions of the test water for a specified period. At the end of the exposure period, survival (acute tests) or other, non-lethal endpoints (e.g., growth, reproduction) are quantified and a dose-response relationship is developed. Then, standard statistics are calculated based on the dose-response curve.

The statistic used to describe acute toxicity is the median lethal concentration (LC50), which is the concentration of test water that causes 50% mortality. Statistics used to describe sublethal toxicity are the IC50 and the IC25 (for "inhibition concentration"). The inhibition concentration is the concentration causing a given percent reduction in growth or reproduction. For example an IC50 for growth would be the CT water concentration causing a 50% reduction in growth.

Two additional numerical expressions of toxicity include the Lowest Observed Effects Concentration (LOEC) and the No Observed Effects Concentration (NOEC). The LOEC is the lowest concentration in the dilution series used in a test at which the biological response of interest (reduction in growth or reproduction) is observed. The NOEC is the highest concentration of test water at which adverse effects are not observed; it is always the next lowest concentration after the LOEC in the dilution series.

The above statistics can be converted to Toxic Units, which are useful in the modelling of toxicity in receiving waters. Unlike the concentration of a test water representing the LC50, the value of the TU is directly proportional to the degree of potential adverse effects (e.g., higher acute TU values represent greater potential for lethal effects). The number of acute Toxic Units (TUa) associated with a water sample can be calculated as 100/LC50. For example, if the LC50 is 20%, TUa=5. Chronic Toxic Units (TUc) are calculated similarly, using the IC25 determined by a chronic toxicity test.

V-1.4.3 Representative Reclamation Waters

Reclamation waters produced by Suncor were considered representative of future reclamation waters associated with the Project. Assumptions specific to the selection of representative reclamation waters include the following:

- tests on Tar Island Dyke (TID) seepage water are applicable to future tailings sand seepage water and tailings water produced by the Project; and

- CT water and TID water tests are sufficient to predict overall potential to cause effects in the receiving environment despite the fact that the actual cause of CT or TID toxicity is not yet thoroughly characterized.

V-1.4.4 Toxicity Testing of Representative Reclamation Waters

Toxicity of CT water was investigated using the same battery of standard aquatic toxicity tests as those used previously to assess toxicity of TID water (Golder 1996f). Data presented by Golder (1996f) and results of toxicity tests using recently produced Suncor CT water (Suncor 1997, unpublished data) were included in the evaluation. During these tests, acute toxicity was determined for:

- two water flea species (crustaceans): *Daphnia magna* and *Ceriodaphnia dubia* (endpoint is survival); and

- two fish species: rainbow trout (*Oncorhynchus mykiss*) and fathead minnow (*Pimephales promelas)* (endpoint is survival).

Chronic toxicity was determined for:

- the freshwater alga *Selenastrum capricornutum* (endpoint is growth);

- the water flea *Ceriodaphnia dubia* (endpoint is reproduction); and

- fathead minnow (endpoint is growth).

The acute toxicity of CT water varied considerably among the four test species (Table V-4). The order of sensitivity from least to most sensitive species was *Daphnia magna* << fathead minnow < rainbow trout < *Ceriodaphnia*. The two most sensitive test species, rainbow trout and *Ceriodaphnia*, had LC50s of 35 to 37%. The least sensitive test species, *Daphnia magna*, had no mortality at any test concentration, including 100% CT water.

Table V-4 Toxicity of CT Water and TID Seepage Water, Based on Data Available to the End of 1997

Test	Endpoint	CT Water [a]		TID Water [b]	
		Range	n	Range	n
72 h Algal Growth Inhibition Test using the freshwater alga *Selenastrum capricornutum*	IC25 (%)	25 - 50	4	32 - >100	7
	IC50 (%)	41 - 78	4	46 - >100	7
	NOEC (%)	25	4	25 - 100	7
	LOEC (%)	50	4	50 - >100	7
48 h *Daphnia magna* Survival Test	LC25 (%)	>100	3	>100	7
	LC50 (%)	>100	3	>100	3
	NOEC (%)	100	3	100	6
	LOEC (%)	>100	3	>100	6
7 day *Ceriodaphnia dubia* Survival Test	LC25 (%)	27 - 95	5	15 - 96	7
	LC50 (%)	35 - >100	5	18 - >100	7
	NOEC (%)	25 - 100	5	25 - 100	7
	LOEC (%)	50 - >100	5	12.5 - 50	7
7 day *Ceriodaphnia dubia* Reproduction Test	IC25 (%)	13.9 - 62.5	5	14 - 32	7
	IC50 (%)	19.9 - 75	5	18 - 52	7
	NOEC (%)	12.5 - 50	5	12.5 - 25	7
	LOEC (%)	25 - 100	5	25 - 50	7
96 h Rainbow Trout Survival Test	LC25 (%)	31	1	-	-
	LC50 (%)	37 - >100	11	15[c] - 62	8
	NOEC (%)	25	1	25	2
	LOEC (%)	50	1	50	3
7 d Fathead Minnow Survival Test	LC25 (%)	33 - 62	3	33 - 61	3
	LC50 (%)	41 - 75	3	64 - 74	3
	NOEC (%)	12.5 - 50	3	50	3
	LOEC (%)	25 - 100	3	100	3
7 d Fathead Minnow Growth Test	IC25 (%)	26 - >50	3	9 - 41	3
	IC50 (%)	36 - >50	3	29 - 67	3
	NOEC (%)	12.5 - 50	3	<6.25 - 25	3
	LOEC (%)	25 - >50	3	6.25 - 50	3

NOTES: [a] CT water data were obtained from the following sources: EVS (1996), Golder (1997k), Golder (1996f), Suncor's 1995 CT studies and Suncor's 1997 CT studies.
[b] TID water data were obtained from HydroQual (1996).
[c] The value of 15 was considered not representative by HydroQual; the next higher value is 27.

Chronic toxicity of CT water was greatest in *Ceriodaphnia* (Table V-4). The order of sensitivity from least to most sensitive species was fathead minnow < *Selenastrum* < *Ceriodaphnia*. The lowest concentration of CT water required to produce a 25% reduction in reproduction (IC25) in *Ceriodaphnia* was 14%. The other two species tested were more tolerant. Growth of the alga *Selenastrum* and the fathead minnow was reduced by 25% at the lowest CT water concentrations of 25% and 26%, respectively.

The acute toxicity of TID water was similar to that reported for CT water (Table V-4). The order of species sensitivity from least to most sensitive was *Daphnia magna* < *Ceriodaphnia* < fathead minnow < rainbow trout. The LC50 for the most sensitive species, rainbow trout, was 27% (discounting results for one sample considered non-representative at the time of toxicity testing).

The chronic toxicity of TID water was greatest to fathead minnows (Table V-4), with a lowest IC25 of 9%. Reproduction of *Ceriodaphnia* was reduced by 25% at 14% CT water concentration. Thus, the order of species

sensitivity from least to most sensitive was *Selenastrum* < *Ceriodaphnia* < fathead minnow.

V-1.4.5 Use of Toxicity Data in the Impact Assessment

The toxicity data summarized above provided the basis for the prediction of effects on the KIR fish species, as well as on the aquatic ecosystem as a whole (including benthic invertebrate communities and algal communities).

The IC25 was used as the primary measurement of chronic effects rather than NOECs or LOECs, based upon recommendations by Environment Canada (1996). The reasons for this are: (1) the possible values of NOEC and LOEC are limited to whatever concentrations were chosen by the investigator; i.e., they are not statistically-derived point estimates like the IC25; (2) the particular concentrations which emerge as LOEC and NOEC are very much governed by the design and power of the experiment (Environment Canada 1996); and (3) based on empirical data summarized by the U.S. EPA (1991), the IC25 is a reasonable estimate of the NOEC.

Consistent with protocols recommended by AEP (1995d), rainbow trout and *Daphnia magna* data were used to represent acute toxicity; *Ceriodaphnia*, *Selenastrum* and fathead minnow data were used to represent chronic toxicity.

Concentrations of Suncor's CT water representing the LC50 and the IC25 to the most sensitive test organisms were used to assign acute and chronic Toxic Units, respectively, to CT water. Data generated for TID water were used as the surrogate for tailings sand seepage water toxicity. In the absence of more recent data, values deemed representative of TID water toxicity in the Steepbank Mine EIA (Golder 1996j) were assigned to tailings sand seepage waters (acute toxicity: trout LC50 of 35.4; chronic toxicity: *Ceriodaphnia* IC25 of 16). The resulting TU values are shown in Table V-5.

Table V-5 Toxic Unit Values Assigned to Reclamation Waters

Reclamation Water	TUa	TUc
Tailings sand seepage water	2.8	6.3
CT water	2.7	7.2

During water quality modelling, the TUa and TUc values were treated as chemical concentrations. Predicted toxicity levels were compared with toxicity guidelines to evaluate the potential for acute or chronic effects on aquatic organisms.

Table V-6 1997 Baseline Water Quality in the Athabasca River at 10% River Width

Substance (mg/L)	7Q10						Mean Open-Water					
	west*		east*				west*		east*			
			below'		above'				below'		above'	
Aluminum - Total	0.09		0.06		0.06		0.68	C	0.68	C	0.65	C
Ammonia - Total	0.37		0.03		0.03		0.14		0.01		0.02	
Antimony - Total	2.6E-05	n.g.	0.0E+00	n.g.	8.1E-08	n.g.	1.0E-05		5.5E-17		5.2E-07	
Arsenic - Total	0.0004		0.0004		0.0004		0.0012	HC	0.0012	HC	0.0011	HC
Barium - Total	0.09		0.09		0.09		0.07		0.07		0.07	
Benzo(a)anthracene grp	3.8E-06	n.g.	1.5E-06	n.g.	1.5E-06	n.g.	1.5E-06		5.7E-07		5.4E-07	
Benzo(a)pyrene grp	1.8E-06	n.g.	3.0E-07	n.g.	3.1E-07	n.g.	7.2E-07		1.1E-07		1.1E-07	
Beryllium-Total	7.9E-05		4.0E-05		4.0E-05		1.0E-03		1.0E-03		9.6E-04	
Boron - Total	0.03		0.04		0.04		0.04		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.4	n.g.	50.3	n.g.	50.3	n.g.	31.0	n.g.	30.8	n.g.	30.5	n.g.
Chloride	10.2		10.7		10.7		3.8		3.9		3.8	
Chromium - Total	0.003		0.003		0.003		0.004		0.004		0.004	
Conductivity	401	n.g.	416	n.g.	416	n.g.	234	n.g.	236	n.g.	231	n.g.
Copper - Total	0.002		0.001		0.001		0.004		0.004		0.003	
Dissolved Organic Carbon	8.6	n.g.	8.2	n.g.	8.2	n.g.	8.6	n.g.	9.5	n.g.	9.5	n.g.
Iron - Total	0.25		0.20		0.20		2.99	C HNC	2.99	C HNC	2.87	C HNC
Lead - Total	2.0E-04		7.7E-05		8.1E-05		7.7E-05		4.8E-06		6.6E-06	
Magnesium	14.0	n.g.	14.0	n.g.	14.0	n.g.	7.8	n.g.	7.8	n.g.	7.7	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.40	HNC	0.40	HNC	0.38	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.9E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	7.2E-03		2.6E-05		3.8E-05		2.8E-03		5.2E-06		1.5E-04	
Naphthenic Acids	0.06	n.g.	0.06	n.g.	0.06	n.g.	0.02	n.g.	0.01	n.g.	0.01	
Nickel - Total	2.1E-03		9.1E-05		9.2E-05		8.1E-04		1.1E-04		1.1E-04	
Nitrate	0.17		0.16		0.16		0.01		0.00		0.00	
Phenolics - Total	0.003		0.003		0.003		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0001		0.0001		0.0002		0.0002		0.0002	
Silver - Total	2.6E-05		5.1E-06		5.1E-06		1.0E-05		1.9E-06		1.7E-06	
Sodium	19.6	n.g.	20.3	n.g.	20.3	n.g.	8.0	n.g.	8.2	n.g.	8.1	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	41.0	n.g.	39.7	n.g.	39.3	n.g.	20.2	n.g.	19.4	n.g.	18.7	n.g.
Total Dissolved Solids	247	n.g.	254	n.g.	254	n.g.	153	n.g.	153	n.g.	150	n.g.
Total PAHs	5.1E-05	n.g.	2.5E-05	n.g.	2.6E-05	n.g.	2.0E-05	n.g.	9.4E-06	n.g.	8.9E-06	n.g.
Acute Toxicity (TUa)	0.003		2.7E-11		2.4E-05		0.001		1.8E-11		7.4E-05	
Chronic Toxicity (TUc)	0.136		6.1E-11		4.6E-04		0.053		4.5E-11		0.003	
Vanadium - Total	0.016		0.002		0.002		0.010		0.004		0.004	
Zinc - Total	0.009		0.008		0.009		0.012		0.012		0.012	

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River

Table V-7 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments) (Page 1 of 3)

Substance (mg/L)	2005			2010			2015		
	west*	east*		west*	east*		west*	east*	
		below'	above'		below'	above'		below'	above'
Aluminum - Total	0.07	0.06	0.08	0.06	0.06	0.07	0.06	0.06	0.07
Ammonia - Total	0.21	0.03	0.07	0.17	0.03	0.05	0.17	0.03	0.05
Antimony - Total	2.1E-05 n.g.	6.9E-14 n.g.	2.1E-05 n.g.	1.1E-05 n.g.	7.7E-08 n.g.	9.7E-06 n.g.	1.1E-05 n.g.	7.7E-08 n.g.	9.7E-06 n.g.
Arsenic - Total	0.0005	0.0004	0.0012	0.0004	0.0004	0.0008	0.0004	0.0004	0.0008
Barium - Total	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Benzo(a)anthracene grp	1.1E-05 n.g.	1.5E-06 n.g.	1.5E-06 n.g.	2.1E-06 n.g.	1.6E-06 n.g.	1.6E-06 n.g.	2.1E-06 n.g.	1.6E-06 n.g.	1.6E-06 n.g.
Benzo(a)pyrene grp	3.4E-06 n.g.	3.1E-07 n.g.	3.1E-07 n.g.	8.9E-07 n.g.	3.3E-07 n.g.	3.3E-07 n.g.	8.9E-07 n.g.	3.3E-07 n.g.	3.3E-07 n.g.
Beryllium-Total	4.8E-05	4.2E-05	8.2E-05	1.7E-05	4.1E-05	5.5E-05	1.7E-05	4.1E-05	5.5E-05
Boron - Total	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Cadmium - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Calcium	50.7 n.g.	50.4 n.g.	52.8 n.g.	50.1 n.g.	50.3 n.g.	51.4 n.g.	50.1 n.g.	50.3 n.g.	51.4 n.g.
Chloride	7.4	10.7	10.7	7.1	10.7	10.7	7.1	10.7	10.7
Chromium - Total	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003
Conductivity	413 n.g.	416 n.g.	425 n.g.	403 n.g.	416 n.g.	418 n.g.	403 n.g.	416 n.g.	418 n.g.
Copper - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Dissolved Organic Carbon	8.5 n.g.	8.2 n.g.	8.4 n.g.	8.2 n.g.	8.2 n.g.	8.3 n.g.	8.2 n.g.	8.2 n.g.	8.3 n.g.
Iron - Total	0.2	0.2	0.5	0.2	0.2	0.3	0.2	0.2	0.3
Lead - Total	1.9E-04	7.8E-05	1.7E-04	8.3E-05	7.9E-05	1.1E-04	8.3E-05	7.9E-05	1.1E-04
Magnesium	13.9 n.g.	14.1 n.g.	14.1 n.g.	13.9 n.g.	14.0 n.g.	14.1 n.g.	13.9 n.g.	14.0 n.g.	14.1 n.g.
Manganese - Total	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.
Mercury - Total	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C
Molybdenum - Total	0.01	2.6E-05	0.0002	0.003	0.0001	0.0001	0.003	0.0001	0.0001
Naphthenic Acids	0.70 n.g.	0.06 n.g.	0.06 n.g.	0.13 n.g.	0.06 n.g.	0.06 n.g.	0.13 n.g.	0.06 n.g.	0.06 n.g.
Nickel - Total	9.6E-04	9.3E-05	9.5E-05	7.7E-04	9.3E-05	9.5E-05	7.7E-04	9.3E-05	9.5E-05
Nitrate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Phenolics - Total	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Selenium - Total	0.0001	0.0001	0.0006	0.0001	0.0001	0.0003	0.0001	0.0001	0.0003
Silver - Total	2.2E-05	6.0E-06	6.0E-06	1.1E-05	5.3E-06	5.3E-06	1.1E-05	5.3E-06	5.3E-06
Sodium	20.4 n.g.	20.3 n.g.	20.3 n.g.	17.9 n.g.	20.3 n.g.	20.3 n.g.	17.9 n.g.	20.3 n.g.	20.3 n.g.
Strontium	0.35 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.	0.34 n.g.
Sulphate	47.3 n.g.	39.7 n.g.	39.0 n.g.	40.6 n.g.	39.7 n.g.	39.0 n.g.	40.6 n.g.	39.7 n.g.	39.0 n.g.
Total Dissolved Solids	255 n.g.	254 n.g.	258 n.g.	246 n.g.	254 n.g.	255 n.g.	246 n.g.	254 n.g.	255 n.g.
Total PAHs	2.0E-04 n.g.	2.6E-05 n.g.	2.6E-05 n.g.	3.5E-05 n.g.	2.7E-05 n.g.	2.7E-05 n.g.	3.5E-05 n.g.	2.7E-05 n.g.	2.7E-05 n.g.
Acute Toxicity (TUa)	0.02	1.5E-10	0.0001	0.006	0.0001	0.0001	0.006	0.0001	0.0001
Chronic Toxicity (TUc)	0.08	0.009	0.009	0.03	0.006	0.006	0.03	0.006	0.006
Vanadium - Total	0.008	0.002	0.002	0.008	0.002	0.002	0.008	0.002	0.002
Zinc - Total	0.008	0.008	0.017	0.008	0.009	0.012	0.008	0.009	0.012

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-7 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments)
(Page 2 of 3)

Substance (mg/L)	2020			2025			2030		
	west*	east*		west*	east*		west*	east*	
		below'	above'		below'	above'		below'	above'
Aluminum - Total	0.07	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.07
Ammonia - Total	0.20	0.03	0.04	0.20	0.03	0.04	0.20	0.03	0.05
Antimony - Total	1.9E-05 n.g.	7.7E-08 n.g.	7.6E-06 n.g.	1.9E-05 n.g.	7.7E-08 n.g.	7.6E-06 n.g.	1.9E-05 n.g.	9.1E-08 n.g.	8.1E-06 n.g.
Arsenic - Total	0.0004	0.0004	0.0007	0.0004	0.0004	0.0007	0.0004	0.0004	0.0007
Barium - Total	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Benzo(a)anthracene grp	9.8E-06 n.g.	1.6E-06 n.g.	1.6E-06 n.g.	9.8E-06 n.g.	1.6E-06 n.g.	1.6E-06 n.g.	9.8E-06 n.g.	1.6E-06 n.g.	1.6E-06 n.g.
Benzo(a)pyrene grp	3.2E-06 n.g.	3.3E-07 n.g.	3.3E-07 n.g.	3.2E-06 n.g.	3.3E-07 n.g.	3.3E-07 n.g.	3.2E-06 n.g.	3.3E-07 n.g.	3.3E-07 n.g.
Beryllium-Total	5.4E-05	4.4E-05	5.4E-05	5.4E-05	4.4E-05	5.4E-05	5.4E-05	4.4E-05	5.7E-05
Boron - Total	0.06	0.04	0.04	0.06	0.04	0.04	0.06	0.04	0.04
Cadmium - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Calcium	50.7 n.g.	50.4 n.g.	51.2 n.g.	50.7 n.g.	50.4 n.g.	51.2 n.g.	50.7 n.g.	50.4 n.g.	51.3 n.g.
Chloride	7.4	10.7	10.8	7.4	10.7	10.8	7.4	10.7	10.8
Chromium - Total	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Conductivity	414 n.g.	417 n.g.	419 n.g.	414 n.g.	417 n.g.	419 n.g.	414 n.g.	417 n.g.	420 n.g.
Copper - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Dissolved Organic Carbon	8.5 n.g.	8.2 n.g.	8.3 n.g.	8.5 n.g.	8.2 n.g.	8.3 n.g.	8.5 n.g.	8.2 n.g.	8.3 n.g.
Iron - Total	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.3
Lead - Total	1.8E-04	7.8E-05	1.1E-04	1.8E-04	7.8E-05	1.1E-04	1.8E-04	7.8E-05	1.1E-04
Magnesium	14.0 n.g.	14.1 n.g.	14.1 n.g.	14.0 n.g.	14.1 n.g.	14.1 n.g.	14.0 n.g.	14.1 n.g.	14.1 n.g.
Manganese - Total	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.	0.1 n.g.
Mercury - Total	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C	0.0001 C
Molybdenum - Total	0.012	0.001	0.001	0.012	0.001	0.001	0.012	0.001	0.001
Naphthenic Acids	0.63 n.g.	0.07 n.g.	0.07 n.g.	0.63 n.g.	0.07 n.g.	0.07 n.g.	0.63 n.g.	0.07 n.g.	0.07 n.g.
Nickel - Total	1.4E-03	3.2E-04	3.3E-04	1.4E-03	3.2E-04	3.3E-04	1.4E-03	3.2E-04	3.3E-04
Nitrate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Phenolics - Total	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Selenium - Total	0.0001	0.0001	0.0003	0.0001	0.0001	0.0003	0.0001	0.0001	0.0003
Silver - Total	2.6E-05	7.8E-06	7.8E-06	2.6E-05	7.8E-06	7.8E-06	2.6E-05	7.8E-06	7.8E-06
Sodium	35.6 n.g.	27.8 n.g.	27.9 n.g.	35.6 n.g.	27.8 n.g.	27.9 n.g.	35.6 n.g.	27.8 n.g.	27.9 n.g.
Strontium	0.35 n.g.	0.34 n.g.	0.34 n.g.	0.35 n.g.	0.34 n.g.	0.34 n.g.	0.35 n.g.	0.34 n.g.	0.34 n.g.
Sulphate	46.7 n.g.	39.7 n.g.	39.1 n.g.	46.7 n.g.	39.7 n.g.	39.1 n.g.	46.7 n.g.	39.7 n.g.	39.1 n.g.
Total Dissolved Solids	255 n.g.	254 n.g.	255 n.g.	255 n.g.	254 n.g.	255 n.g.	255 n.g.	254 n.g.	256 n.g.
Total PAHs	1.9E-04 n.g.	2.9E-05 n.g.	2.9E-05 n.g.	1.9E-04 n.g.	2.9E-05 n.g.	2.9E-05 n.g.	1.9E-04 n.g.	2.9E-05 n.g.	3.0E-05 n.g.
Acute Toxicity (TUa)	0.02	0.0001	0.0002	0.02	0.0001	0.0002	0.02	0.0001	0.0002
Chronic Toxicity (TUc)	0.09	0.02	0.02	0.09	0.02	0.02	0.09	0.02	0.02
Vanadium - Total	0.008	0.002	0.002	0.008	0.002	0.002	0.008	0.002	0.002
Zinc - Total	0.008	0.009	0.011	0.008	0.009	0.011	0.008	0.009	0.012

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-7 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments) (Page 3 of 3)

Substance (mg/L)	2044						Far Future					
	west*		east*				west*		east*			
			below'		above'				below'		above'	
Aluminum - Total	0.06		0.06		0.08		0.06		0.06		0.08	
Ammonia - Total	0.05		0.03		0.07		0.05		0.03		0.07	
Antimony - Total	4.1E-06	n.g.	8.7E-08	n.g.	5.9E-06	n.g.	4.1E-06	n.g.	1.0E-07	n.g.	6.0E-06	n.g.
Arsenic - Total	0.0004		0.0004		0.0005		0.0004		0.0004		0.0005	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	3.6E-06	n.g.	1.6E-06	n.g.	1.4E-05	n.g.	3.6E-06	n.g.	1.6E-06	n.g.	1.4E-05	n.g.
Benzo(a)pyrene grp	1.1E-06	n.g.	3.3E-07	n.g.	1.9E-06	n.g.	1.1E-06	n.g.	3.3E-07	n.g.	1.9E-06	n.g.
Beryllium-Total	1.9E-05		4.6E-05		9.0E-05		1.9E-05		4.6E-05		9.0E-05	
Boron - Total	0.04		0.04		0.08		0.04		0.04		0.08	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.3	n.g.	50.4	n.g.	51.1	n.g.	50.3	n.g.	50.4	n.g.	51.1	n.g.
Chloride	5.4		10.8		11.0		5.4		10.8		11.0	
Chromium - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	403	n.g.	417	n.g.	452	n.g.	403	n.g.	417	n.g.	452	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.1	n.g.	8.2	n.g.	8.9	n.g.	8.1	n.g.	8.2	n.g.	8.9	n.g.
Iron - Total	0.2		0.2		0.2		0.2		0.2		0.2	
Lead - Total	4.5E-05		7.9E-05		1.5E-04		4.5E-05		7.9E-05		1.5E-04	
Magnesium	13.9	n.g.	14.1	n.g.	14.3	n.g.	13.9	n.g.	14.1	n.g.	14.3	n.g.
Manganese - Total	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.1	n.g.
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.004		0.0001		0.005		0.004		0.0001		0.005	
Naphthenic Acids	0.24	n.g.	0.07	n.g.	0.26	n.g.	0.24	n.g.	0.07	n.g.	0.26	n.g.
Nickel - Total	1.5E-04		1.0E-04		1.9E-04		1.5E-04		1.0E-04		1.9E-04	
Nitrate	0.2		0.2		0.2		0.2		0.2		0.2	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0001		0.0001		0.0001		0.0001	
Silver - Total	8.2E-06		8.9E-06		1.4E-05		8.2E-06		9.0E-06		1.4E-05	
Sodium	19.8	n.g.	20.4	n.g.	30.0	n.g.	19.8	n.g.	20.4	n.g.	30.0	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.35	n.g.	0.34	n.g.	0.34	n.g.	0.35	n.g.
Sulphate	42.6	n.g.	39.8	n.g.	45.1	n.g.	42.6	n.g.	39.8	n.g.	45.1	n.g.
Total Dissolved Solids	247	n.g.	255	n.g.	270	n.g.	247	n.g.	255	n.g.	270	n.g.
Total PAHs	7.3E-05	n.g.	2.7E-05	n.g.	1.4E-04	n.g.	7.3E-05	n.g.	2.7E-05	n.g.	1.4E-04	n.g.
Acute Toxicity (TUa)	0.007		0.0001		0.007		0.007		0.0002		0.007	
Chronic Toxicity (TUc)	0.03		0.02		0.04		0.03		0.02		0.04	
Vanadium - Total	0.002		0.002		0.003		0.002		0.002		0.003	
Zinc - Total	0.007		0.009		0.010		0.007		0.009		0.010	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-8 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments)
(Page 1 of 3)

Substance (mg/L)	2005						2010						2015					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.08		0.01		0.03		0.06		0.01		0.02		0.06		0.01		0.02	
Antimony - Total	8.2E-06		4.9E-14		1.0E-05		4.2E-06		3.1E-08		3.8E-06		4.2E-06		3.1E-08		3.8E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0017	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	4.4E-06	HC	5.7E-07		5.4E-07		8.2E-07		5.9E-07		5.6E-07		8.2E-07		5.9E-07		5.6E-07	
Benzo(a)pyrene grp	1.4E-06		1.1E-07		1.3E-07		3.5E-07		1.2E-07		1.1E-07		3.5E-07		1.2E-07		1.1E-07	
Beryllium-Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Boron - Total	0.05		0.05		0.05		0.04		0.05		0.05		0.04		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	31.0	n.g.	30.8	n.g.	32.7	n.g.	30.7	n.g.	30.8	n.g.	31.6	n.g.	30.7	n.g.	30.8	n.g.	31.6	n.g.
Chloride	2.7		3.9		3.8		2.6		3.9		3.8		2.6		3.9		3.8	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	237	n.g.	236	n.g.	243	n.g.	232	n.g.	236	n.g.	237	n.g.	232	n.g.	236	n.g.	237	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.6	n.g.	9.6	n.g.	11.1	n.g.	8.5	n.g.	9.6	n.g.	11.0	n.g.	8.5	n.g.	9.6	n.g.	11.0	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.79	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC
Lead - Total	7.6E-05		4.8E-06		9.1E-05		3.2E-05		5.2E-06		6.3E-05		3.2E-05		5.2E-06		6.3E-05	
Magnesium	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.7	n.g.	7.8	n.g.	8.0	n.g.	7.7	n.g.	7.8	n.g.	8.0	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.4E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	4.4E-03		5.2E-06		2.4E-04		1.3E-03		3.0E-05		9.0E-05		1.3E-03		3.0E-05		9.0E-05	
Naphthenic Acids	0.29	n.g.	0.01	n.g.	0.49	n.g.	0.05	n.g.	0.01	n.g.	0.48	n.g.	0.05	n.g.	0.01	n.g.	0.48	n.g.
Nickel - Total	3.7E-04		1.1E-04		1.4E-04		3.0E-04		1.1E-04		1.4E-04		3.0E-04		1.1E-04		1.4E-04	
Nitrate	0.004		0.0002		0.007		0.004		0.0002		0.006		0.004		0.0002		0.006	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0004		0.0002		0.0002		0.0003		0.0002		0.0002		0.0003	
Silver - Total	8.6E-06		2.2E-06		2.0E-06		4.3E-06		1.9E-06		1.7E-06		4.3E-06		1.9E-06		1.7E-06	
Sodium	8.2	n.g.	8.2	n.g.	8.5	n.g.	7.2	n.g.	8.2	n.g.	8.5	n.g.	7.2	n.g.	8.2	n.g.	8.5	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	22.6	n.g.	19.4	n.g.	17.9	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.
Total Dissolved Solids	155	n.g.	153	n.g.	156	n.g.	151	n.g.	153	n.g.	153	n.g.	151	n.g.	153	n.g.	153	n.g.
Total PAHs	8.4E-05	n.g.	9.4E-06	n.g.	9.0E-06	n.g.	1.4E-05	n.g.	1.0E-05	n.g.	9.4E-06	n.g.	1.4E-05	n.g.	1.0E-05	n.g.	9.4E-06	n.g.
Acute Toxicity (TUa)	0.008		1.0E-10		3.6E-04		0.002		4.7E-05		1.3E-04		0.002		4.7E-05		1.3E-04	
Chronic Toxicity (TUc)	0.03		0.003		0.003		0.01		0.002		0.002		0.01		0.002		0.002	
Vanadium - Total	0.007		0.004		0.004		0.006		0.004		0.004		0.006		0.004		0.004	
Zinc - Total	0.011		0.012		0.016		0.011		0.012		0.013		0.011		0.012		0.013	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-8 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments) (Page 2 of 3)

Substance (mg/L)	2020						2025						2030					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.08		0.01		0.02		0.08		0.01		0.02		0.08		0.01		0.02	
Antimony - Total	7.7E-06		3.1E-08		3.1E-06		7.7E-06		3.1E-08		3.1E-06		7.7E-06		3.7E-08		3.5E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	4.0E-06	HC	5.9E-07		5.6E-07		4.0E-06	HC	5.9E-07		5.6E-07		4.0E-06	HC	6.0E-07		5.7E-07	
Benzo(a)pyrene grp	1.3E-06		1.2E-07		1.2E-07		1.3E-06		1.2E-07		1.2E-07		1.3E-06		1.2E-07		1.2E-07	
Beryllium-Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Boron - Total	0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	31.0	n.g.	30.8	n.g.	31.6	n.g.	31.0	n.g.	30.8	n.g.	31.6	n.g.	31.0	n.g.	30.8	n.g.	31.7	n.g.
Chloride	2.7		3.9		3.8		2.7		3.9		3.8		2.7		3.9		3.8	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	238	n.g.	237	n.g.	237	n.g.	238	n.g.	237	n.g.	237	n.g.	238	n.g.	237	n.g.	238	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.6	n.g.	9.6	n.g.	11.0	n.g.	8.6	n.g.	9.6	n.g.	11.0	n.g.	8.6	n.g.	9.6	n.g.	11.0	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC
Lead - Total	7.2E-05		5.2E-06		6.1E-05		7.2E-05		5.2E-06		6.1E-05		7.2E-05		5.2E-06		6.5E-05	
Magnesium	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.0	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	4.9E-03		4.1E-04		4.0E-04		4.9E-03		4.1E-04		4.0E-04		4.9E-03		4.1E-04		4.0E-04	
Naphthenic Acids	0.26	n.g.	0.01	n.g.	0.48	n.g.	0.26	n.g.	0.01	n.g.	0.48	n.g.	0.26	n.g.	0.01	n.g.	0.48	n.g.
Nickel - Total	5.5E-04		2.0E-04		2.1E-04		5.5E-04		2.0E-04		2.1E-04		5.5E-04		2.0E-04		2.1E-04	
Nitrate	0.004		0.0002		0.006		0.004		0.0002		0.006		0.004		0.0002		0.006	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002	
Silver - Total	1.0E-05		2.8E-06		2.6E-06		1.0E-05		2.8E-06		2.6E-06		1.0E-05		2.8E-06		2.6E-06	
Sodium	14.5	n.g.	11.0	n.g.	10.8	n.g.	14.5	n.g.	11.0	n.g.	10.8	n.g.	14.5	n.g.	11.0	n.g.	10.8	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	22.4	n.g.	19.4	n.g.	18.1	n.g.	22.4	n.g.	19.4	n.g.	18.1	n.g.	22.4	n.g.	19.4	n.g.	18.1	n.g.
Total Dissolved Solids	155	n.g.	153	n.g.	153	n.g.	155	n.g.	153	n.g.	153	n.g.	155	n.g.	153	n.g.	154	n.g.
Total PAHs	7.8E-05	n.g.	1.1E-05	n.g.	1.0E-05	n.g.	7.8E-05	n.g.	1.1E-05	n.g.	1.0E-05	n.g.	7.8E-05	n.g.	1.1E-05	n.g.	1.0E-05	n.g.
Acute Toxicity (TUa)	0.008		4.7E-05		3.9E-04		0.008		4.7E-05		3.9E-04		0.008		5.6E-05		3.9E-04	
Chronic Toxicity (TUc)	0.04		0.006		0.006		0.04		0.006		0.006		0.04		0.006		0.006	
Vanadium - Total	0.007		0.004		0.004		0.007		0.004		0.004		0.007		0.004		0.004	
Zinc - Total	0.011		0.012		0.013		0.011		0.012		0.013		0.011		0.012		0.013	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-8 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments)
(Page 3 of 3)

	2044						Far Future					
			east*						east*			
Substance (mg/L)	west*		below'		above'		west*		below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.02		0.01		0.03		0.02		0.01		0.03	
Antimony - Total	1.7E-06		3.6E-08		1.9E-06		1.7E-06		4.1E-08		1.9E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0013	HC	0.0012	HC	0.0012	HC	0.0013	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.5E-06		6.0E-07		4.8E-06	HC	1.5E-06		6.0E-07		4.8E-06	HC
Benzo(a)pyrene grp	4.4E-07		1.2E-07		6.2E-07		4.4E-07		1.2E-07		6.2E-07	
Beryllium-Total	0.001		0.001		0.001		0.001		0.001		0.001	
Boron - Total	0.04		0.05		0.06		0.04		0.05		0.06	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.8	n.g.	30.8	n.g.	31.6	n.g.	30.8	n.g.	30.8	n.g.	31.6	n.g.
Chloride	1.9		3.9		4.0		1.9		3.9		4.0	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	232	n.g.	236	n.g.	249	n.g.	232	n.g.	236	n.g.	249	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.6	n.g.	11.2	n.g.	8.5	n.g.	9.6	n.g.	11.2	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.76	C HNC	2.99	C HNC	2.99	C HNC	2.76	C HNC
Lead - Total	1.8E-05		5.2E-06		7.3E-05		1.8E-05		5.3E-06		7.3E-05	
Magnesium	7.7	n.g.	7.8	n.g.	8.1	n.g.	7.7	n.g.	7.8	n.g.	8.1	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.36	HNC	0.40	HNC	0.40	HNC	0.36	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	1.4E-03		3.3E-05		1.5E-03		1.4E-03		3.8E-05		1.5E-03	
Naphthenic Acids	0.10	n.g.	0.01	n.g.	0.55	n.g.	0.10	n.g.	0.01	n.g.	0.55	n.g.
Nickel - Total	6.0E-05		1.2E-04		1.7E-04		6.0E-05		1.2E-04		1.7E-04	
Nitrate	0.0001		0.0002		0.007		0.0001		0.0002		0.007	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0002		0.0002		0.0002		0.0002	
Silver - Total	3.3E-06		3.3E-06		4.6E-06		3.3E-06		3.3E-06		4.6E-06	
Sodium	8.0	n.g.	8.2	n.g.	12.0	n.g.	8.0	n.g.	8.2	n.g.	12.0	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	20.6	n.g.	19.4	n.g.	18.9	n.g.	20.6	n.g.	19.4	n.g.	18.9	n.g.
Total Dissolved Solids	151	n.g.	153	n.g.	159	n.g.	151	n.g.	153	n.g.	159	n.g.
Total PAHs	3.0E-05	n.g.	1.0E-05	n.g.	4.6E-05	n.g.	3.0E-05	n.g.	1.0E-05	n.g.	4.6E-05	n.g.
Acute Toxicity (TUa)	0.003		5.3E-05		0.002		0.003		6.2E-05		0.002	
Chronic Toxicity (TUc)	0.01		0.008		0.01		0.01		0.008		0.01	
Vanadium - Total	0.004		0.004		0.004		0.004		0.004		0.004	
Zinc - Total	0.011		0.012		0.012		0.011		0.012		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-9 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments + Project) (Page 1 of 3)

Substance (mg/L)	2005						2010						2015					
	west*		east* below'		east* above'		west*		east* below'		east* above'		west*		east* below'		east* above'	
Aluminum - Total	0.06		0.06		0.08		0.06		0.06		0.07		0.06		0.06		0.07	
Ammonia - Total	0.18		0.03		0.07		0.17		0.03		0.05		0.17		0.03		0.05	
Antimony - Total	1.0E-05	n.g.	7.9E-08	n.g.	2.2E-05	n.g.	1.1E-05	n.g.	1.4E-07	n.g.	9.7E-06	n.g.	1.1E-05	n.g.	1.1E-06	n.g.	1.1E-05	n.g.
Arsenic - Total	0.0004		0.0004		0.0012		0.0004		0.0004		0.0008		0.0004		0.0004		0.0008	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	1.5E-06	n.g.	6.6E-07	n.g.	6.6E-07	n.g.	2.1E-06	n.g.	6.7E-07	n.g.	6.7E-07	n.g.	2.1E-06	n.g.	1.7E-06	n.g.	1.7E-06	n.g.
Benzo(a)pyrene grp	7.0E-07	n.g.	1.4E-07	n.g.	1.4E-07	n.g.	8.9E-07	n.g.	1.5E-07	n.g.	1.5E-07	n.g.	8.9E-07	n.g.	3.6E-07	n.g.	3.6E-07	n.g.
Beryllium-Total	1.4E-05		2.2E-05		6.4E-05		1.7E-05		2.0E-05		3.7E-05		1.7E-05		4.2E-05		5.8E-05	
Boron - Total	0.03		0.04		0.04		0.04		0.04		0.04		0.04		0.04		0.04	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.1	n.g.	50.3	n.g.	52.8	n.g.	50.1	n.g.	50.3	n.g.	51.4	n.g.	50.1	n.g.	50.5	n.g.	51.5	n.g.
Chloride	7.0		7.5		7.5		7.1		7.3		7.3		7.1		10.5		10.5	
Chromium - Total	0.003		0.003		0.004		0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	401	n.g.	408	n.g.	417	n.g.	403	n.g.	407	n.g.	411	n.g.	403	n.g.	416	n.g.	419	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.2	n.g.	8.2	n.g.	8.3	n.g.	8.2	n.g.	8.2	n.g.	8.2	n.g.	8.2	n.g.	8.1	n.g.	8.2	n.g.
Iron - Total	0.20		0.20		0.46		0.19		0.20		0.31		0.19		0.21		0.32	
Lead - Total	7.5E-05		7.1E-05		1.6E-04		8.3E-05		7.1E-05		1.1E-04		8.3E-05		8.4E-05		1.2E-04	
Magnesium	13.9	n.g.	14.0	n.g.	14.0	n.g.	13.9	n.g.	14.0	n.g.	14.0	n.g.	13.9	n.g.	14.1	n.g.	14.1	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.13	n.g.	0.10	n.g.	0.10	n.g.	0.11	n.g.	0.10	n.g.	0.10	n.g.	0.12	n.g.
Mercury - Total	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.8E-05	C
Molybdenum - Total	2.8E-03		8.8E-05		2.1E-04		3.3E-03		1.4E-04		1.8E-04		3.3E-03		2.8E-04		3.1E-04	
Naphthenic Acids	0.12	n.g.	0.06	n.g.	0.06	n.g.	0.13	n.g.	0.06	n.g.	0.06	n.g.	0.13	n.g.	0.07	n.g.	0.07	n.g.
Nickel - Total	7.9E-04		7.9E-05		8.1E-05		7.7E-04		7.7E-05		8.0E-05		7.7E-04		9.6E-05		9.8E-05	
Nitrate	0.17		0.16		0.16		0.17		0.16		0.16		0.17		0.16		0.16	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0006		0.0001		0.0001		0.0003		0.0001		0.0001		0.0003	
Silver - Total	1.0E-05		6.1E-06		6.1E-06		1.1E-05		5.4E-06		5.4E-06		1.1E-05		6.0E-06		6.0E-06	
Sodium	17.6	n.g.	18.2	n.g.	18.2	n.g.	17.9	n.g.	18.1	n.g.	18.1	n.g.	17.9	n.g.	20.2	n.g.	20.3	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	40.2	n.g.	39.8	n.g.	39.1	n.g.	40.6	n.g.	39.8	n.g.	39.1	n.g.	40.6	n.g.	39.8	n.g.	39.3	n.g.
Total Dissolved Solids	246	n.g.	249	n.g.	253	n.g.	246	n.g.	249	n.g.	250	n.g.	246	n.g.	254	n.g.	256	n.g.
Total PAHs	2.3E-05	n.g.	1.2E-05	n.g.	1.2E-05	n.g.	3.5E-05	n.g.	1.2E-05	n.g.	1.2E-05	n.g.	3.5E-05	n.g.	3.0E-05	n.g.	3.0E-05	n.g.
Acute Toxicity (TUa)	0.004		0.0001		9.9E-05		0.006		0.0002		0.0002		0.006		0.0003		0.0003	
Chronic Toxicity (TUc)	0.04		0.01		0.01		0.03		0.01		0.01		0.04		0.01		0.01	
Vanadium - Total	0.008		0.002		0.002		0.008		0.002		0.002		0.008		0.002		0.002	
Zinc - Total	0.008		0.008		0.017		0.008		0.008		0.012		0.008		0.009		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-9 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments + Project)
(Page 2 of 3)

Substance (mg/L)	2020						2025						2030					
	west*		east* below'		east* above'		west*		east* below'		east* above'		west*		east* below'		east* above'	
Aluminum - Total	0.06		0.06		0.07		0.06		0.06		0.07		0.06		0.06		0.07	
Ammonia - Total	0.18		0.03		0.05		0.18		0.03		0.05		0.18		0.03		0.05	
Antimony - Total	1.2E-05	n.g.	1.3E-06	n.g.	8.6E-06	n.g.	1.2E-05	n.g.	1.4E-06	n.g.	8.7E-06	n.g.	1.2E-05	n.g.	4.7E-07	n.g.	8.4E-06	n.g.
Arsenic - Total	0.0004		0.0004		0.0007		0.0004		0.0004		0.0007		0.0004		0.0004		0.0007	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	3.6E-06	n.g.	2.4E-06	n.g.	2.4E-06	n.g.	3.6E-06	n.g.	2.8E-06	n.g.	2.8E-06	n.g.	3.6E-06	n.g.	2.9E-06	n.g.	2.9E-06	n.g.
Benzo(a)pyrene grp	1.3E-06	n.g.	5.0E-07	n.g.	5.0E-07	n.g.	1.3E-06	n.g.	5.8E-07	n.g.	5.9E-07	n.g.	1.3E-06	n.g.	5.9E-07	n.g.	5.9E-07	n.g.
Beryllium-Total	3.1E-05		6.0E-05		6.8E-05		3.1E-05		7.3E-05		7.9E-05		3.1E-05		7.6E-05		8.8E-05	
Boron - Total	0.04		0.04		0.04		0.04		0.04		0.04		0.04		0.04		0.04	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.3	n.g.	50.5	n.g.	51.3	n.g.	50.3	n.g.	50.6	n.g.	51.4	n.g.	50.3	n.g.	50.5	n.g.	51.4	n.g.
Chloride	7.2		12.5		12.5		7.2		14.1		14.2		7.2		14.6		14.7	
Chromium - Total	0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	407	n.g.	423	n.g.	424	n.g.	407	n.g.	427	n.g.	429	n.g.	407	n.g.	429	n.g.	431	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.3	n.g.	8.1	n.g.	8.2	n.g.	8.3	n.g.	8.1	n.g.	8.2	n.g.	8.3	n.g.	8.1	n.g.	8.2	n.g
Iron - Total	0.19		0.21		0.30		0.19		0.21		0.30		0.19		0.20		0.30	
Lead - Total	1.0E-04		9.0E-05		1.2E-04		1.0E-04		9.5E-05		1.2E-04		1.0E-04		9.2E-05		1.3E-04	
Magnesium	13.9	n.g.	14.1	n.g.	14.1	n.g.	13.9	n.g.	14.1	n.g.	14.1	n.g.	13.9	n.g.	14.2	n.g.	14.2	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.11	n.g.	0.10	n.g.	0.10	n.g.	0.11	n.g.	0.10	n.g.	0.10	n.g.	0.11	n.g
Mercury - Total	1.0E-04	C	1.0E-04	C	9.8E-05	C	1.0E-04	C	1.0E-04	C	9.8E-05	C	1.0E-04	C	1.0E-04	C	9.9E-05	C
Molybdenum - Total	6.7E-03		1.5E-03		1.5E-03		6.7E-03		1.5E-03		1.5E-03		6.7E-03		1.4E-03		1.4E-03	
Naphthenic Acids	0.24	n.g.	0.08	n.g.	0.08	n.g.	0.24	n.g.	0.09	n.g.	0.09	n.g.	0.24	n.g.	0.09	n.g.	0.09	n.g.
Nickel - Total	1.3E-03		3.4E-04		3.5E-04		1.3E-03		3.7E-04		3.8E-04		1.3E-03		3.9E-04		3.9E-04	
Nitrate	0.17		0.16		0.16		0.17		0.16		0.16		0.17		0.16		0.16	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0003		0.0001		0.0001		0.0003		0.0001		0.0001		0.0003	
Silver - Total	1.8E-05		9.3E-06		9.3E-06		1.8E-05		1.2E-05		1.2E-05		1.8E-05		1.3E-05		1.3E-05	
Sodium	33.8	n.g.	29.2	n.g.	29.3	n.g.	33.8	n.g.	30.3	n.g.	30.5	n.g.	33.8	n.g.	30.8	n.g.	30.9	n.g.
Strontium	0.34	n.g.	0.35	n.g.	0.35	n.g.	0.34	n.g.	0.35	n.g.	0.35	n.g.	0.34	n.g.	0.35	n.g.	0.35	n.g.
Sulphate	42.0	n.g.	40.0	n.g.	39.6	n.g.	42.0	n.g.	40.1	n.g.	39.7	n.g.	42.0	n.g.	40.1	n.g.	39.7	n.g.
Total Dissolved Solids	249	n.g.	258	n.g.	259	n.g.	249	n.g.	261	n.g.	262	n.g.	249	n.g.	262	n.g.	263	n.g.
Total PAHs	6.9E-05	n.g.	4.5E-05	n.g.	4.6E-05	n.g.	6.9E-05	n.g.	5.4E-05	n.g.	5.4E-05	n.g.	6.9E-05	n.g.	5.5E-05	n.g.	5.5E-05	n.g.
Acute Toxicity (TUa)	0.009		0.0003		0.0003		0.009		0.0003		0.0003		0.009		0.0003		0.0003	
Chronic Toxicity (TUc)	0.06		0.02		0.02		0.06		0.02		0.02		0.06		0.02		0.02	
Vanadium - Total	0.008		0.002		0.002		0.008		0.002		0.002		0.008		0.002		0.002	
Zinc - Total	0.008		0.009		0.011		0.008		0.009		0.012		0.008		0.008		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-9 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (Approved Developments + Project) (Page 3 of 3)

Substance (mg/L)	2044						Far Future					
	west*		east*				west*		east*			
			below'		above'				below'		above'	
Aluminum - Total	0.06		0.09		0.10	C	0.06		0.06		0.08	
Ammonia - Total	0.05		0.03		0.07		0.05		0.03		0.07	
Antimony - Total	4.1E-06	n.g.	2.1E-05	n.g.	2.4E-05	n.g.	4.1E-06	n.g.	2.0E-06	n.g.	7.6E-06	n.g.
Arsenic - Total	0.0004		0.0005		0.0006		0.0004		0.0004		0.0005	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	3.6E-06	n.g.	4.8E-06	n.g.	1.7E-05	n.g.	3.6E-06	n.g.	1.5E-06	n.g.	1.4E-05	n.g.
Benzo(a)pyrene grp	1.1E-06	n.g.	1.1E-06	n.g.	2.5E-06	n.g.	1.1E-06	n.g.	3.1E-07	n.g.	1.9E-06	n.g.
Beryllium-Total	1.9E-05		1.1E-04		1.5E-04		1.9E-05		4.4E-05		8.7E-05	
Boron - Total	0.04		0.09		0.12		0.04		0.04		0.08	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.3	n.g.	51.6	n.g.	52.1	n.g.	50.3	n.g.	50.6	n.g.	51.2	n.g.
Chloride	5.4		10.1		10.2		5.4		9.4		9.6	
Chromium - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	403	n.g.	440	n.g.	473	n.g.	403	n.g.	415	n.g.	450	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.1	n.g.	9.1	n.g.	9.7	n.g.	8.1	n.g.	8.5	n.g.	9.1	n.g.
Iron - Total	0.18		0.22		0.26		0.18		0.21		0.25	
Lead - Total	4.5E-05		3.0E-04		3.5E-04		4.5E-05		9.6E-05		1.6E-04	
Magnesium	13.9	n.g.	14.2	n.g.	14.4	n.g.	13.9	n.g.	14.1	n.g.	14.3	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.
Mercury - Total	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.7E-05	C
Molybdenum - Total	3.6E-03		1.6E-02		2.0E-02		3.6E-03		1.6E-03		5.9E-03	
Naphthenic Acids	0.24	n.g.	0.13	n.g.	0.31	n.g.	0.24	n.g.	0.07	n.g.	0.26	n.g.
Nickel - Total	1.5E-04		4.2E-04		4.9E-04		1.5E-04		1.2E-04		2.0E-04	
Nitrate	0.16		0.16		0.16		0.16		0.16		0.16	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0002		0.0001		0.0001		0.0001	
Silver - Total	8.2E-06		3.1E-05		3.5E-05		8.2E-06		1.1E-05		1.6E-05	
Sodium	19.8	n.g.	26.3	n.g.	35.4	n.g.	19.8	n.g.	20.2	n.g.	29.7	n.g.
Strontium	0.34	n.g.	0.36	n.g.	0.36	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	42.6	n.g.	53.1	n.g.	57.8	n.g.	42.6	n.g.	40.6	n.g.	45.9	n.g.
Total Dissolved Solids	247	n.g.	272	n.g.	286	n.g.	247	n.g.	254	n.g.	269	n.g.
Total PAHs	7.3E-05	n.g.	3.9E-04	n.g.	4.7E-04	n.g.	7.3E-05	n.g.	5.5E-05	n.g.	1.6E-04	n.g.
Acute Toxicity (TUa)	0.007		0.003		0.01		0.007		0.001		0.008	
Chronic Toxicity (TUc)	0.03		0.03		0.04		0.03		0.02		0.04	
Vanadium - Total	0.002		0.004		0.004		0.002		0.002		0.003	
Zinc - Total	0.007		0.010		0.010		0.007		0.009		0.010	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-10 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments + Project)
(Page 1 of 3)

Substance (mg/L)	2005						2010						2015					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.07		0.01		0.03		0.06		0.01		0.02		0.06		0.01		0.02	
Antimony - Total	4.0E-06		3.1E-08		1.0E-05		4.2E-06		5.4E-08		3.8E-06		4.2E-06		4.2E-07		4.0E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0017	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	5.9E-07		2.4E-07		2.3E-07		8.2E-07		2.5E-07		2.4E-07		8.2E-07		6.3E-07		6.1E-07	
Benzo(a)pyrene grp	2.7E-07		5.0E-08		4.9E-08		3.5E-07		5.4E-08		5.2E-08		3.5E-07		1.3E-07		1.3E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.0E-04		1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.1E-04	
Boron - Total	0.04		0.05		0.05		0.04		0.05		0.05		0.04		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.7	n.g.	30.7	n.g.	32.7	n.g.	30.7	n.g.	30.7	n.g.	31.6	n.g.	30.7	n.g.	30.8	n.g.	31.6	n.g.
Chloride	2.5		2.7		2.7		2.6		2.6		2.7		2.6		3.8		3.8	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	232	n.g.	233	n.g.	240	n.g.	232	n.g.	233	n.g.	235	n.g.	232	n.g.	236	n.g.	237	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.5	n.g.	11.0	n.g.	8.5	n.g.	9.5	n.g.	11.0	n.g.	8.5	n.g.	9.5	n.g.	11.0	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.79	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC
Lead - Total	2.9E-05		2.4E-06		8.9E-05		3.2E-05		2.5E-06		6.0E-05		3.2E-05		7.0E-06		6.4E-05	
Magnesium	7.7	n.g.	7.8	n.g.	8.0	n.g.	7.7	n.g.	7.8	n.g.	7.9	n.g.	7.7	n.g.	7.8	n.g.	8.0	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.4E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	1.1E-03		2.9E-05		1.1E-04		1.3E-03		4.8E-05		1.0E-04		1.3E-03		1.0E-04		1.3E-04	
Naphthenic Acids	0.05	n.g.	0.01	n.g.	0.49	n.g.	0.05	n.g.	0.01	n.g.	0.48	n.g.	0.05	n.g.	0.01	n.g.	0.48	n.g.
Nickel - Total	3.1E-04		1.1E-04		1.4E-04		3.0E-04		1.1E-04		1.4E-04		3.0E-04		1.1E-04		1.4E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0004		0.0002		0.0002		0.0003		0.0002		0.0002		0.0003	
Silver - Total	4.0E-06		2.2E-06		2.0E-06		4.3E-06		2.0E-06		1.8E-06		4.3E-06		2.2E-06		2.0E-06	
Sodium	7.1	n.g.	7.4	n.g.	7.8	n.g.	7.2	n.g.	7.4	n.g.	7.7	n.g.	7.2	n.g.	8.2	n.g.	8.5	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	19.6	n.g.	19.4	n.g.	17.8	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.
Total Dissolved Solids	151	n.g.	151	n.g.	154	n.g.	151	n.g.	151	n.g.	152	n.g.	151	n.g.	153	n.g.	153	n.g.
Total PAHs	9.0E-06	n.g.	4.5E-06	n.g.	4.3E-06	n.g.	1.4E-05	n.g.	4.6E-06	n.g.	4.4E-06	n.g.	1.4E-05	n.g.	1.1E-05	n.g.	1.1E-05	n.g.
Acute Toxicity (TUa)	0.001		3.9E-05		9.0E-05		0.002		7.0E-05		0.0002		0.002		0.0001		0.0002	
Chronic Toxicity (TUc)	0.02		0.003		0.003		0.01		0.002		0.002		0.01		0.002		0.002	
Vanadium - Total	0.006		0.004		0.004		0.006		0.004		0.004		0.006		0.004		0.004	
Zinc - Total	0.011		0.012		0.016		0.011		0.012		0.013		0.011		0.012		0.013	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-10 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments + Project) (Page 2 of 3)

Substance (mg/L)	2020						2025						2030					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.07		0.01		0.02		0.07		0.01		0.02		0.07		0.01		0.02	
Antimony - Total	4.9E-06		4.6E-07		3.4E-06		4.9E-06		5.2E-07		3.4E-06		4.9E-06		1.8E-07		3.6E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.4E-06		8.8E-07		8.3E-07		1.4E-06		1.0E-06		9.7E-07		1.4E-06		1.1E-06		9.9E-07	
Benzo(a)pyrene grp	5.3E-07		1.8E-07		1.8E-07		5.3E-07		2.2E-07		2.0E-07		5.3E-07		2.2E-07		2.0E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.2E-04	
Boron - Total	0.04		0.05		0.05		0.04		0.05		0.05		0.04		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.8	n.g.	30.8	n.g.	31.6	n.g.	30.8	n.g.	30.8	n.g.	31.6	n.g.	30.8	n.g.	30.8	n.g.	31.7	n.g.
Chloride	2.6		4.6		4.4		2.6		5.2		4.9		2.6		5.3		5.1	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	234	n.g.	238	n.g.	239	n.g.	234	n.g.	240	n.g.	240	n.g.	234	n.g.	240	n.g.	241	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.5	n.g.	10.9	n.g.	8.5	n.g.	9.5	n.g.	10.9	n.g.	8.5	n.g.	9.5	n.g.	10.9	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC	2.99	C HNC	2.99	C HNC	2.78	C HNC
Lead - Total	4.0E-05		9.4E-06		6.4E-05		4.0E-05		1.1E-05		6.6E-05		4.0E-05		1.0E-05		6.9E-05	
Magnesium	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.0	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	2.7E-03		5.4E-04		4.9E-04		2.7E-03		5.5E-04		5.0E-04		2.7E-03		5.3E-04		4.8E-04	
Naphthenic Acids	0.10	n.g.	0.01	n.g.	0.48	n.g.	0.10	n.g.	0.02	n.g.	0.49	n.g.	0.10	n.g.	0.02	n.g.	0.49	n.g.
Nickel - Total	5.0E-04		2.0E-04		2.2E-04		5.0E-04		2.1E-04		2.3E-04		5.0E-04		2.2E-04		2.3E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002		0.0002	
Silver - Total	7.2E-06		3.4E-06		3.1E-06		7.2E-06		4.3E-06		3.8E-06		7.2E-06		4.8E-06		4.3E-06	
Sodium	13.8	n.g.	11.5	n.g.	11.2	n.g.	13.8	n.g.	11.9	n.g.	11.5	n.g.	13.8	n.g.	12.1	n.g.	11.7	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	20.4	n.g.	19.5	n.g.	18.0	n.g.	20.4	n.g.	19.5	n.g.	18.0	n.g.	20.4	n.g.	19.6	n.g.	18.0	n.g.
Total Dissolved Solids	152	n.g.	154	n.g.	154	n.g.	152	n.g.	155	n.g.	155	n.g.	152	n.g.	156	n.g.	156	n.g.
Total PAHs	2.8E-05	n.g.	1.7E-05	n.g.	1.6E-05	n.g.	2.8E-05	n.g.	2.0E-05	n.g.	1.9E-05	n.g.	2.8E-05	n.g.	2.0E-05	n.g.	1.9E-05	n.g.
Acute Toxicity (TUa)	0.004		0.0001		0.0002		0.004		0.0001		0.0002		0.004		0.0001		0.0002	
Chronic Toxicity (TUc)	0.03		0.006		0.006		0.03		0.006		0.006		0.03		0.006		0.006	
Vanadium - Total	0.006		0.004		0.004		0.006		0.004		0.004		0.006		0.004		0.004	
Zinc - Total	0.011		0.012		0.013		0.011		0.012		0.013		0.011		0.012		0.013	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-10 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (Approved Developments + Project)
(Page 3 of 3)

	2044						Far Future					
			east*						east*			
Substance (mg/L)	west*		below'		above'		west*		below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.02		0.01		0.03		0.02		0.01		0.03	
Antimony - Total	1.7E-06		7.6E-06		7.8E-06		1.7E-06		7.1E-07		2.3E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0013	HC	0.0012	HC	0.0012	HC	0.0013	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.5E-06		1.8E-06		5.7E-06	HC	1.5E-06		5.7E-07		4.7E-06	HC
Benzo(a)pyrene grp	4.4E-07		3.9E-07		8.3E-07		4.4E-07		1.2E-07		6.1E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.2E-04		1.0E-03		1.0E-03		9.1E-04	
Boron - Total	0.04		0.06		0.07		0.04		0.05		0.06	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.8	n.g.	31.3	n.g.	32.0	n.g.	30.8	n.g.	30.9	n.g.	31.6	n.g.
Chloride	1.9		3.7		3.6		1.9		3.4		3.4	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	232	n.g.	245	n.g.	256	n.g.	232	n.g.	236	n.g.	249	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.8	n.g.	11.5	n.g.	8.5	n.g.	9.6	n.g.	11.3	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.76	C HNC	2.99	C HNC	2.99	C HNC	2.76	C HNC
Lead - Total	1.8E-05		8.8E-05		1.4E-04		1.8E-05		1.1E-05		7.7E-05	
Magnesium	7.7	n.g.	7.9	n.g.	8.1	n.g.	7.7	n.g.	7.8	n.g.	8.1	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.36	HNC	0.40	HNC	0.40	HNC	0.36	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	1.4E-03		6.0E-03		6.3E-03		1.4E-03		5.7E-04		2.0E-03	
Naphthenic Acids	0.10	n.g.	0.03	n.g.	0.57	n.g.	0.10	n.g.	0.01	n.g.	0.55	n.g.
Nickel - Total	6.0E-05		2.3E-04		2.7E-04		6.0E-05		1.2E-04		1.8E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0002		0.0002		0.0002		0.0002	
Silver - Total	3.3E-06		1.2E-05		1.1E-05		3.3E-06		3.8E-06		5.0E-06	
Sodium	8.0	n.g.	10.5	n.g.	13.6	n.g.	8.0	n.g.	8.2	n.g.	11.8	n.g.
Strontium	0.22	n.g.	0.23	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	20.6	n.g.	24.5	n.g.	22.5	n.g.	20.6	n.g.	19.9	n.g.	19.1	n.g.
Total Dissolved Solids	151	n.g.	160	n.g.	164	n.g.	151	n.g.	153	n.g.	158	n.g.
Total PAHs	3.0E-05	n.g.	1.4E-04	n.g.	1.5E-04	n.g.	3.0E-05	n.g.	2.0E-05	n.g.	5.3E-05	n.g.
Acute Toxicity (TUa)	0.003		0.001		0.003		0.003		0.0002		0.002	
Chronic Toxicity (TUc)	0.01		0.01		0.01		0.01		0.008		0.01	
Vanadium - Total	0.004		0.005		0.004		0.004		0.004		0.004	
Zinc - Total	0.011		0.012		0.013		0.011		0.012		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-11 Predicted Annual Average Water Quality in McLean Creek.
(Page 1 of 2)

Substance	1997 mg/L		2005 mg/L		2010 mg/L		2015 mg/L		2020 mg/L	
Aluminum - Total	0.31	C	0.29	C	0.29	C	0.31	C	0.31	C
Ammonia - Total	0.03		0.03		0.03		0.11		0.10	
Antimony - Total	0	-	0	-	0	-	4.3E-05		4.0E-05	
Arsenic - Total	0.0007	HC	0.0005	HC	0.0005	HC	0.0022	HC	0.0020	HC
Barium - Total	0.05		0.04		0.04		0.05		0.05	
Benzo(a)anthracene grp	0	-	0	-	0	-	0	-	0	-
Benzo(a)pyrene grp	0	-	0	-	0	-	0	-	0	-
Beryllium-Total	0.0005		0.0002		0.0002		0.0002		0.0003	
Boron - Total	0.18		0.13		0.13		0.12		0.12	
Cadmium - Total	0.003	C	0.003	C	0.003	C	0.003	C	0.003	C
Calcium	43.8	n.g.	41.0	n.g.	41.0	n.g.	46.3	n.g.	46.0	n.g.
Chloride	15.7		12.8		12.8		11.3		11.5	
Chromium - Total	0.002		0.001		0.001		0.003		0.002	
Conductivity	413	n.g.	354	n.g.	354	n.g.	369	n.g.	370	n.g.
Copper - Total	0.003		0.002		0.002		0.003		0.003	
Dissolved Organic Carbon	20.3	n.g.	20.9	n.g.	20.9	n.g.	20.1	n.g.	20.1	n.g.
Iron - Total	0.7	HNC	0.8	HNC	0.8	HNC	1.2	C HNC	1.2	C HNC
Lead - Total	8.5E-05		3.8E-05		3.8E-05		1.9E-04		1.8E-04	
Magnesium	12.4	n.g.	11.6	n.g.	11.6	n.g.	11.6	n.g.	11.7	n.g.
Manganese - Total	0.11	HNC	0.07	HNC	0.07	HNC	0.13	HNC	0.13	HNC
Mercury - Total	0	-	0	-	0	-	0	-	0	-
Molybdenum - Total	0.0013		0.0006		0.0006		0.0007		0.0007	
Naphthenic Acids	0.87	n.g.	0.39	n.g.	0.39	n.g.	0.29	n.g.	0.32	n.g.
Nickel - Total	0.003		0.001		0.001		0.001		0.001	
Nitrate	0.05		0.02		0.02		0.02		0.02	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.00005		0.00002		0.00002		0.001		0.0010	
Silver - Total	0.0004		0.0002		0.0002		0.0001		0.0001	
Sodium	39.8	n.g.	25.3	n.g.	25.3	n.g.	21.6	n.g.	22.5	n.g.
Strontium	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.1	n.g.
Sulphate	23.6	n.g.	16.6	n.g.	16.6	n.g.	14.5	n.g.	15.0	n.g.
Total Dissolved Solids	234	n.g.	197	n.g.	197	n.g.	204	n.g.	205	n.g.
Total PAH's	1.1E-04	n.g.	4.8E-05	n.g.	4.8E-05	n.g.	3.6E-05	n.g.	4.0E-05	n.g.
Acute Toxicity (TUa)	0	-	0	-	0	-	0	-	0	-
Chronic Toxicity (TUc)	0	-	0	-	0	-	0	-	0	-
Vanadium - Total	0.001		0.001		0.001		0.001		0.001	
Zinc - Total	0.03		0.02		0.02		0.04		0.04	

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic,
HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-11 Predicted Annual Average Water Quality in McLean Creek.
(Page 2 of 2)

Substance	2025 mg/L		2030 mg/L		2044 mg/L		Far Future mg/L	
Aluminum - Total	0.32	C	0.31	C	0.31	C	0.37	C
Ammonia - Total	0.11		0.03		0.03		0.01	
Antimony - Total	4.9E-05		0	-	0	-	7.9E-05	
Arsenic - Total	0.0025	HC	0.0008	HC	0.0008	HC	0.0009	HC
Barium - Total	0.06		0.06		0.05		0.05	
Benzo(a)anthracene grp	0	-	0	-	0	-	2.6E-18	
Benzo(a)pyrene grp	0	-	0	-	0	-	1.2E-22	
Beryllium-Total	0.0004		0.0006		0.0005		0.0005	
Boron - Total	0.15		0.19		0.18		0.36	
Cadmium - Total	0.003	C	0.003	C	0.003	C	0.002	
Calcium	49.0	n.g.	44.5	n.g.	43.8	n.g.	54.5	n.g.
Chloride	11.5		13.0		15.8		14.4	
Chromium - Total	0.003		0.002		0.002		0.002	
Conductivity	407	n.g.	417	n.g.	414	n.g.	507	n.g.
Copper - Total	0.004		0.003		0.003		0.004	
Dissolved Organic Carbon	19.6	n.g.	20.1	n.g.	20.2	n.g.	25.7	n.g.
Iron - Total	1.3	C HNC	0.7	HNC	0.7	HNC	0.9	HNC
Lead - Total	2.5E-04		9.7E-05		8.5E-05		9.1E-04	
Magnesium	12.2	n.g.	12.6	n.g.	12.4	n.g.	14.1	n.g.
Manganese - Total	0.17	HNC	0.12	HNC	0.11	HNC	0.08	HNC
Mercury - Total	0	-	0	-	0	-	2.2E-06	
Molybdenum - Total	0.0013		0.0015		0.0013		0.063	
Naphthenic Acids	0.62	n.g.	0.98	n.g.	0.88	n.g.	0.35	n.g.
Nickel - Total	0.002		0.004		0.003		0.002	
Nitrate	0.04		0.06		0.05		0.03	
Phenolics - Total	0.002		0.002		0.002		0.002	
Selenium - Total	0.001		0.00006		0.00005		0.0002	
Silver - Total	0.0003		0.0004		0.0004		0.0002	
Sodium	30.3	n.g.	40.9	n.g.	40.0	n.g.	58.1	n.g.
Strontium	0.1	n.g.	0.1	n.g.	0.1	n.g.	0.2	n.g.
Sulphate	19.3	n.g.	25.4	n.g.	23.7	n.g.	70.2	n.g.
Total Dissolved Solids	228	n.g.	236	n.g.	234	n.g.	314	n.g.
Total PAH's	7.6E-05	n.g.	1.2E-04	n.g.	1.1E-04	n.g.	1.5E-03	n.g.
Acute Toxicity (TUa)	0	-	0	-	0	-	0.004	
Chronic Toxicity (TUc)	0	-	0	-	0	-	0.006	
Vanadium - Total	0.002		0.002		0.001		0.008	
Zinc - Total	0.04		0.03		0.03		0.03	

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic,
HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-12 Predicted Water Quality in McLean Creek Assuming No Natural Surface Flow. (Page 1 of 2)

Substance	1997 mg/L		2005 mg/L		2010 mg/L		2015 mg/L		2020 mg/L	
Aluminum - Total	0.50	C	0.50	C	0.50	C	0.52	C	0.52	C
Ammonia - Total	0	-	0	-	0	-	0.62		0.58	
Antimony - Total	0	-	0	-	0	-	0.0003		0.0003	
Arsenic - Total	0.004		0.004		0.004		0.015	C	0.014	C
Barium - Total	0.21		0.21		0.21		0.20		0.20	
Benzo(a)anthracene grp	0	-	0	-	0	-	0	-	0	-
Benzo(a)pyrene grp	0	-	0	-	0	-	0	-	0	-
Beryllium-Total	0.004		0.004		0.004		0.002		0.002	
Boron - Total	0.82	C	0.82	C	0.82	C	0.29		0.32	
Cadmium - Total	0.004	C	0.004	C	0.004	C	0.001		0.001	
Calcium	79.7	n.g.	79.7	n.g.	79.7	n.g.	97.6	n.g.	96.5	n.g.
Chloride	53.2		53.2		53.2		17.0		18.2	
Chromium - Total	0.013	C	0.013	C	0.013	C	0.020	A C	0.019	A C
Conductivity	1175	n.g.	1175	n.g.	1175	n.g.	794	n.g.	813	n.g.
Copper - Total	0.01	C	0.01	C	0.01	C	0.01	C	0.01	C
Dissolved Organic Carbon	12.0	n.g.	12.0	n.g.	12.0	n.g.	11.3	n.g.	11.3	n.g.
Iron - Total	0.5		0.5		0.5		4.3	C	4.1	C
Lead - Total	0.0007		0.0007		0.0007		0.002		0.001	
Magnesium	22.6	n.g.	22.6	n.g.	22.6	n.g.	16.1	n.g.	16.4	n.g.
Manganese - Total	0.59		0.59		0.59		0.73		0.72	
Mercury - Total	0	-	0	-	0	-	0	-	0	-
Molybdenum - Total	0.011		0.011		0.011		0.006		0.006	
Naphthenic Acids	7.13	n.g.	7.13	n.g.	7.13	n.g.	2.28	n.g.	2.57	n.g.
Nickel - Total	0.03		0.03		0.03		0.01		0.01	
Nitrate	0.38		0.38		0.38		0.13		0.15	
Phenolics - Total	0	-	0	-	0	-	0	-	0	-
Selenium - Total	0.0004		0.0004		0.0004		0.0083	C	0.0078	C
Silver - Total	0.003		0.003		0.003		0.001		0.001	
Sodium	229	n.g.	229	n.g.	229	n.g.	77	n.g.	85	n.g.
Strontium	0.3	n.g.	0.3	n.g.	0.3	n.g.	0.2	n.g.	0.2	n.g.
Sulphate	114	n.g.	114	n.g.	114	n.g.	39	n.g.	43	n.g.
Total Dissolved Solids	714	n.g.	714	n.g.	714	n.g.	455	n.g.	469	n.g.
Total PAHs	0.0009	n.g.	0.0009	n.g.	0.0009	n.g.	0.0003	n.g.	0.0003	n.g.
Acute Toxicity (TUa)	0	-	0	-	0	-	0	-	0	-
Chronic Toxicity (TUc)	0	-	0	-	0	-	0	-	0	-
Vanadium - Total	0.012		0.012		0.012		0.007		0.007	
Zinc - Total	0.04		0.04		0.04		0.15		0.14	

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic,

Table V-12 Predicted Water Quality in McLean Creek Assuming No Natural Surface Flow. (Page 2 of 2)

Substance	2025 mg/L		2030 mg/L		2044 mg/L		Far Future mg/L	
Aluminum - Total	0.51	C	0.50	C	0.50	C	0.50	C
Ammonia - Total	0.48		0	-	0	-	0	-
Antimony - Total	0.0003		0	-	0	-	0	-
Arsenic - Total	0.012	C	0.004		0.004		0.004	
Barium - Total	0.21		0.21		0.21		0.21	
Benzo(a)anthracene grp	0	-	0	-	0	-	0	-
Benzo(a)pyrene grp	0	-	0	-	0	-	0	-
Beryllium-Total	0.002		0.004		0.004		0.004	
Boron - Total	0.40		0.80	C	0.82	C	0.82	C
Cadmium - Total	0.002	C	0.004	C	0.004	C	0.004	C
Calcium	93.6	n.g.	79.8	n.g.	79.7	n.g.	79.7	n.g.
Chloride	15.7		28.6		53.2		53.2	
Chromium - Total	0.018	A C	0.013	C	0.013	C	0.013	C
Conductivity	848	n.g.	1095	n.g.	1175	n.g.	1175	n.g.
Copper - Total	0.01	C	0.01	C	0.01	C	0.01	C
Dissolved Organic Carbon	11.5	n.g.	12.1	n.g.	12.0	n.g.	12.0	n.g.
Iron - Total	3.5	C	0.5		0.5		0.5	
Lead - Total	0.001		0.0007		0.0007		0.0007	
Magnesium	17.4	n.g.	22.2	n.g.	22.6	n.g.	22.6	n.g.
Manganese - Total	0.70		0.59		0.59		0.59	
Mercury - Total	0	-	0	-	0	-	0	-
Molybdenum - Total	0.007		0.011		0.011		0.011	
Naphthenic Acids	3.34	n.g.	7.05	n.g.	7.13	n.g.	7.13	n.g.
Nickel - Total	0.01		0.03		0.03		0.03	
Nitrate	0.19		0.38		0.38		0.38	
Phenolics - Total	0	-	0	-	0	-	0	-
Selenium - Total	0.0065	C	0.0004		0.0004		0.0004	
Silver - Total	0.001		0.003		0.003		0.003	
Sodium	104	n.g.	211	n.g.	229	n.g.	229	n.g.
Strontium	0.2	n.g.	0.3	n.g.	0.3	n.g.	0.3	n.g.
Sulphate	56	n.g.	115	n.g.	114	n.g.	114	n.g.
Total Dissolved Solids	495	n.g.	666	n.g.	714	n.g.	714	n.g.
Total PAHs	0.0004	n.g.	0.0009	n.g.	0.0009	n.g.	0.0009	n.g.
Acute Toxicity (TUa)	0	-	0	-	0	-	0	-
Chronic Toxicity (TUc)	0	-	0	-	0	-	0	-
Vanadium - Total	0.008		0.012		0.012		0.012	
Zinc - Total	0.13		0.04		0.04		0.04	

n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic,

Table V-13 Predicted Annual Average Water Quality in Shipyard Lake.

	Year									
	1997	2005	2010	2015	2020	2025	2030	2044	Far	Max
Flow (m^3/s)	0.15	0.20	0.20	0.10	0.16	0.16	0.16	0.16	0.16	0.79
Substance	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Aluminum - Total	0.20	0.22	0.22	0.22	0.48	0.49	0.49	0.21	0.21	0.64
Ammonia - Total	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02
Antimony - Total	0	0	0	0	0	0	0	0	0	0
Arsenic - Total	0.0004	0.0005	0.0006	0.0005	0.0009	0.0009	0.0009	0.0004	0.0004	0.0011
Barium - Total	0.05	0.04	0.04	0.05	0.07	0.08	0.08	0.05	0.05	0.08
Benzo(a)anthracene grp	0	0	0	0	0	0	0	0	0	0
Benzo(a)pyrene grp	0	0	0	0	0	0	0	0	0	0
Beryllium-Total	2.5E-05	0.0002	0.0002	0.0002	0.001	0.001	0.001	2.4E-05	2.4E-05	0.001
Boron - Total	0.18	0.13	0.12	0.19	0.19	0.27	0.27	0.19	0.19	0.27
Cadmium - Total	2.0E-06	1.6E-04	1.7E-04	1.6E-04	6.5E-04	6.2E-04	6.1E-04	1.4E-08	8.7E-09	9.3E-04
Calcium	50.1	51.3	51.3	51.9	40.2	39.6	39.6	50.7	50.7	52.0
Chloride	103	13.6	8.8	81	126	214	213	105	105	219
Chromium - Total	0.0004	0.0005	0.0005	0.001	0.003	0.002	0.002	5.4E-08	3.5E-08	0.004
Conductivity	653	374	359	605	701	988	985	660	659	1005
Copper - Total	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.002	0.002	0.003
Dissolved Organic Carbon	22.4	22.1	22.1	22.0	13.8	13.1	13.1	22.2	22.2	22.4
Iron - Total	0.9	0.8	0.8	0.8	2.0	2.1	2.1	0.8	0.8	2.8
Lead - Total	4.9E-05	2.8E-05	2.9E-05	2.8E-05	1.2E-05	6.0E-07	7.8E-14	3.3E-33	1.3E-149	4.9E-05
Magnesium	14.4	13.5	13.4	14.7	12.2	13.3	13.3	14.7	14.7	15.7
Manganese - Total	0.06	0.07	0.08	0.08	0.27	0.27	0.27	0.06	0.06	0.37
Mercury - Total	0.0E+00	8.2E-10	3.6E-10	7.2E-10	5.8E-05	6.1E-05	6.1E-05	1.4E-09	8.7E-10	9.1E-05
Molybdenum - Total	5.4E-06	4.3E-04	4.5E-04	4.3E-04	1.8E-04	9.4E-06	1.2E-12	5.1E-32	2.1E-148	4.5E-04
Naphthenic Acids	0.5	0.3	0.3	0.6	0.7	1.0	1.0	0.5	0.5	1.1
Nickel - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0003	0.0003	0.001
Nitrate	0.005	0.019	0.020	0.019	0.008	0.002	0.002	0.005	0.005	0.020
Phenolics - Total	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.002
Selenium - Total	2.0E-07	1.6E-05	1.7E-05	1.6E-05	1.2E-04	1.2E-04	1.2E-04	2.7E-09	1.7E-09	1.8E-04
Silver - Total	6.1E-06	1.2E-04	1.2E-04	1.2E-04	5.6E-05	1.3E-05	1.0E-05	4.7E-06	4.7E-06	1.2E-04
Sodium	89	26.0	22.6	78	108	173	173	90	90	177
Strontium	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.2	0.2	0.4
Sulphate	7.8	12.3	12.6	12.3	16.2	14.7	14.7	8.0	8.0	18.7
Total Dissolved Solids	387	218	209	356	423	595	593	388	388	605
Total PAHs	3.5E-05	3.6E-05	3.6E-05	6.1E-05	5.9E-05	7.8E-05	7.7E-05	3.5E-05	3.5E-05	7.9E-05
Acute Toxicity (TUa)	0	0	0	0	0	0	0	0	0	0
Chronic Toxicity (TUc)	0	0	0	0	0	0	0	0	0	0
Vanadium - Total	5.9E-06	0.0005	0.0005	0.0005	0.003	0.002	0.002	5.4E-08	0.000	0.004
Zinc - Total	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03

Table V-14 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (CEA)
(Page 1 of 3)

Substance (mg/L)	2005						2010						2015					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.06		0.06		0.08		0.06		0.06		0.07		0.06		0.06		0.07	
Ammonia - Total	0.18		0.03		0.07		0.17		0.03		0.05		0.17		0.03		0.05	
Antimony - Total	1.0E-05	n.g.	7.9E-08	n.g.	2.2E-05	n.g.	1.1E-05	n.g.	1.4E-07	n.g.	1.0E-05	n.g.	1.1E-05	n.g.	1.1E-06	n.g.	1.1E-05	n.g.
Arsenic - Total	0.0004		0.0004		0.0013		0.0004		0.0004		0.0008		0.0004		0.0004		0.0008	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	1.5E-06	n.g.	6.6E-07	n.g.	6.6E-07	n.g.	2.1E-06	n.g.	6.7E-07	n.g.	6.7E-07	n.g.	2.1E-06	n.g.	1.7E-06	n.g.	1.7E-06	n.g.
Benzo(a)pyrene grp	7.0E-07	n.g.	1.4E-07	n.g.	1.4E-07	n.g.	8.9E-07	n.g.	1.5E-07	n.g.	1.5E-07	n.g.	8.9E-07	n.g.	3.6E-07	n.g.	3.6E-07	n.g.
Beryllium-Total	1.4E-05		2.2E-05		6.4E-05		1.7E-05		2.0E-05		3.8E-05		1.7E-05		4.2E-05		5.9E-05	
Boron - Total	0.03		0.04		0.04		0.04		0.04		0.04		0.04		0.04		0.04	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.1	n.g.	50.3	n.g.	52.8	n.g.	50.1	n.g.	50.3	n.g.	51.5	n.g.	50.1	n.g.	50.5	n.g.	51.6	n.g
Chloride	7.0		7.5		7.5		7.1		7.3		7.3		7.1		10.5		10.5	
Chromium - Total	0.003		0.003		0.004		0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	401	n.g.	408	n.g.	417	n.g.	403	n.g.	407	n.g.	411	n.g.	403	n.g.	416	n.g.	419	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.2	n.g.	8.2	n.g.	8.3	n.g.	8.2	n.g.	8.2	n.g.	8.2	n.g.	8.2	n.g.	8.1	n.g.	8.2	n.g.
Iron - Total	0.20		0.20		0.46		0.19		0.20		0.32		0.19		0.21		0.33	
Lead - Total	7.5E-05		7.1E-05		1.6E-04		8.3E-05		7.1E-05		1.1E-04		8.3E-05		8.4E-05		1.2E-04	
Magnesium	13.9	n.g.	14.0	n.g.	14.0	n.g.	13.9	n.g.	14.0	n.g.	14.0	n.g.	13.9	n.g.	14.1	n.g.	14.1	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.13	n.g.	0.10	n.g.	0.10	n.g.	0.11	n.g.	0.10	n.g.	0.10	n.g.	0.12	n.g.
Mercury - Total	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.8E-05	C
Molybdenum - Total	2.8E-03		8.8E-05		2.1E-04		3.3E-03		1.4E-04		1.8E-04		3.3E-03		2.8E-04		3.1E-04	
Naphthenic Acids	0.12	n.g.	0.06	n.g.	0.06	n.g.	0.13	n.g.	0.06	n.g.	0.06	n.g.	0.13	n.g.	0.07	n.g.	0.07	n.g.
Nickel - Total	7.9E-04		7.9E-05		8.1E-05		7.7E-04		7.7E-05		8.0E-05		7.7E-04		9.6E-05		9.8E-05	
Nitrate	0.17		0.16		0.16		0.17		0.16		0.16		0.17		0.16		0.16	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0006		0.0001		0.0001		0.0003		0.0001		0.0001		0.0004	
Silver - Total	1.0E-05		6.1E-06		6.1E-06		1.1E-05		5.4E-06		5.4E-06		1.1E-05		6.0E-06		6.0E-06	
Sodium	17.6	n.g.	18.2	n.g.	18.2	n.g.	17.9	n.g.	18.1	n.g.	18.1	n.g.	17.9	n.g.	20.2	n.g.	20.3	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	40.2	n.g.	39.8	n.g.	39.1	n.g.	40.6	n.g.	39.8	n.g.	39.1	n.g.	40.6	n.g.	39.8	n.g.	39.3	n.g.
Total Dissolved Solids	246	n.g.	249	n.g.	253	n.g.	246	n.g.	249	n.g.	250	n.g.	246	n.g.	254	n.g.	256	n.g.
Total PAHs	2.3E-05	n.g.	1.2E-05	n.g.	1.2E-05	n.g.	3.5E-05	n.g.	1.2E-05	n.g.	1.2E-05	n.g.	3.5E-05	n.g.	3.0E-05	n.g.	3.0E-05	n.g.
Acute Toxicity (TUa)	0.004		0.0001		9.9E-05		0.006		0.0002		0.0002		0.006		0.0003		0.0003	
Chronic Toxicity (TUc)	0.04		0.01		0.01		0.03		0.01		0.01		0.04		0.01		0.01	
Vanadium - Total	0.008		0.002		0.002		0.008		0.002		0.002		0.008		0.002		0.002	
Zinc - Total	0.008		0.008		0.017		0.008		0.008		0.012		0.008		0.009		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-14 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (CEA)
(Page 2 of 3)

Substance (mg/L)	2020			2025			2030		
	west*	east* below'	east* above'	west*	east* below'	east* above'	west*	east* below'	east* above'
Aluminum - Total	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.07
Ammonia - Total	0.18	0.03	0.05	0.18	0.03	0.05	0.18	0.03	0.05
Antimony - Total	1.2E-05 n.g.	1.3E-06 n.g.	9.2E-06 n.g.	1.2E-05 n.g.	1.4E-06 n.g.	9.4E-06 n.g.	1.2E-05 n.g.	4.7E-07 n.g.	9.1E-06 n.g.
Arsenic - Total	0.0004	0.0004	0.0007	0.0004	0.0004	0.0008	0.0004	0.0004	0.0007
Barium - Total	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Benzo(a)anthracene grp	3.6E-06 n.g.	2.4E-06 n.g.	2.4E-06 n.g.	3.6E-06 n.g.	2.8E-06 n.g.	2.8E-06 n.g.	3.6E-06 n.g.	2.9E-06 n.g.	3.4E-06 n.g.
Benzo(a)pyrene grp	1.3E-06 n.g.	5.0E-07 n.g.	5.0E-07 n.g.	1.3E-06 n.g.	5.8E-07 n.g.	5.9E-07 n.g.	1.3E-06 n.g.	5.9E-07 n.g.	6.3E-07 n.g.
Beryllium-Total	3.1E-05	6.0E-05	7.0E-05	3.1E-05	7.3E-05	8.1E-05	3.1E-05	7.6E-05	9.1E-05
Boron - Total	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Cadmium - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Calcium	50.3 n.g.	50.5 n.g.	51.4 n.g.	50.3 n.g.	50.6 n.g.	51.5 n.g.	50.3 n.g.	50.5 n.g.	51.5 n.g.
Chloride	7.2	12.5	12.5	7.2	14.1	14.2	7.2	14.6	14.7
Chromium - Total	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Conductivity	407 n.g.	423 n.g.	425 n.g.	407 n.g.	427 n.g.	429 n.g.	407 n.g.	429 n.g.	433 n.g.
Copper - Total	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Dissolved Organic Carbon	8.3 n.g.	8.1 n.g.	8.2 n.g.	8.3 n.g.	8.1 n.g.	8.2 n.g.	8.3 n.g.	8.1 n.g.	8.2 n.g.
Iron - Total	0.19	0.21	0.30	0.19	0.21	0.31	0.19	0.20	0.31
Lead - Total	1.0E-04	9.0E-05	1.2E-04	1.0E-04	9.5E-05	1.2E-04	1.0E-04	9.2E-05	1.3E-04
Magnesium	13.9 n.g.	14.1 n.g.	14.1 n.g.	13.9 n.g.	14.1 n.g.	14.1 n.g.	13.9 n.g.	14.2 n.g.	14.2 n.g.
Manganese - Total	0.10 n.g.	0.10 n.g.	0.11 n.g.	0.10 n.g.	0.10 n.g.	0.11 n.g.	0.10 n.g.	0.10 n.g.	0.11 n.g.
Mercury - Total	1.0E-04 C	1.0E-04 C	9.8E-05 C	1.0E-04 C	1.0E-04 C	9.8E-05 C	1.0E-04 C	1.0E-04 C	9.9E-05 C
Molybdenum - Total	6.7E-03	1.5E-03	1.5E-03	6.7E-03	1.5E-03	1.5E-03	6.7E-03	1.4E-03	1.5E-03
Naphthenic Acids	0.24 n.g.	0.08 n.g.	0.08 n.g.	0.24 n.g.	0.09 n.g.	0.09 n.g.	0.24 n.g.	0.09 n.g.	0.09 n.g.
Nickel - Total	1.3E-03	3.4E-04	3.5E-04	1.3E-03	3.7E-04	3.8E-04	1.3E-03	3.9E-04	3.9E-04
Nitrate	0.17	0.16	0.16	0.17	0.16	0.16	0.17	0.16	0.16
Phenolics - Total	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Selenium - Total	0.0001	0.0001	0.0003	0.0001	0.0001	0.0003	0.0001	0.0001	0.0003
Silver - Total	1.8E-05	9.3E-06	9.3E-06	1.8E-05	1.2E-05	1.2E-05	1.8E-05	1.3E-05	1.3E-05
Sodium	33.8 n.g.	29.2 n.g.	29.2 n.g.	33.8 n.g.	30.3 n.g.	30.4 n.g.	33.8 n.g.	30.8 n.g.	31.3 n.g.
Strontium	0.34 n.g.	0.35 n.g.	0.35 n.g.	0.34 n.g.	0.35 n.g.	0.35 n.g.	0.34 n.g.	0.35 n.g.	0.35 n.g.
Sulphate	42.0 n.g.	40.0 n.g.	39.6 n.g.	42.0 n.g.	40.1 n.g.	39.7 n.g.	42.0 n.g.	40.1 n.g.	39.9 n.g.
Total Dissolved Solids	249 n.g.	258 n.g.	259 n.g.	249 n.g.	261 n.g.	262 n.g.	249 n.g.	262 n.g.	264 n.g.
Total PAHs	6.9E-05 n.g.	4.5E-05 n.g.	4.6E-05 n.g.	6.9E-05 n.g.	5.4E-05 n.g.	5.4E-05 n.g.	6.9E-05 n.g.	5.5E-05 n.g.	5.6E-05 n.g.
Acute Toxicity (TUa)	0.009	0.0003	0.0003	0.009	0.0003	0.0003	0.009	0.0003	0.0013
Chronic Toxicity (TUc)	0.06	0.02	0.02	0.06	0.02	0.02	0.06	0.02	0.02
Vanadium - Total	0.008	0.002	0.002	0.008	0.002	0.002	0.008	0.002	0.002
Zinc - Total	0.008	0.009	0.012	0.008	0.009	0.012	0.008	0.008	0.012

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-14 Predicted Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions at 10% River Width. (CEA)
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Substance (mg/L)	2044						Far Future					
	west*		east*				west*		east*			
			below'		above'				below'		above'	
Aluminum - Total	0.06		0.09		0.11	C	0.06		0.06		0.09	
Ammonia - Total	0.05		0.03		0.07		0.05		0.03		0.07	
Antimony - Total	4.1E-06	n.g.	2.1E-05	n.g.	2.4E-05	n.g.	4.1E-06	n.g.	2.0E-06	n.g.	7.6E-06	n.g.
Arsenic - Total	0.0004		0.0005		0.0006		0.0004		0.0004		0.0005	
Barium - Total	0.09		0.09		0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	3.6E-06	n.g.	4.8E-06	n.g.	1.9E-05	n.g.	3.6E-06	n.g.	1.5E-06	n.g.	1.6E-05	n.g.
Benzo(a)pyrene grp	1.1E-06	n.g.	1.1E-06	n.g.	2.7E-06	n.g.	1.1E-06	n.g.	3.1E-07	n.g.	2.0E-06	n.g.
Beryllium-Total	1.9E-05		1.1E-04		1.6E-04		1.9E-05		4.4E-05		9.5E-05	
Boron - Total	0.04		0.09		0.13		0.04		0.04		0.09	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	50.3	n.g.	51.6	n.g.	52.2	n.g.	50.3	n.g.	50.6	n.g.	51.3	n.g.
Chloride	5.4		10.1		10.3		5.4		9.4		9.6	
Chromium - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Conductivity	403	n.g.	440	n.g.	481	n.g.	403	n.g.	415	n.g.	459	n.g.
Copper - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.1	n.g.	9.1	n.g.	9.9	n.g.	8.1	n.g.	8.5	n.g.	9.3	n.g.
Iron - Total	0.18		0.22		0.27		0.18		0.21		0.26	
Lead - Total	4.5E-05		3.0E-04		3.5E-04		4.5E-05		9.6E-05		1.6E-04	
Magnesium	13.9	n.g.	14.2	n.g.	14.4	n.g.	13.9	n.g.	14.1	n.g.	14.3	n.g.
Manganese - Total	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.	0.10	n.g.
Mercury - Total	1.0E-04	C	1.0E-04	C	9.7E-05	C	1.0E-04	C	1.0E-04	C	9.7E-05	C
Molybdenum - Total	3.6E-03		1.6E-02		2.0E-02		3.6E-03		1.6E-03		6.0E-03	
Naphthenic Acids	0.24	n.g.	0.13	n.g.	0.34	n.g.	0.24	n.g.	0.07	n.g.	0.29	n.g.
Nickel - Total	1.5E-04		4.2E-04		4.9E-04		1.5E-04		1.2E-04		2.0E-04	
Nitrate	0.16		0.16		0.16		0.16		0.16		0.16	
Phenolics - Total	0.003		0.003		0.003		0.003		0.003		0.003	
Selenium - Total	0.0001		0.0001		0.0002		0.0001		0.0001		0.0001	
Silver - Total	8.2E-06		3.1E-05		3.5E-05		8.2E-06		1.1E-05		1.6E-05	
Sodium	19.8	n.g.	26.3	n.g.	37.7	n.g.	19.8	n.g.	20.2	n.g.	32.0	n.g.
Strontium	0.34	n.g.	0.36	n.g.	0.36	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	42.6	n.g.	53.1	n.g.	58.4	n.g.	42.6	n.g.	40.6	n.g.	46.6	n.g.
Total Dissolved Solids	247	n.g.	272	n.g.	289	n.g.	247	n.g.	254	n.g.	272	n.g.
Total PAHs	7.3E-05	n.g.	3.9E-04	n.g.	4.7E-04	n.g.	7.3E-05	n.g.	5.5E-05	n.g.	1.6E-04	n.g.
Acute Toxicity (TUa)	0.007		0.003		0.01		0.007		0.001		0.01	
Chronic Toxicity (TUc)	0.03		0.03		0.04		0.03		0.02		0.04	
Vanadium - Total	0.002		0.004		0.004		0.002		0.002		0.003	
Zinc - Total	0.007		0.010		0.011		0.007		0.009		0.010	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic

Table V-15 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (CEA)
(Page 1 of 3)

Substance (mg/L)	2005						2010						2015					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.07		0.01		0.03		0.06		0.01		0.02		0.06		0.01		0.02	
Antimony - Total	4.0E-06		3.1E-08		1.1E-05		4.2E-06		5.4E-08		5.1E-06		4.2E-06		4.2E-07		5.4E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0017	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	5.9E-07		2.4E-07		2.3E-07		8.2E-07		2.5E-07		2.4E-07		8.2E-07		6.3E-07		6.1E-07	
Benzo(a)pyrene grp	2.7E-07		5.0E-08		4.9E-08		3.5E-07		5.4E-08		5.2E-08		3.5E-07		1.3E-07		1.3E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.1E-04	
Boron - Total	0.04		0.05		0.05		0.04		0.05		0.05		0.04		0.05		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.7	n.g.	30.7	n.g.	32.9	n.g.	30.7	n.g.	30.7	n.g.	31.8	n.g.	30.7	n.g.	30.8	n.g.	31.9	n.g.
Chloride	2.5		2.7		2.7		2.6		2.6		2.7		2.6		3.8		3.8	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	232	n.g.	233	n.g.	241	n.g.	232	n.g.	233	n.g.	236	n.g.	232	n.g.	236	n.g.	238	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.5	n.g.	11.0	n.g.	8.5	n.g.	9.5	n.g.	10.9	n.g.	8.5	n.g.	9.5	n.g.	10.9	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.80	C HNC	2.99	C HNC	2.99	C HNC	2.79	C HNC	2.99	C HNC	2.99	C HNC	2.79	C HNC
Lead - Total	2.9E-05		2.4E-06		9.2E-05		3.2E-05		2.5E-06		6.5E-05		3.2E-05		7.0E-06		6.9E-05	
Magnesium	7.7	n.g.	7.8	n.g.	8.0	n.g.	7.7	n.g.	7.8	n.g.	7.9	n.g.	7.7	n.g.	7.8	n.g.	8.0	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.4E-05	C	1.0E-04	C	1.0E-04	C	9.4E-05	C	1.0E-04	C	1.0E-04	C	9.4E-05	C
Molybdenum - Total	1.1E-03		2.9E-05		1.2E-04		1.3E-03		4.8E-05		1.1E-04		1.3E-03		1.0E-04		1.4E-04	
Naphthenic Acids	0.05	n.g.	0.01	n.g.	0.48	n.g.	0.05	n.g.	0.01	n.g.	0.46	n.g.	0.05	n.g.	0.01	n.g.	0.46	n.g.
Nickel - Total	3.1E-04		1.1E-04		1.4E-04		3.0E-04		1.1E-04		1.3E-04		3.0E-04		1.1E-04		1.4E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0004		0.0002		0.0002		0.0003		0.0002		0.0002		0.0003	
Silver - Total	4.0E-06		2.2E-06		2.0E-06		4.3E-06		2.0E-06		1.8E-06		4.3E-06		2.2E-06		2.0E-06	
Sodium	7.1	n.g.	7.4	n.g.	7.8	n.g.	7.2	n.g.	7.4	n.g.	7.7	n.g.	7.2	n.g.	8.2	n.g.	8.4	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	19.6	n.g.	19.4	n.g.	17.8	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.	19.8	n.g.	19.4	n.g.	17.9	n.g.
Total Dissolved Solids	151	n.g.	151	n.g.	155	n.g.	151	n.g.	151	n.g.	152	n.g.	151	n.g.	153	n.g.	154	n.g.
Total PAHs	9.0E-06	n.g.	4.5E-06	n.g.	4.3E-06	n.g.	1.4E-05	n.g.	4.6E-06	n.g.	4.4E-06	n.g.	1.4E-05	n.g.	1.1E-05	n.g.	1.1E-05	n.g.
Acute Toxicity (TUa)	0.001		3.9E-05		9.0E-05		0.002		7.0E-05		0.0002		0.002		0.0001		0.0002	
Chronic Toxicity (TUc)	0.02		0.003		0.003		0.01		0.002		0.002		0.01		0.002		0.002	
Vanadium - Total	0.006		0.004		0.004		0.006		0.004		0.004		0.006		0.004		0.004	
Zinc - Total	0.011		0.012		0.016		0.011		0.012		0.014		0.011		0.012		0.014	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-15 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (CEA)
(Page 2 of 3)

Substance (mg/L)	2020						2025						2030					
	west*		east*				west*		east*				west*		east*			
			below'		above'				below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.63	C
Ammonia - Total	0.07		0.01		0.02		0.07		0.01		0.02		0.07		0.01		0.03	
Antimony - Total	4.9E-06		4.6E-07		4.7E-06		4.9E-06		5.2E-07		4.5E-06		4.9E-06		1.8E-07		2.0E-05	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0014	HC	0.0012	HC	0.0012	HC	0.0015	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.4E-06		8.8E-07		8.3E-07		1.4E-06		1.0E-06		9.7E-07		1.4E-06		1.1E-06		3.6E-06	HC
Benzo(a)pyrene grp	5.3E-07		1.8E-07		1.8E-07		5.3E-07		2.2E-07		2.0E-07		5.3E-07		2.2E-07		7.3E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.1E-04		1.0E-03		1.0E-03		9.2E-04		1.0E-03		1.0E-03		9.4E-04	
Boron - Total	0.04		0.05		0.05		0.04		0.05		0.05		0.04		0.05		0.09	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.8	n.g.	30.8	n.g.	31.8	n.g.	30.8	n.g.	30.8	n.g.	31.8	n.g.	30.8	n.g.	30.8	n.g.	33.2	n.g.
Chloride	2.6		4.6		4.4		2.6		5.2		4.9		2.6		5.3		5.6	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	234	n.g.	238	n.g.	240	n.g.	234	n.g.	240	n.g.	241	n.g.	234	n.g.	240	n.g.	270	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.5	n.g.	10.9	n.g.	8.5	n.g.	9.5	n.g.	10.9	n.g.	8.5	n.g.	9.5	n.g.	11.7	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.79	C HNC	2.99	C HNC	2.99	C HNC	2.79	C HNC	2.99	C HNC	2.99	C HNC	2.79	C HNC
Lead - Total	4.0E-05		9.4E-06		6.8E-05		4.0E-05		1.1E-05		6.9E-05		4.0E-05		1.0E-05		2.6E-04	
Magnesium	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.0	n.g.	7.8	n.g.	7.8	n.g.	8.2	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC	0.40	HNC	0.40	HNC	0.37	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.4E-05	C
Molybdenum - Total	2.7E-03		5.4E-04		4.9E-04		2.7E-03		5.5E-04		5.0E-04		2.7E-03		5.3E-04		1.3E-02	
Naphthenic Acids	0.10	n.g.	0.01	n.g.	0.46	n.g.	0.10	n.g.	0.02	n.g.	0.46	n.g.	0.10	n.g.	0.02	n.g.	0.48	n.g.
Nickel - Total	5.0E-04		2.0E-04		2.2E-04		5.0E-04		2.1E-04		2.2E-04		5.0E-04		2.2E-04		4.8E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0003		0.0002		0.0002		0.0003		0.0002		0.0002		0.0003	
Silver - Total	7.2E-06		3.4E-06		3.1E-06		7.2E-06		4.3E-06		3.8E-06		7.2E-06		4.8E-06		2.1E-05	
Sodium	13.8	n.g.	11.5	n.g.	11.2	n.g.	13.8	n.g.	11.9	n.g.	11.5	n.g.	13.8	n.g.	12.1	n.g.	18.1	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	20.4	n.g.	19.5	n.g.	18.0	n.g.	20.4	n.g.	19.5	n.g.	18.1	n.g.	20.4	n.g.	19.6	n.g.	27.1	n.g.
Total Dissolved Solids	152	n.g.	154	n.g.	155	n.g.	152	n.g.	155	n.g.	156	n.g.	152	n.g.	156	n.g.	177	n.g.
Total PAHs	2.8E-05	n.g.	1.7E-05	n.g.	1.6E-05	n.g.	2.8E-05	n.g.	2.0E-05	n.g.	1.9E-05	n.g.	2.8E-05	n.g.	2.0E-05	n.g.	3.0E-04	n.g.
Acute Toxicity (TUa)	0.004		0.0001		0.0002		0.004		0.0001		0.0002		0.004		0.0001		0.002	
Chronic Toxicity (TUc)	0.03		0.006		0.006		0.03		0.006		0.006		0.03		0.006		0.008	
Vanadium - Total	0.006		0.004		0.004		0.006		0.004		0.004		0.006		0.004		0.005	
Zinc - Total	0.011		0.012		0.014		0.011		0.012		0.014		0.011		0.012		0.014	

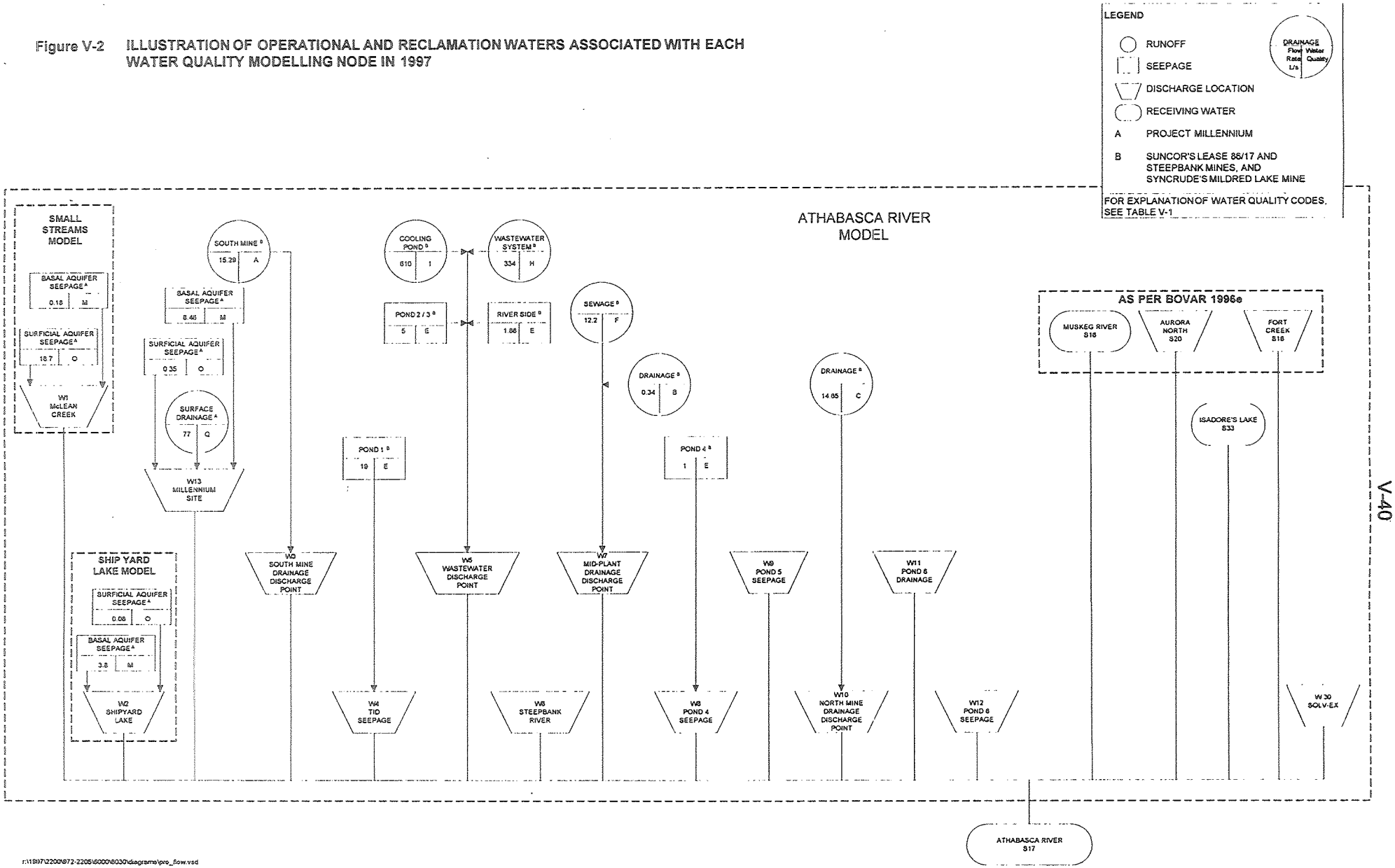
* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Table V-15 Predicted Water Quality in the Athabasca River During Mean Open-Water Flow Conditions at 10% River Width. (CEA)
(Page 3 of 3)

Substance (mg/L)	2044						Far Future					
	west*		east*				west*		east*			
			below'		above'				below'		above'	
Aluminum - Total	0.68	C	0.68	C	0.62	C	0.68	C	0.68	C	0.62	C
Ammonia - Total	0.02		0.01		0.03		0.02		0.01		0.03	
Antimony - Total	1.7E-06		7.6E-06		7.8E-06		1.7E-06		7.1E-07		2.3E-06	
Arsenic - Total	0.0012	HC	0.0012	HC	0.0013	HC	0.0012	HC	0.0012	HC	0.0013	HC
Barium - Total	0.07		0.07		0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.5E-06		1.8E-06		6.6E-06	HC	1.5E-06		5.7E-07		5.7E-06	HC
Benzo(a)pyrene grp	4.4E-07		3.9E-07		8.9E-07		4.4E-07		1.2E-07		6.8E-07	
Beryllium-Total	1.0E-03		1.0E-03		9.2E-04		1.0E-03		1.0E-03		9.1E-04	
Boron - Total	0.04		0.06		0.08		0.04		0.05		0.06	
Cadmium - Total	0.001		0.001		0.001		0.001		0.001		0.001	
Calcium	30.8	n.g.	31.3	n.g.	32.0	n.g.	30.8	n.g.	30.9	n.g.	31.7	n.g.
Chloride	1.9		3.7		3.7		1.9		3.4		3.4	
Chromium - Total	0.004		0.004		0.004		0.004		0.004		0.004	
Conductivity	232	n.g.	245	n.g.	259	n.g.	232	n.g.	236	n.g.	252	n.g.
Copper - Total	0.004		0.004		0.003		0.004		0.004		0.003	
Dissolved Organic Carbon	8.5	n.g.	9.8	n.g.	11.4	n.g.	8.5	n.g.	9.6	n.g.	11.2	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.77	C HNC	2.99	C HNC	2.99	C HNC	2.77	C HNC
Lead - Total	1.8E-05		8.8E-05		1.4E-04		1.8E-05		1.1E-05		8.4E-05	
Magnesium	7.7	n.g.	7.9	n.g.	8.1	n.g.	7.7	n.g.	7.8	n.g.	8.1	n.g.
Manganese - Total	0.40	HNC	0.40	HNC	0.36	HNC	0.40	HNC	0.40	HNC	0.36	HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C	1.0E-04	C	9.5E-05	C
Molybdenum - Total	1.4E-03		6.0E-03		6.3E-03		1.4E-03		5.7E-04		2.0E-03	
Naphthenic Acids	0.10	n.g.	0.03	n.g.	0.52	n.g.	0.10	n.g.	0.01	n.g.	0.50	n.g.
Nickel - Total	6.0E-05		2.3E-04		2.7E-04		6.0E-05		1.2E-04		1.8E-04	
Nitrate	0.00		0.00		0.01		0.00		0.00		0.01	
Phenolics - Total	0.002		0.002		0.002		0.002		0.002		0.002	
Selenium - Total	0.0002		0.0002		0.0002		0.0002		0.0002		0.0002	
Silver - Total	3.3E-06		1.2E-05		1.1E-05		3.3E-06		3.8E-06		5.0E-06	
Sodium	8.0	n.g.	10.5	n.g.	14.5	n.g.	8.0	n.g.	8.2	n.g.	12.7	n.g.
Strontium	0.22	n.g.	0.23	n.g.	0.21	n.g.	0.22	n.g.	0.22	n.g.	0.21	n.g.
Sulphate	20.6	n.g.	24.5	n.g.	22.9	n.g.	20.6	n.g.	19.9	n.g.	19.3	n.g.
Total Dissolved Solids	151	n.g.	160	n.g.	165	n.g.	151	n.g.	153	n.g.	160	n.g.
Total PAHs	3.0E-05	n.g.	1.4E-04	n.g.	1.5E-04	n.g.	3.0E-05	n.g.	2.0E-05	n.g.	5.5E-05	n.g.
Acute Toxicity (TUa)	0.003		0.001		0.004		0.003		0.0002		0.003	
Chronic Toxicity (TUc)	0.01		0.01		0.01		0.01		0.008		0.01	
Vanadium - Total	0.004		0.005		0.004		0.004		0.004		0.004	
Zinc - Total	0.011		0.012		0.013		0.011		0.012		0.012	

* west and east = at 10% river width on the west and east sides of the Athabasca River; 'above and below = above and below the Muskeg River
n.g. = no guideline, A = aquatic life acute, C = aquatic life chronic, HNC = human heath carcinogen, HNC = human health non-carcinogen

Figure V-2 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 1997



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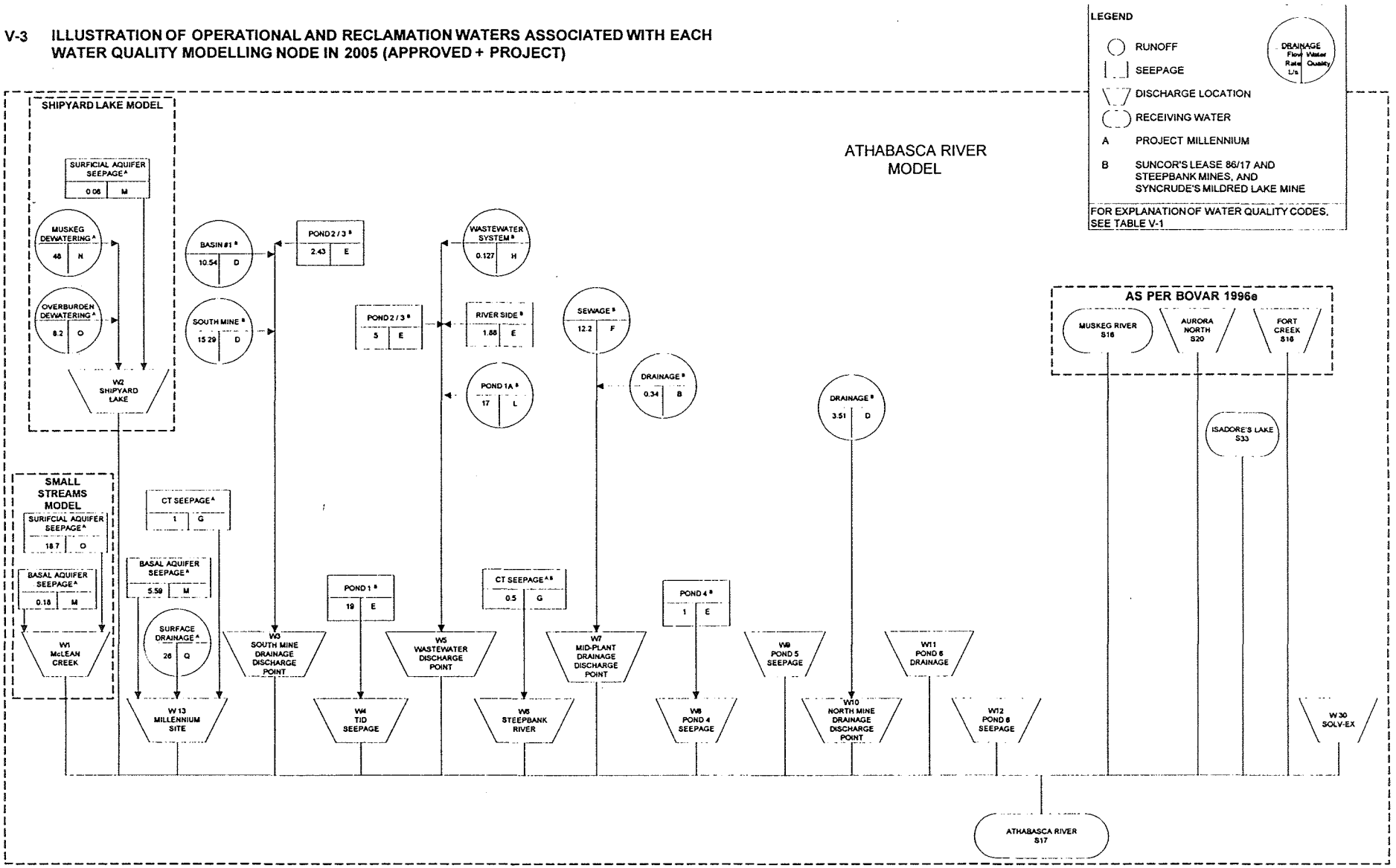
Date Last Revision: 9 Apr 98

Figure V-3 **ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2005 (APPROVED + PROJECT)**



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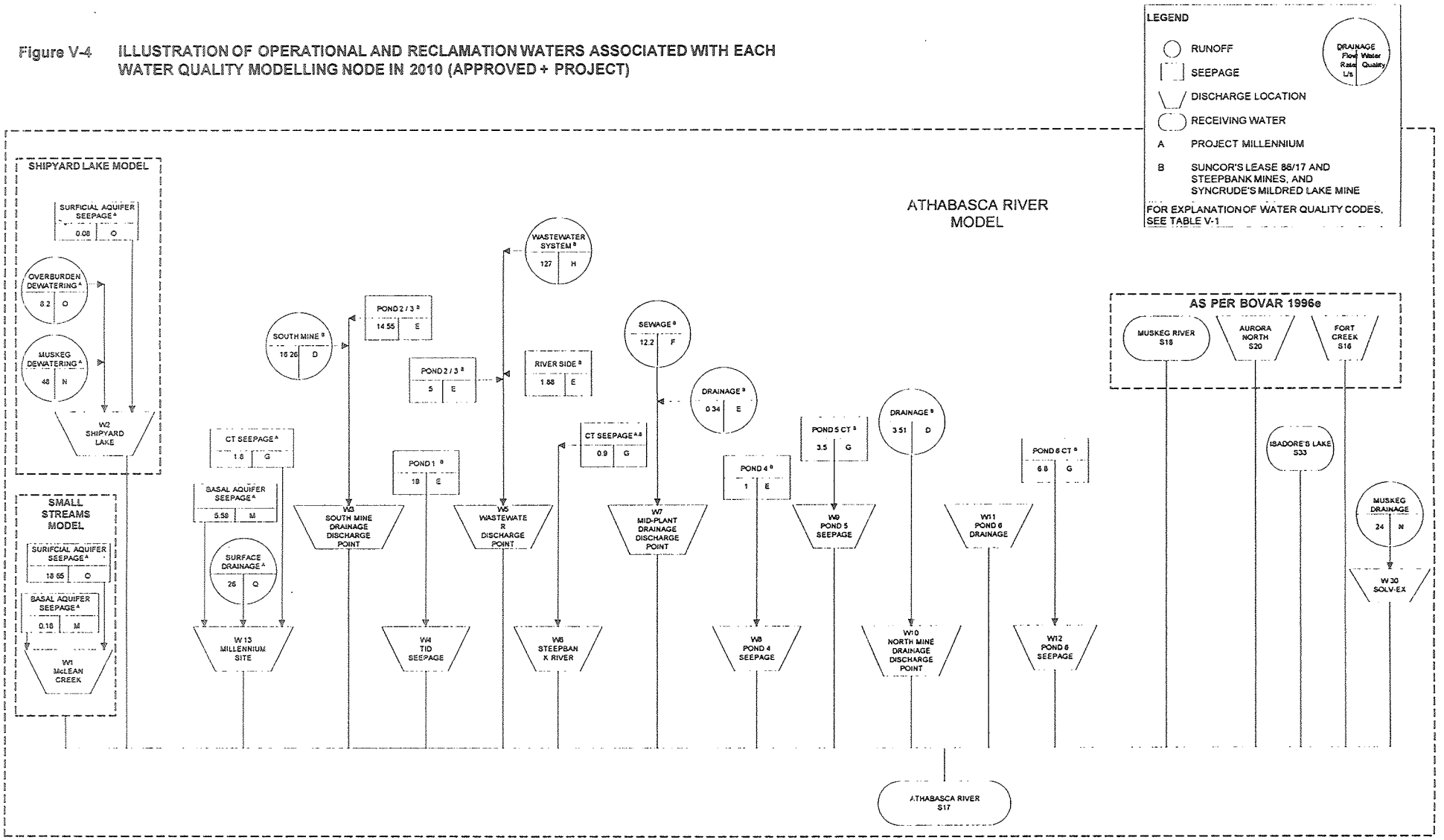
Data Last Revision: 9 Apr 98

Figure V-4 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2010 (APPROVED + PROJECT)



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Date Last Revision: 9 Apr 98

Figure V-5 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2015 (APPROVED + PROJECT)

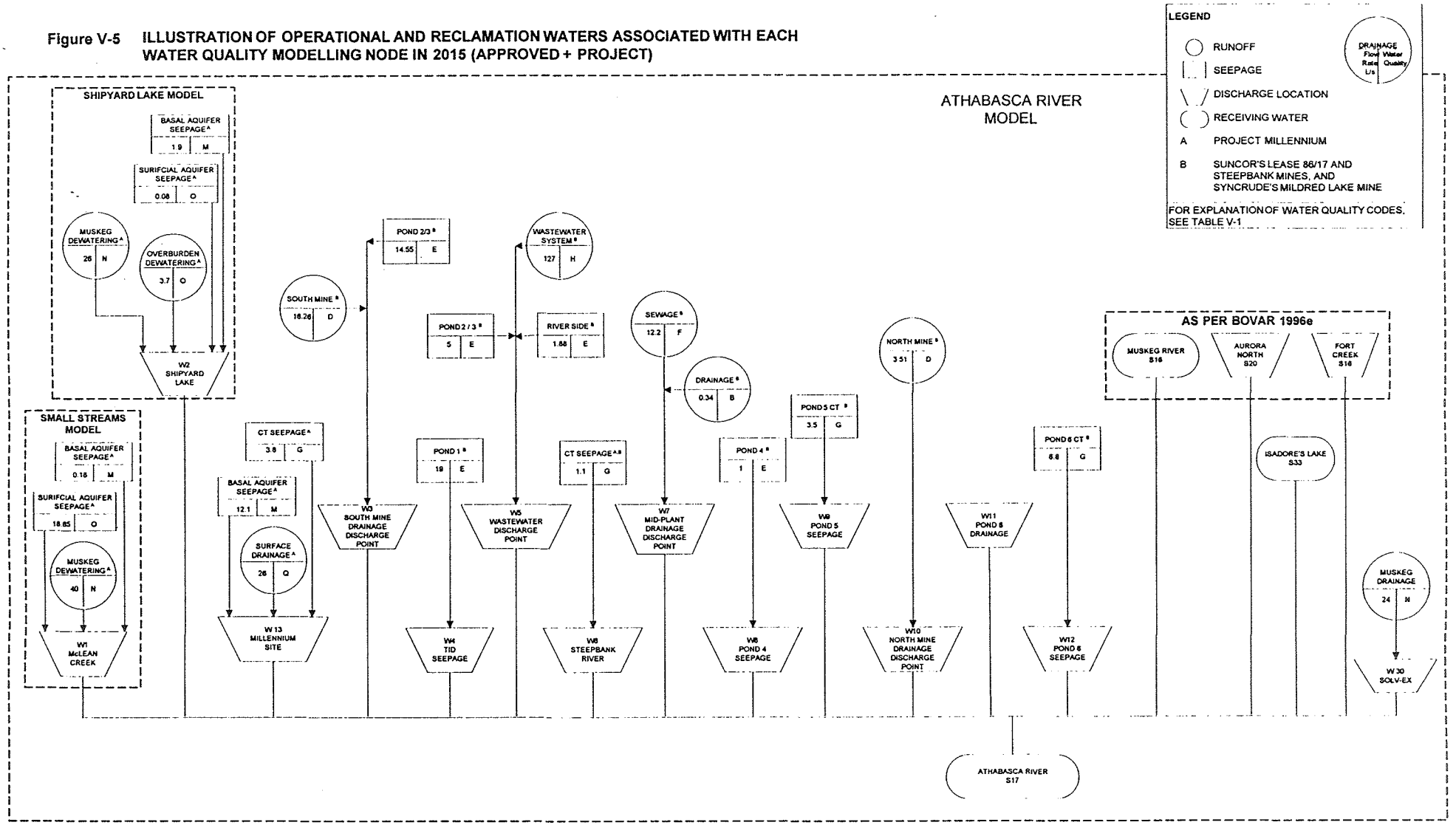

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Figure V-6 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2020 (APPROVED + PROJECT)

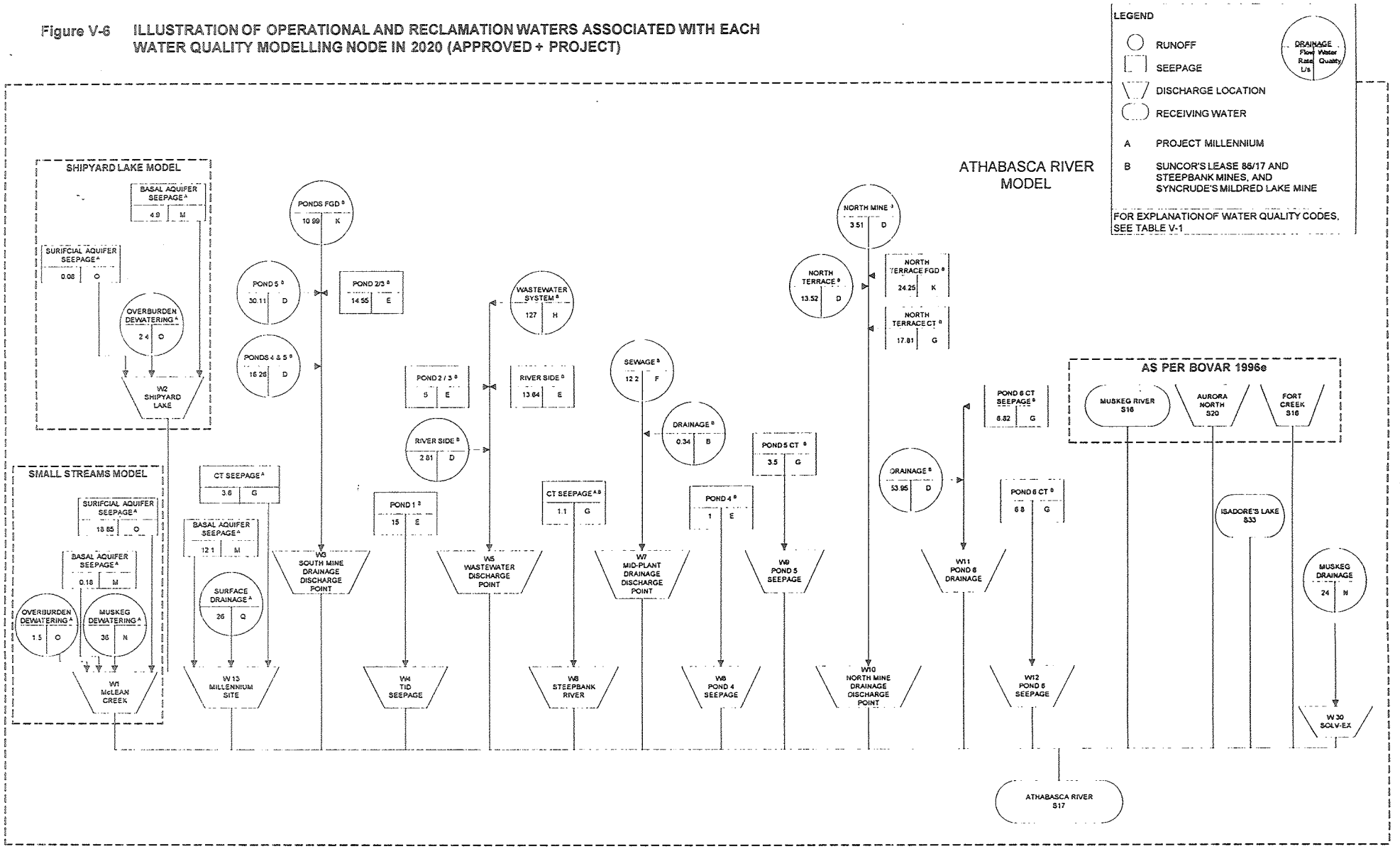

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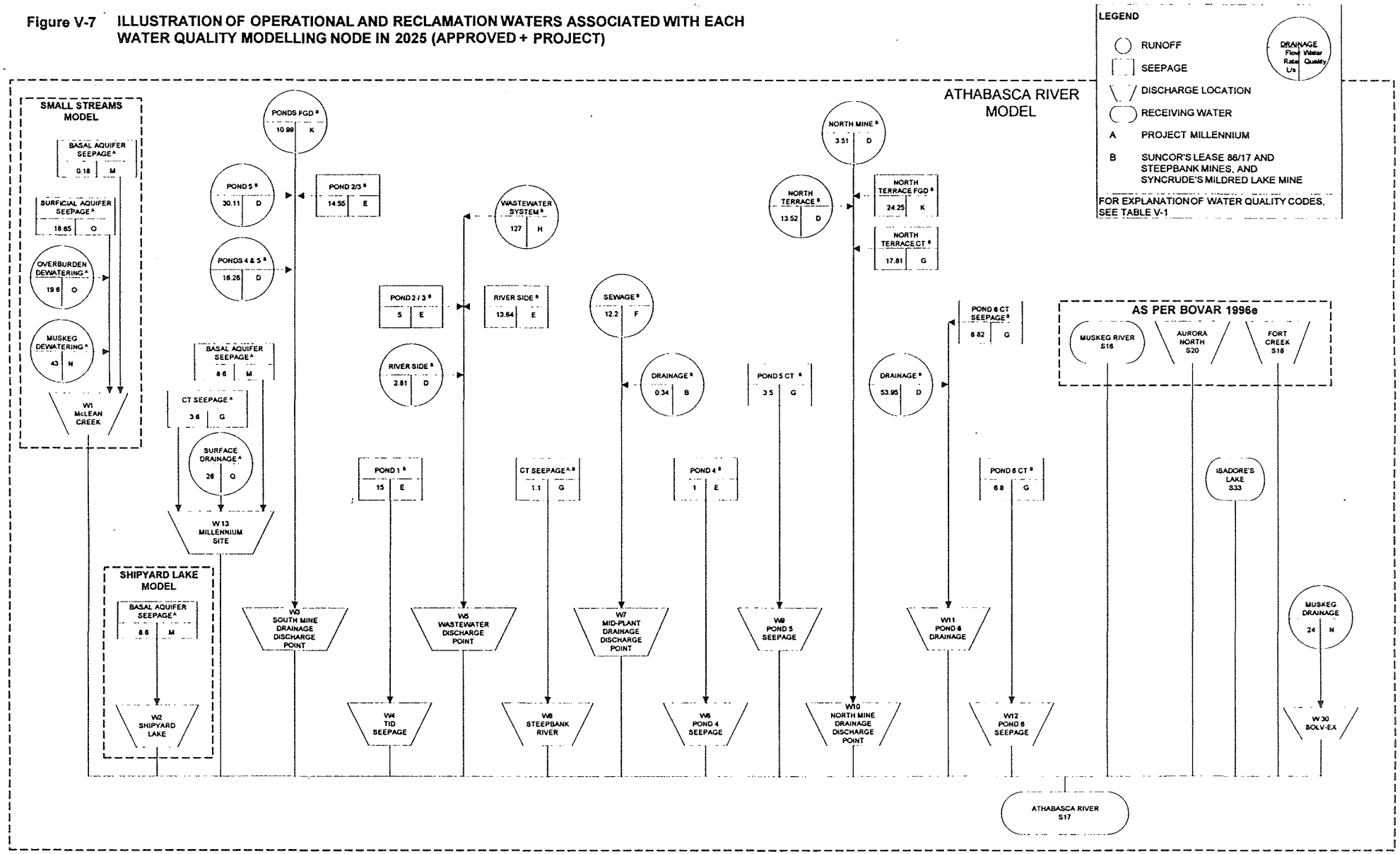
Figure V-7 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2025 (APPROVED + PROJECT)



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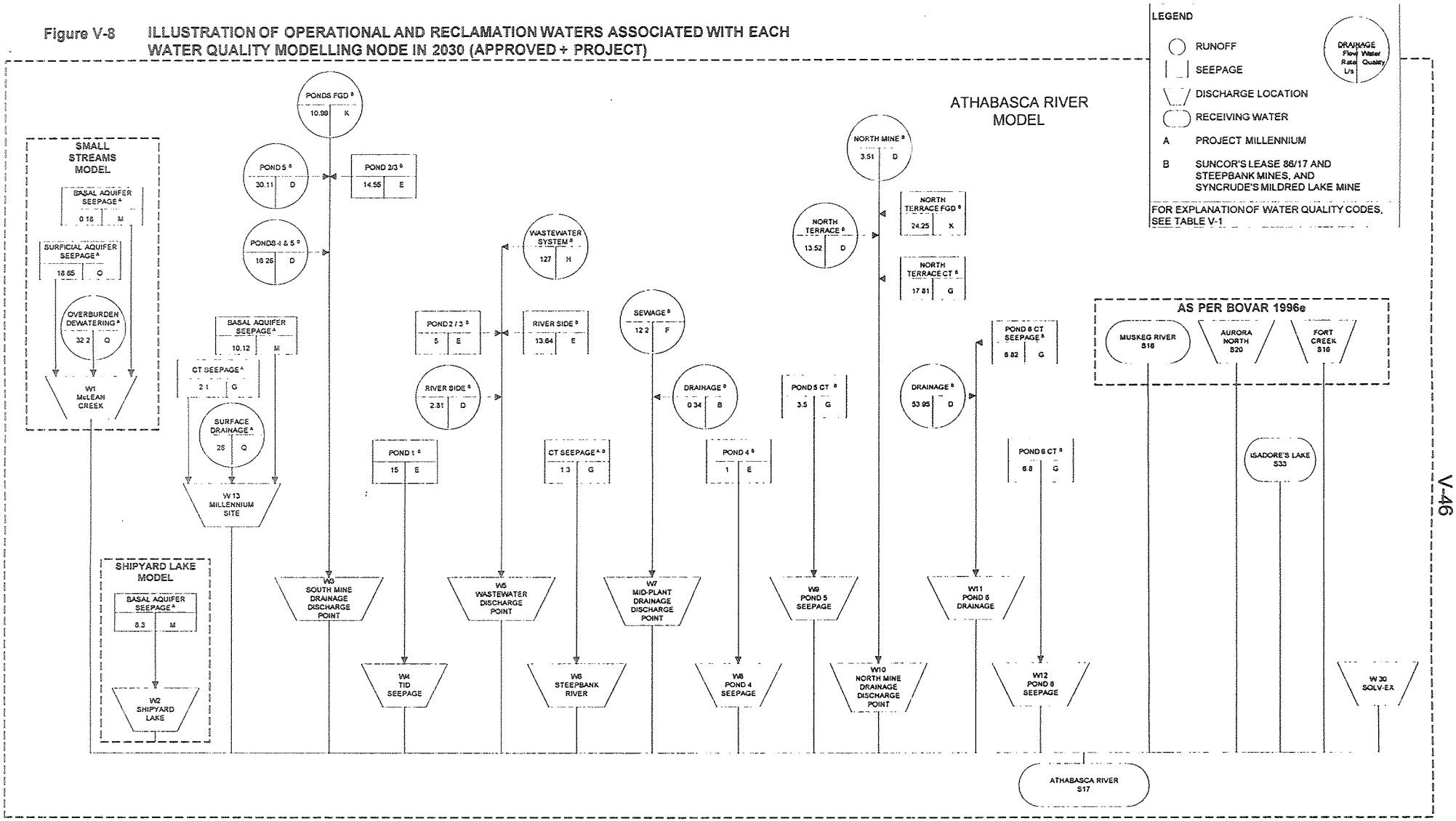
Data Last Revision: 9 Apr 98

Figure V-8 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2030 (APPROVED + PROJECT)



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Date Last Revision: 9 Apr 98

Figure V-9 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2045 (APPROVED + PROJECT)

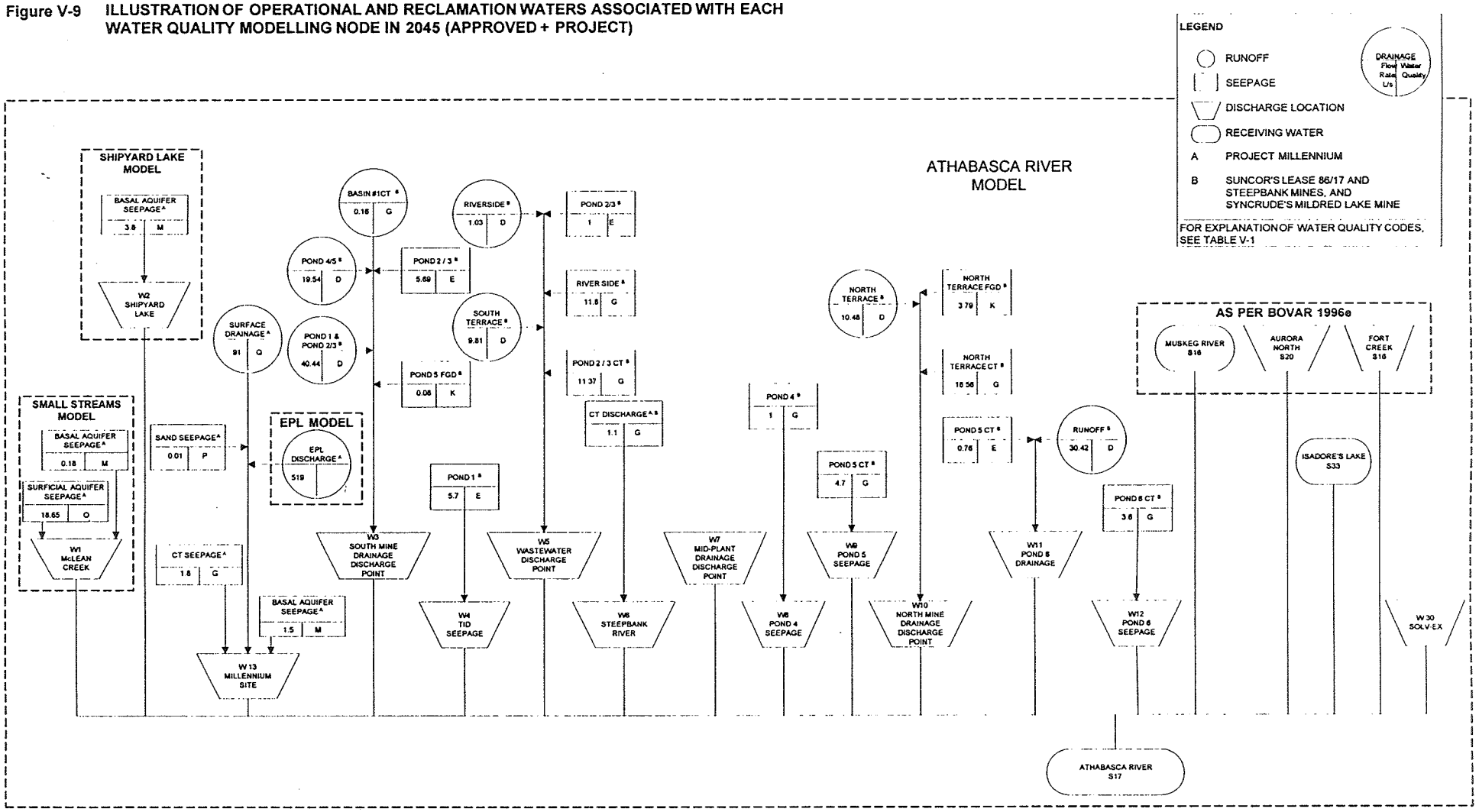

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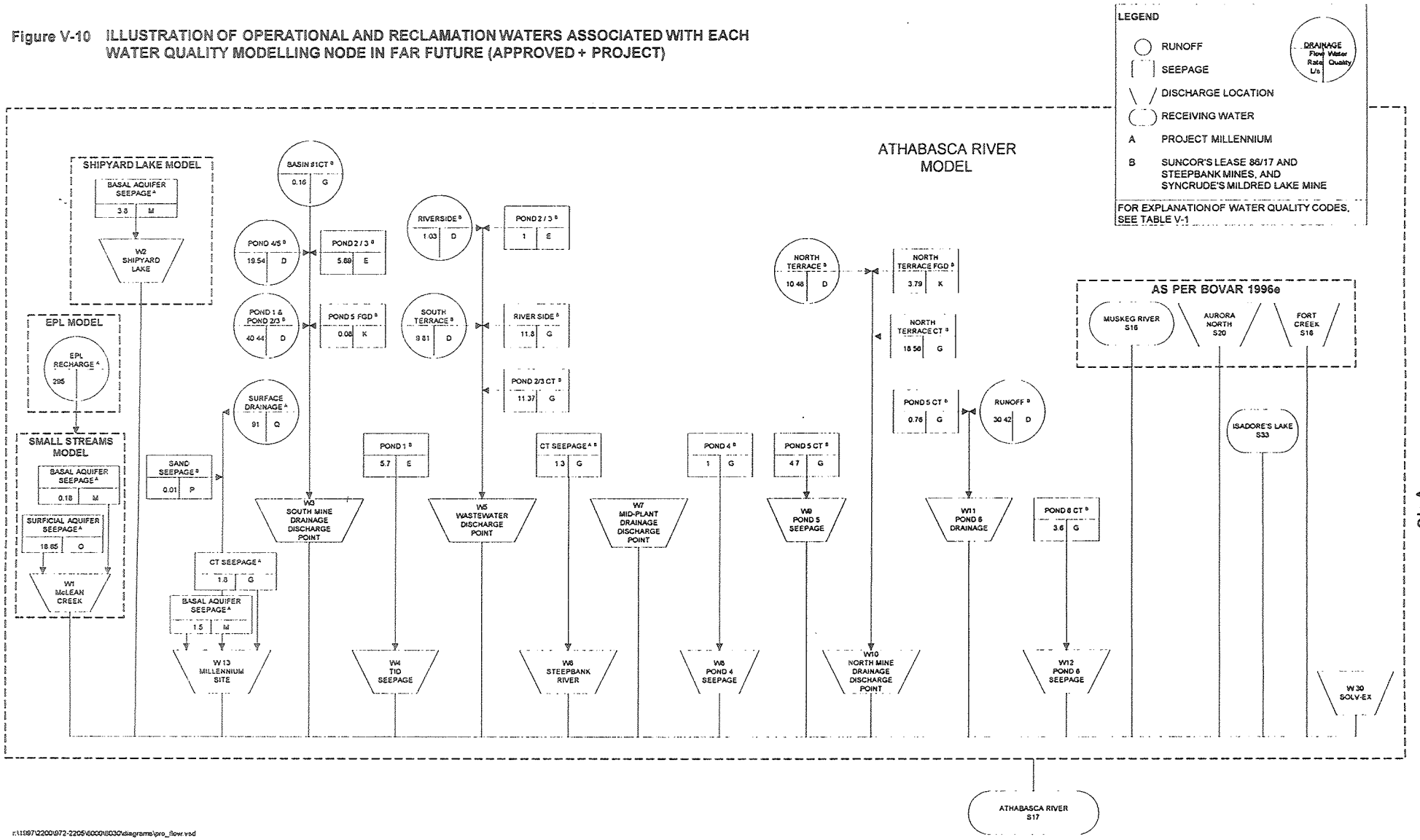
Figure V-10 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN FAR FUTURE (APPROVED + PROJECT)



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Date Last Revision: 9 Apr 98

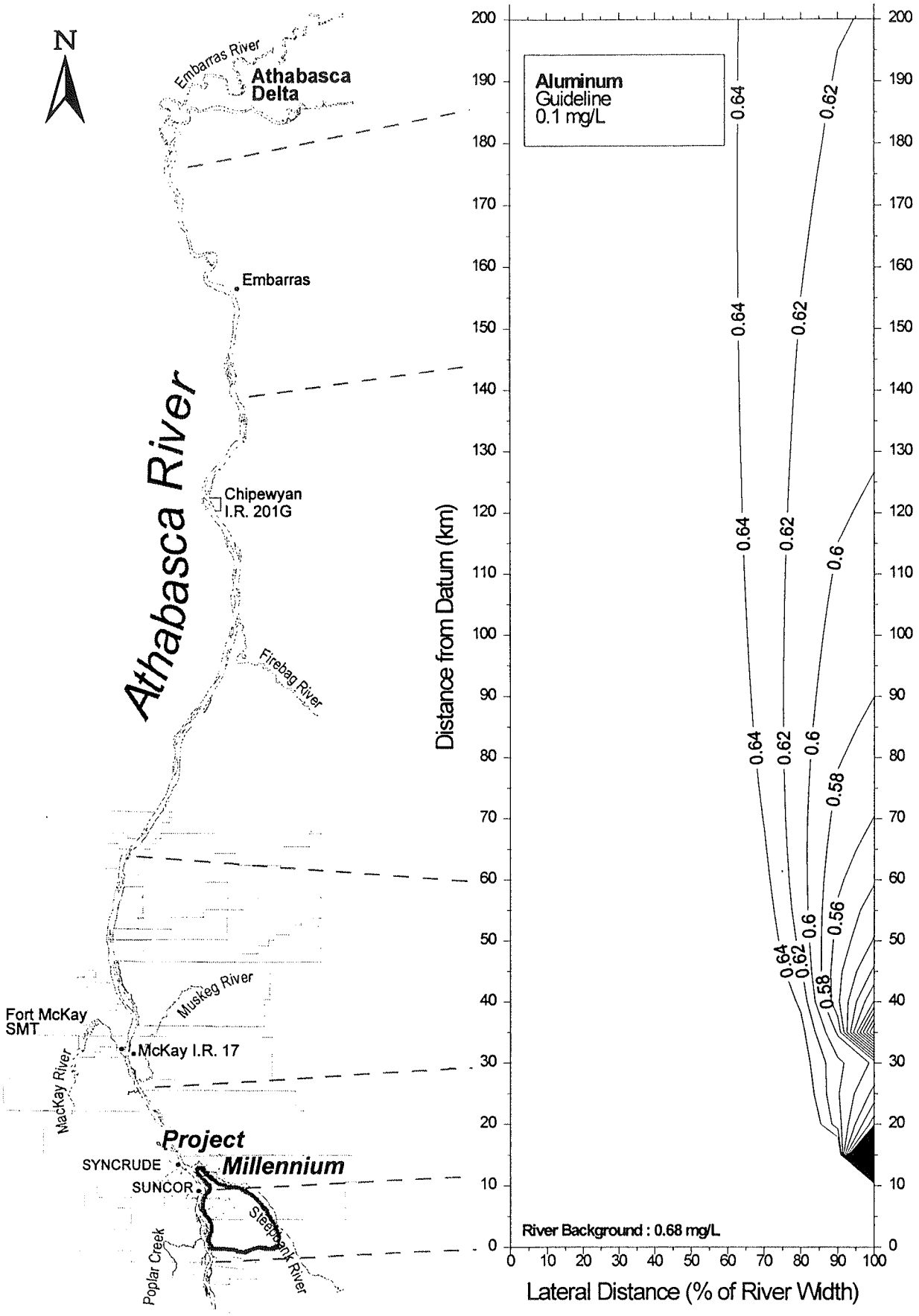

Figure V-11: Aluminum Concentrations in the Athabasca River 2045, mean open water flow (Project)

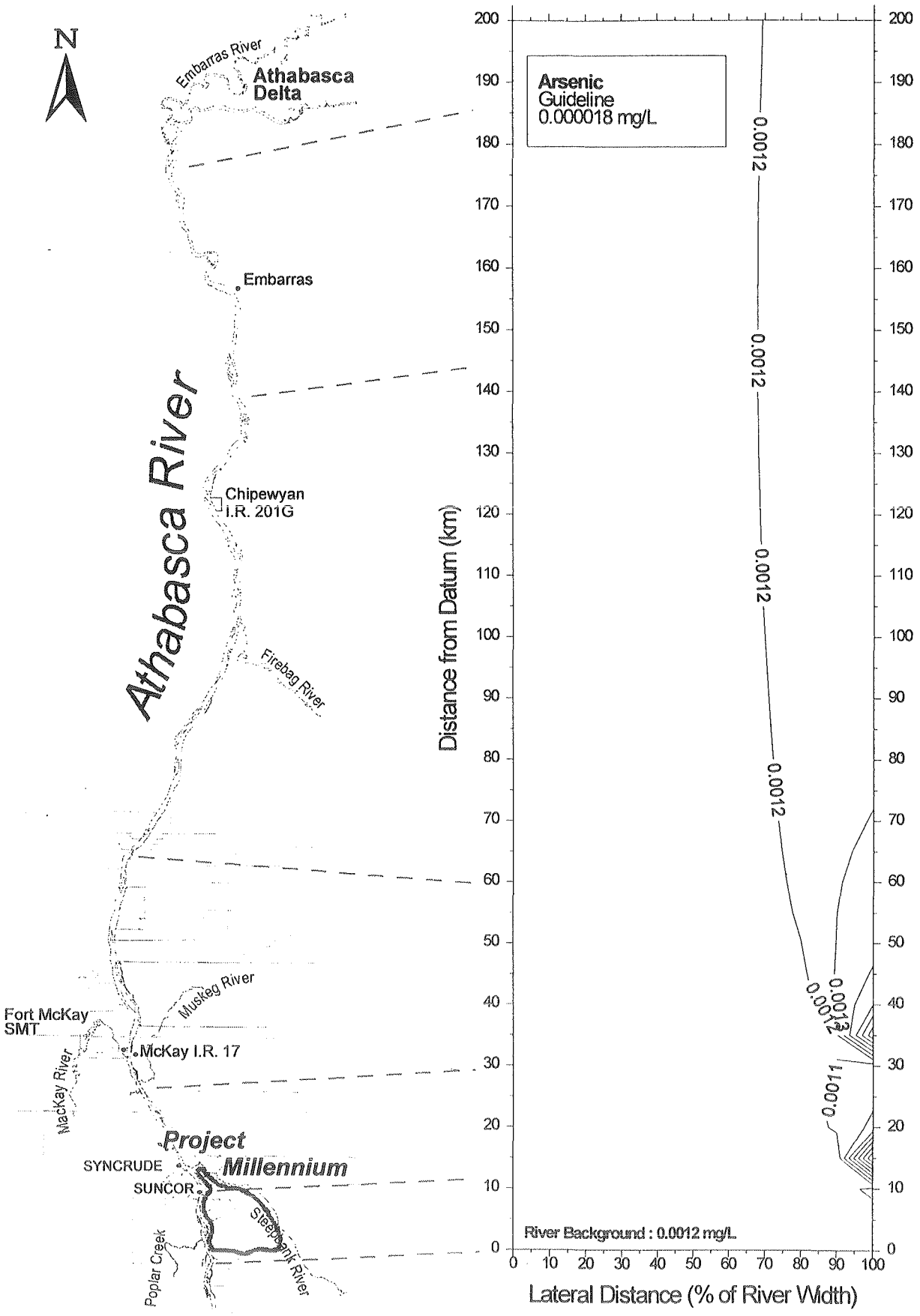

Figure V-12: Arsenic Concentrations in the Athabasca River 2045, mean open water flow (Project)

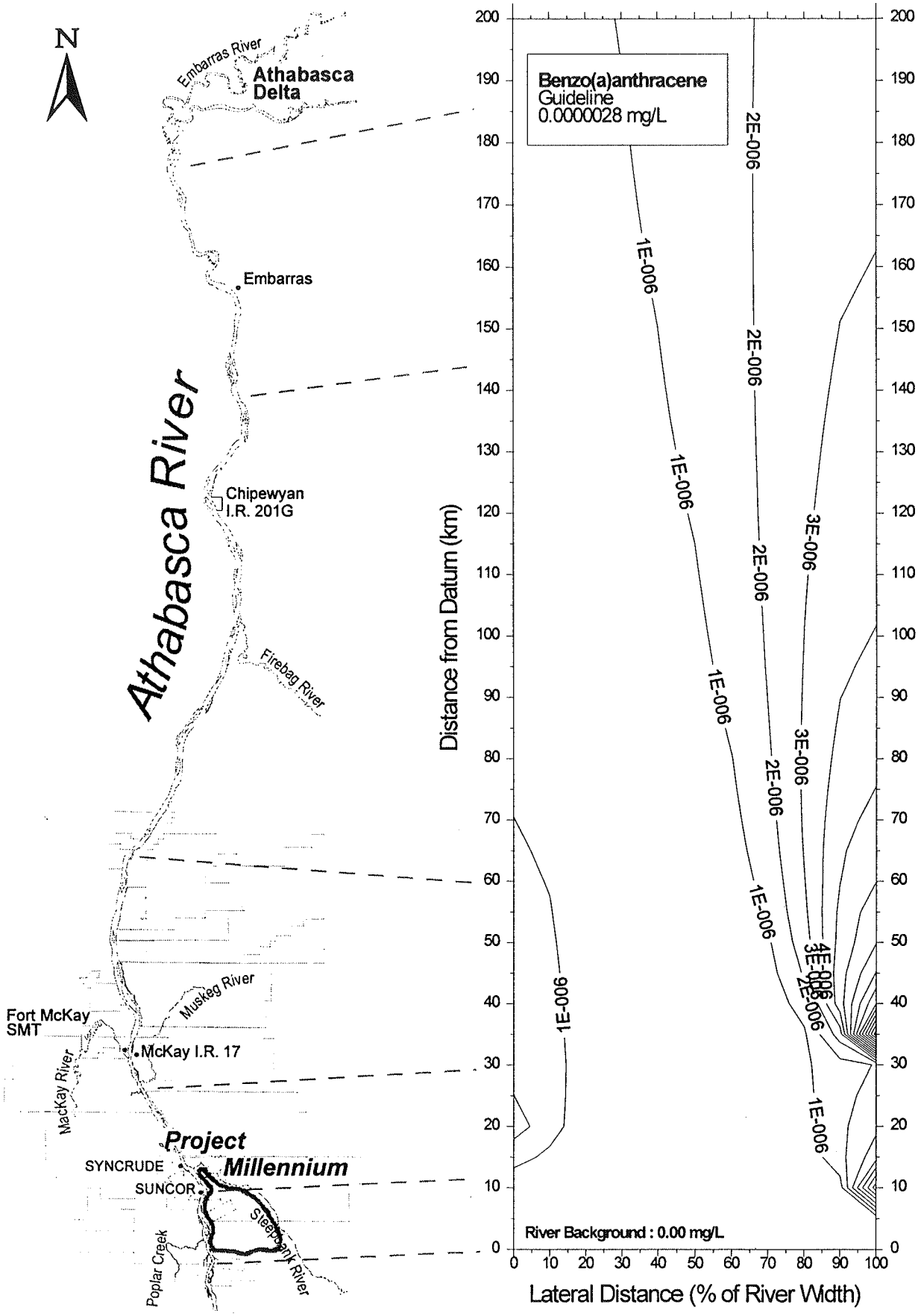

Figure V-13: Benzo(a)anthracene Group Concentrations in the Athabasca River 2045, mean open water flow (Project)

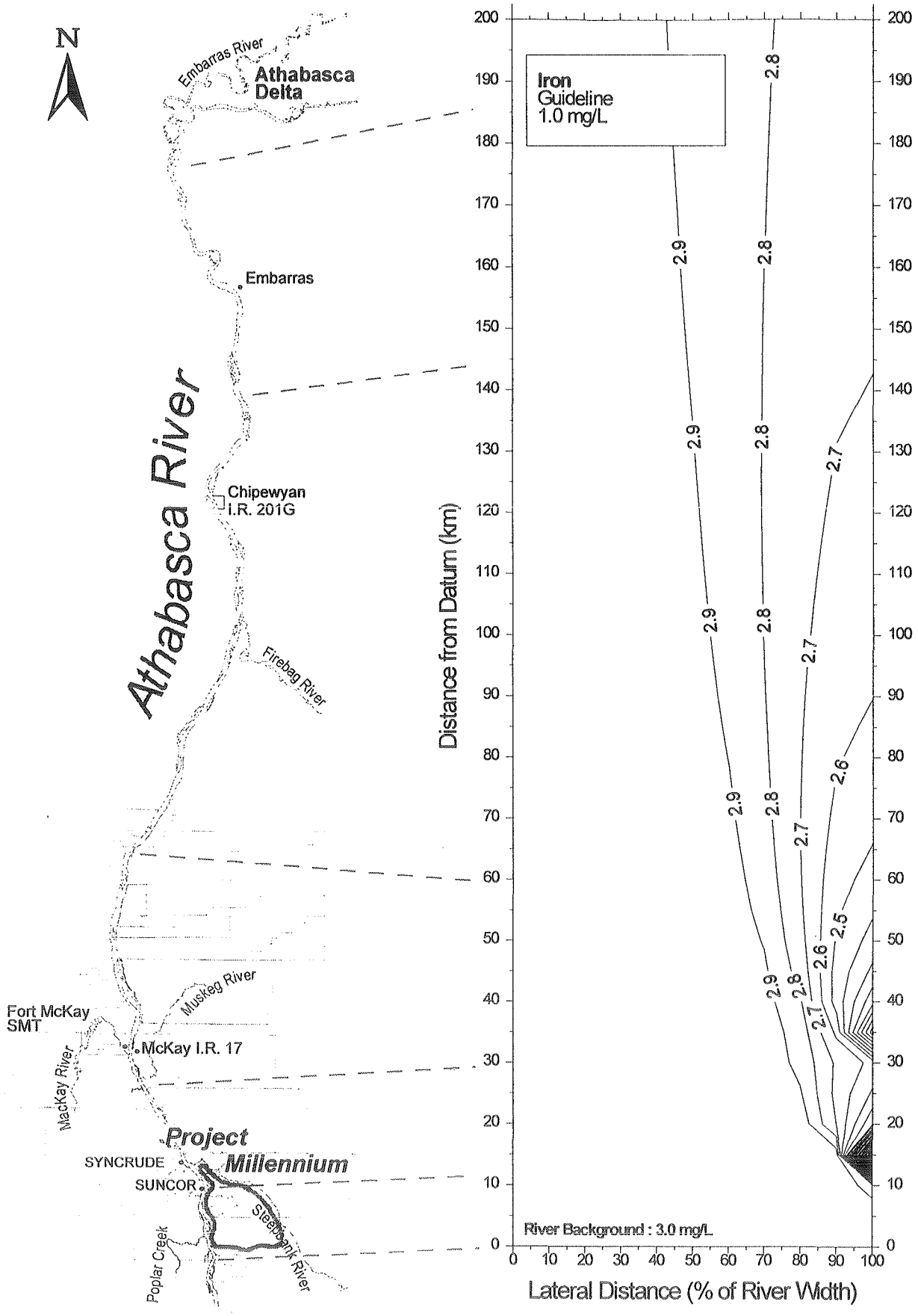

Figure V-14: Iron Concentrations in the Athabasca River 2045, mean open water flow (Project)

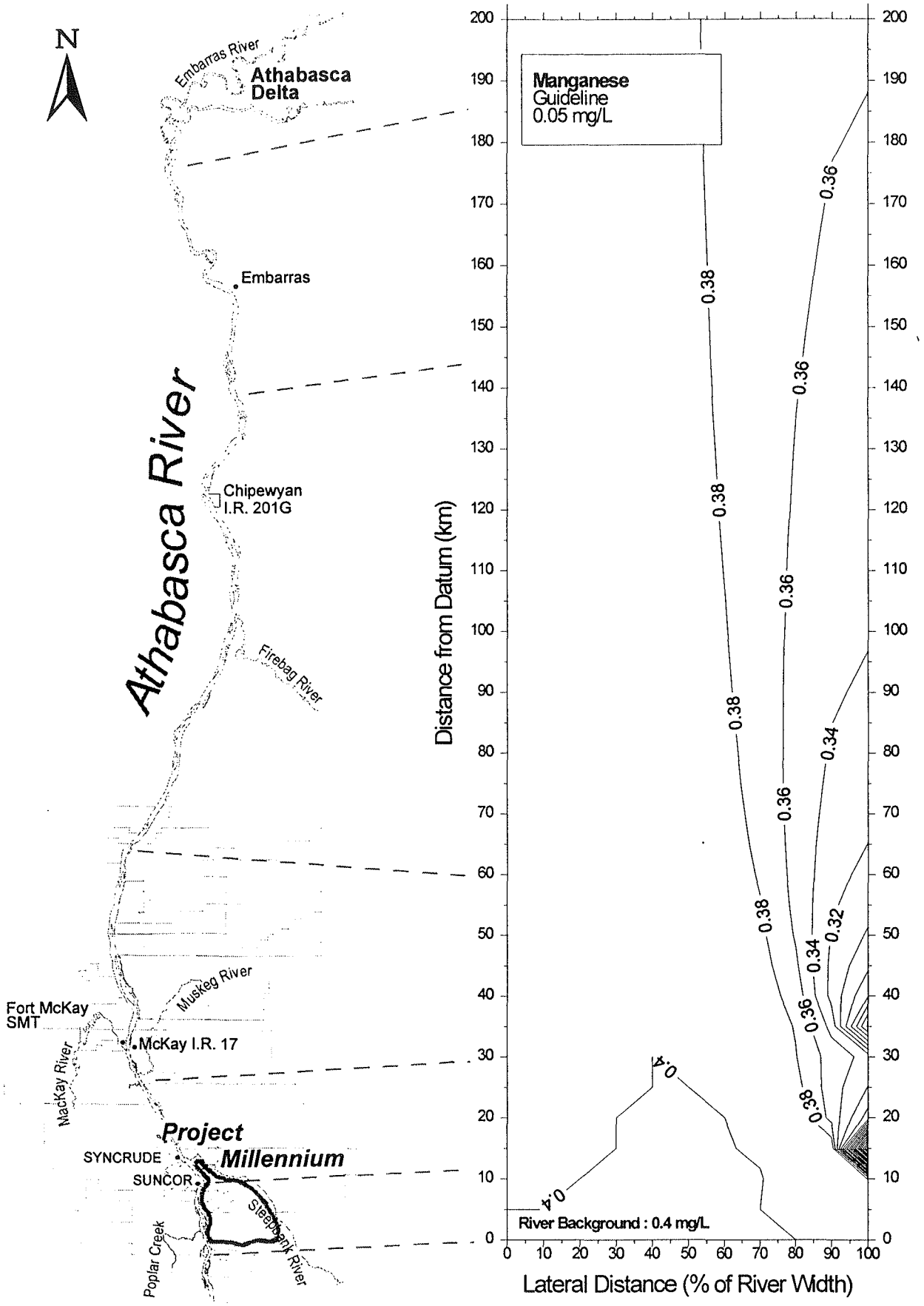

Figure V-15: Manganese Concentrations in the Athabasca River 2045, mean open water flow (Project)

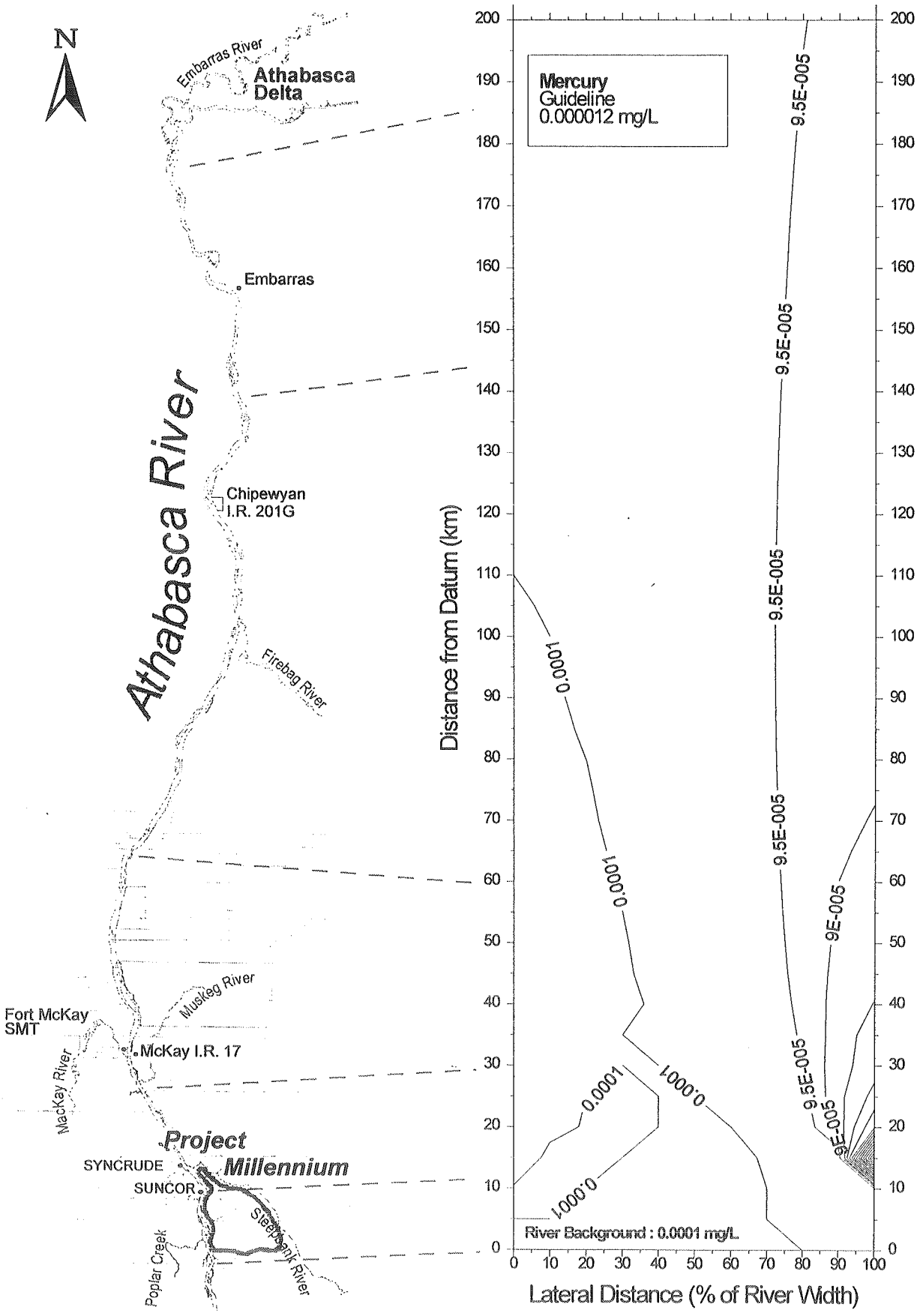

Figure V-16: Mercury Concentrations in the Athabasca River 2045, mean open water flow (Project)

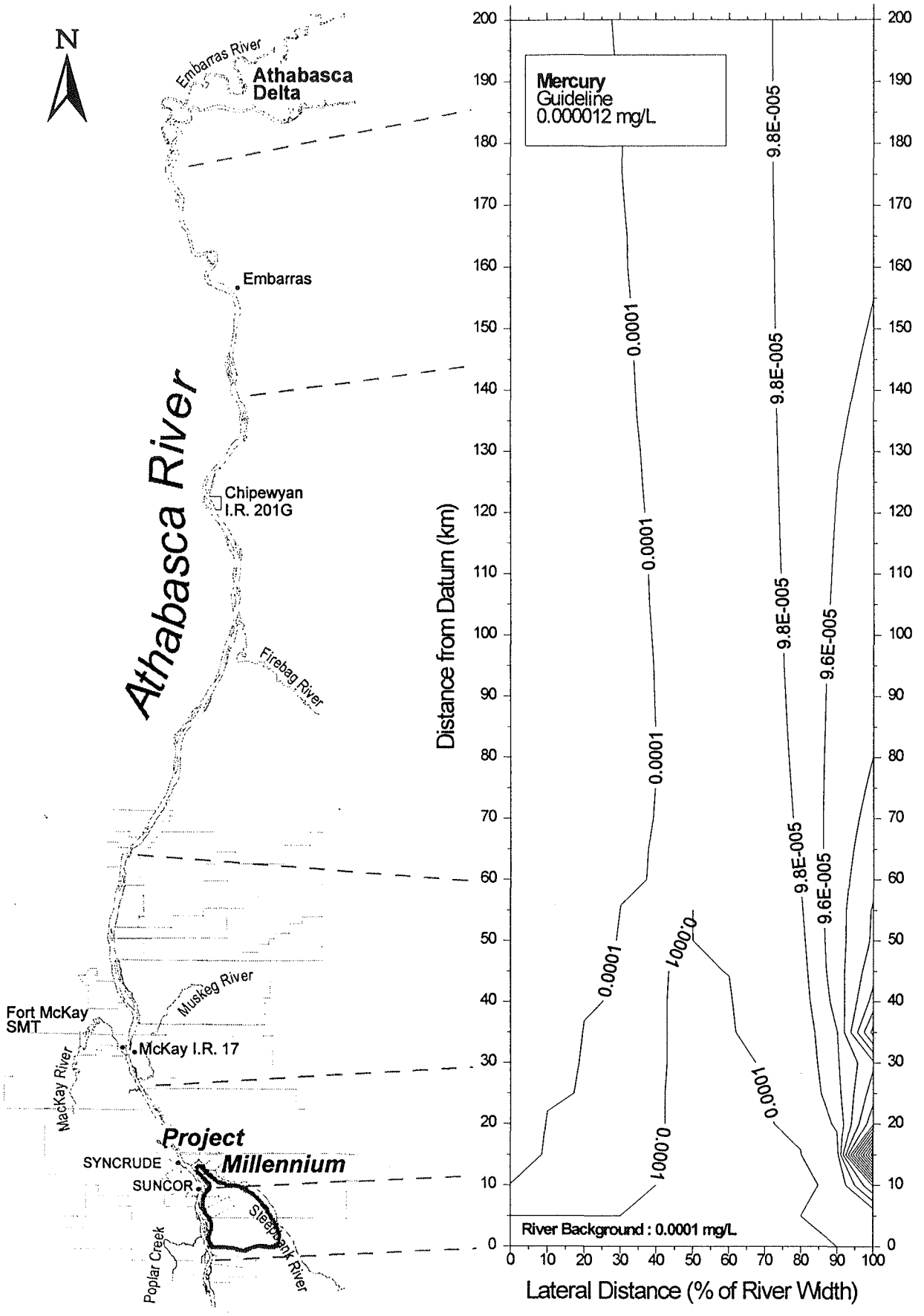

Figure V-17: Mercury Concentrations in the Athabasca River 2045, annual 7Q10 flow (Project)

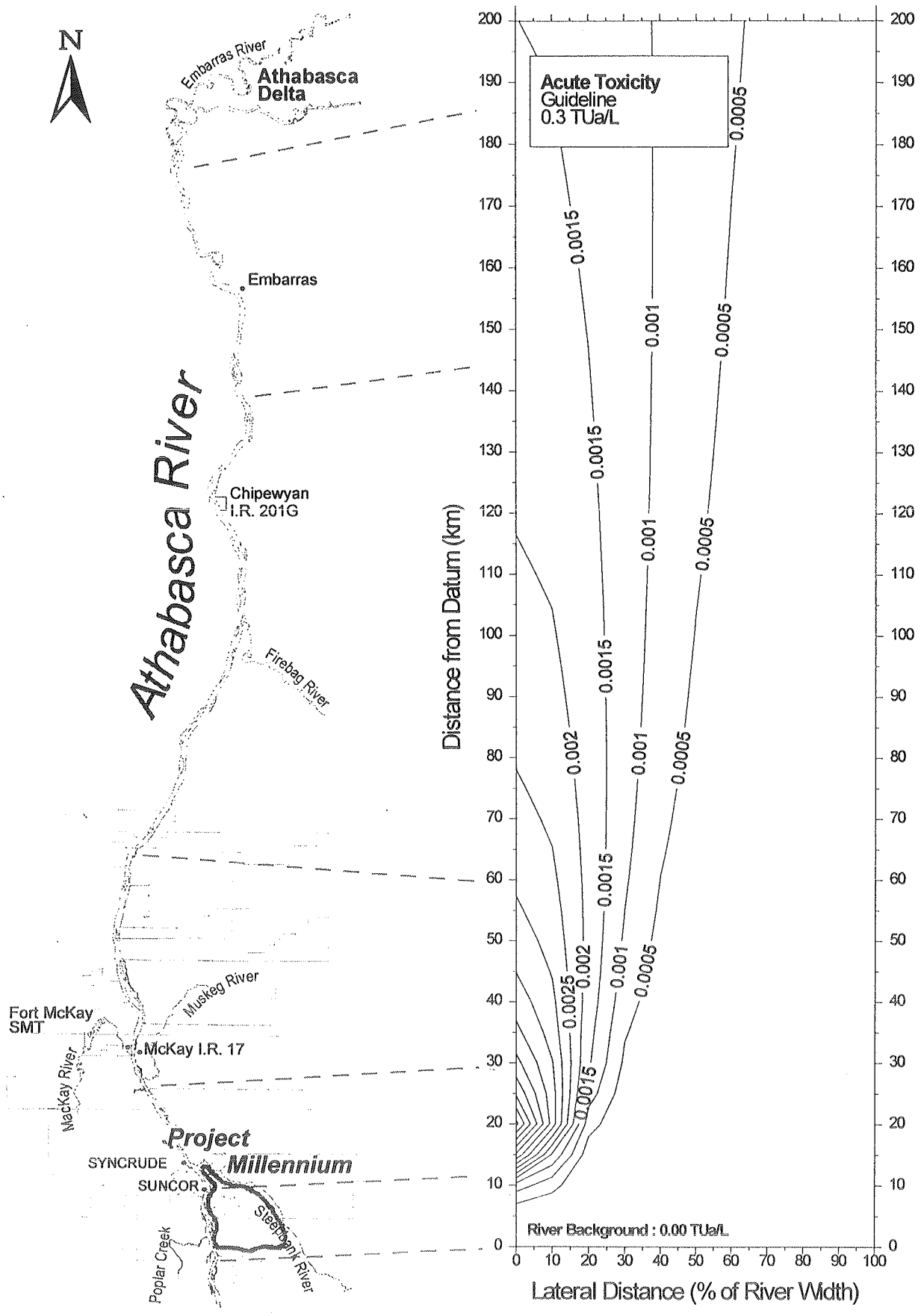

Figure V-18: Acute Toxicity Concentrations in the Athabasca River 2030, mean open water flow (Project)

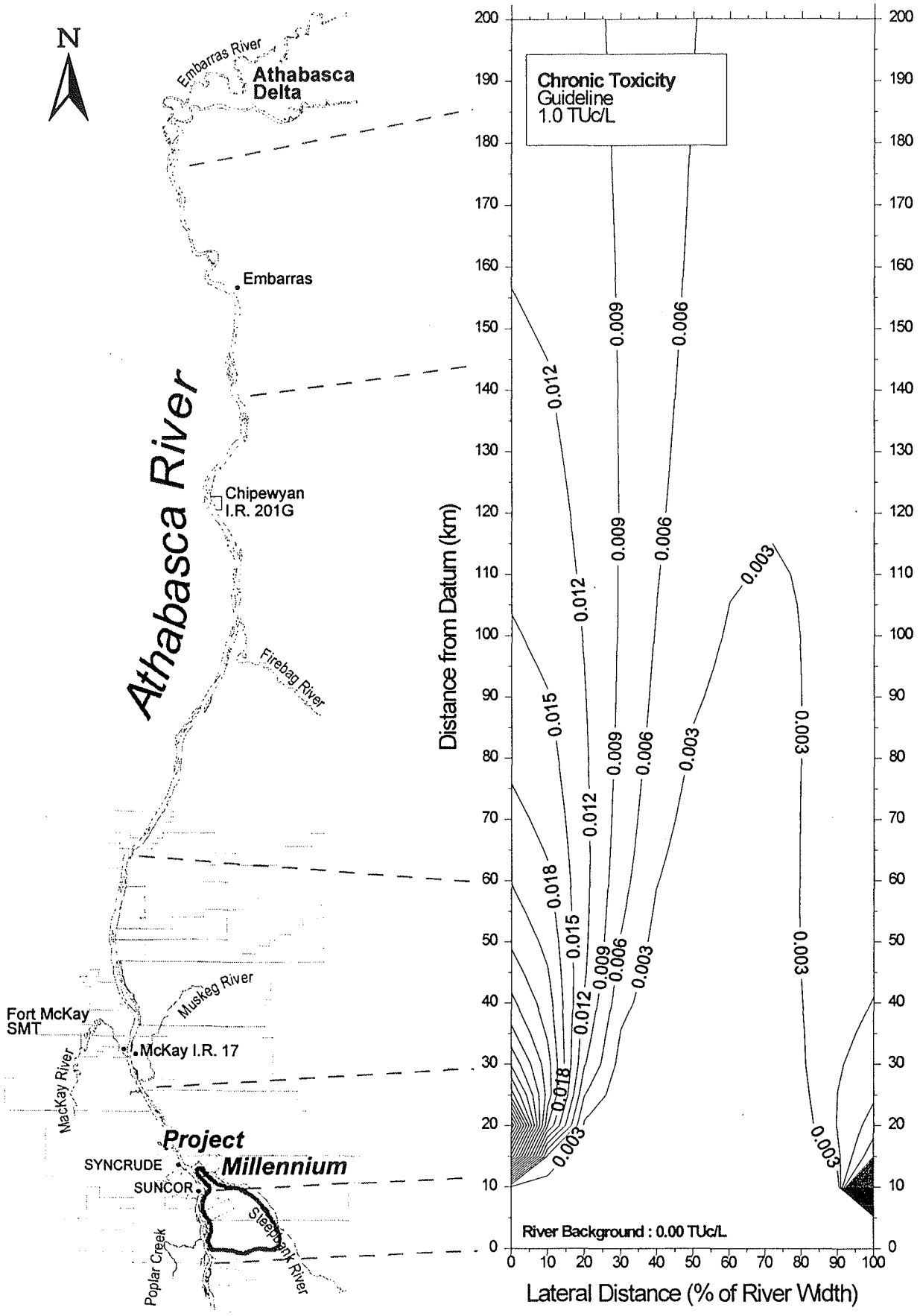

Figure V-19: Chronic Toxicity Concentrations in the Athabasca River 2030, mean open water flow (Project)

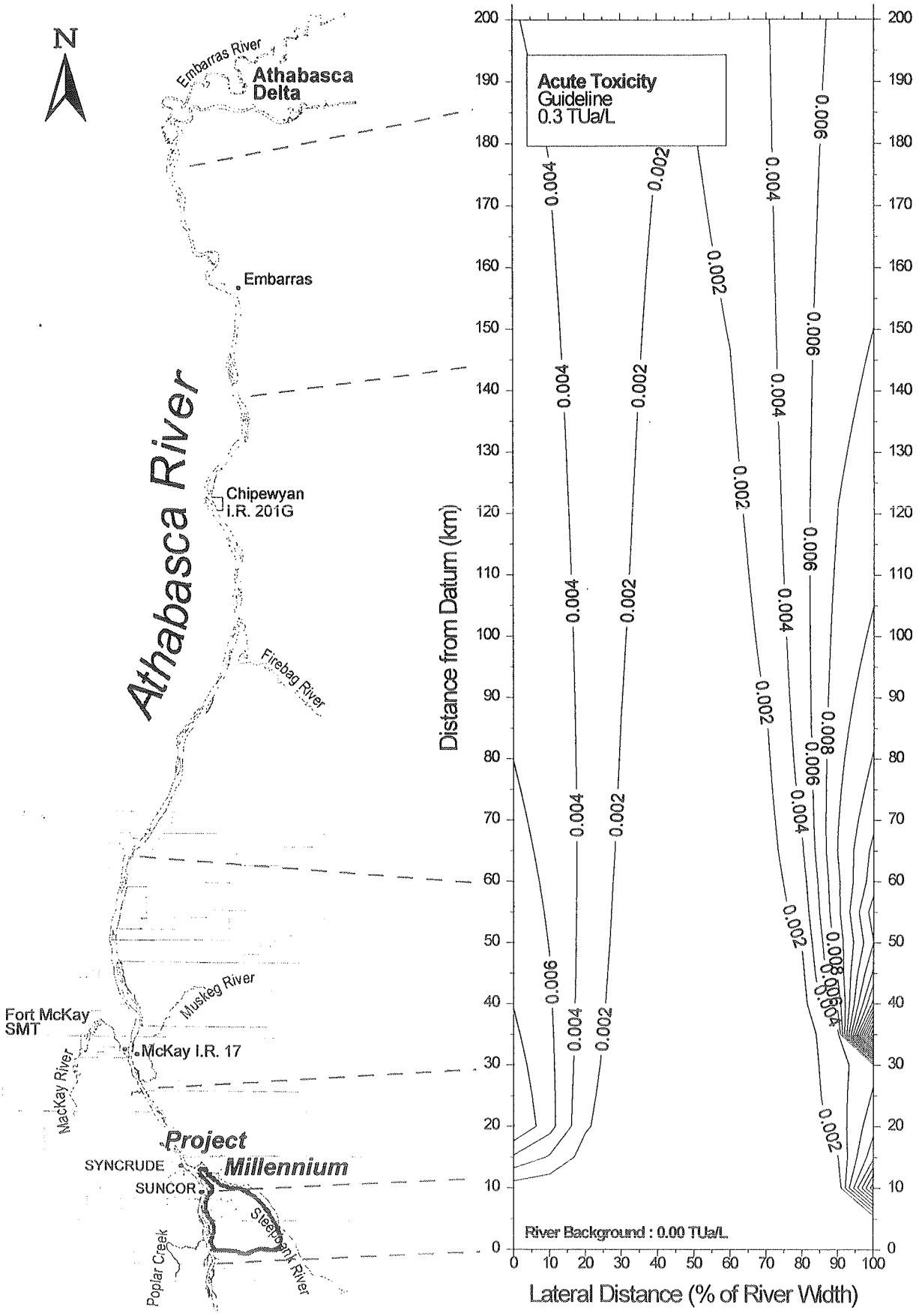

Figure V-20: Acute Toxicity Concentrations in the Athabasca River 2045, annual 7Q10 flow (Project)

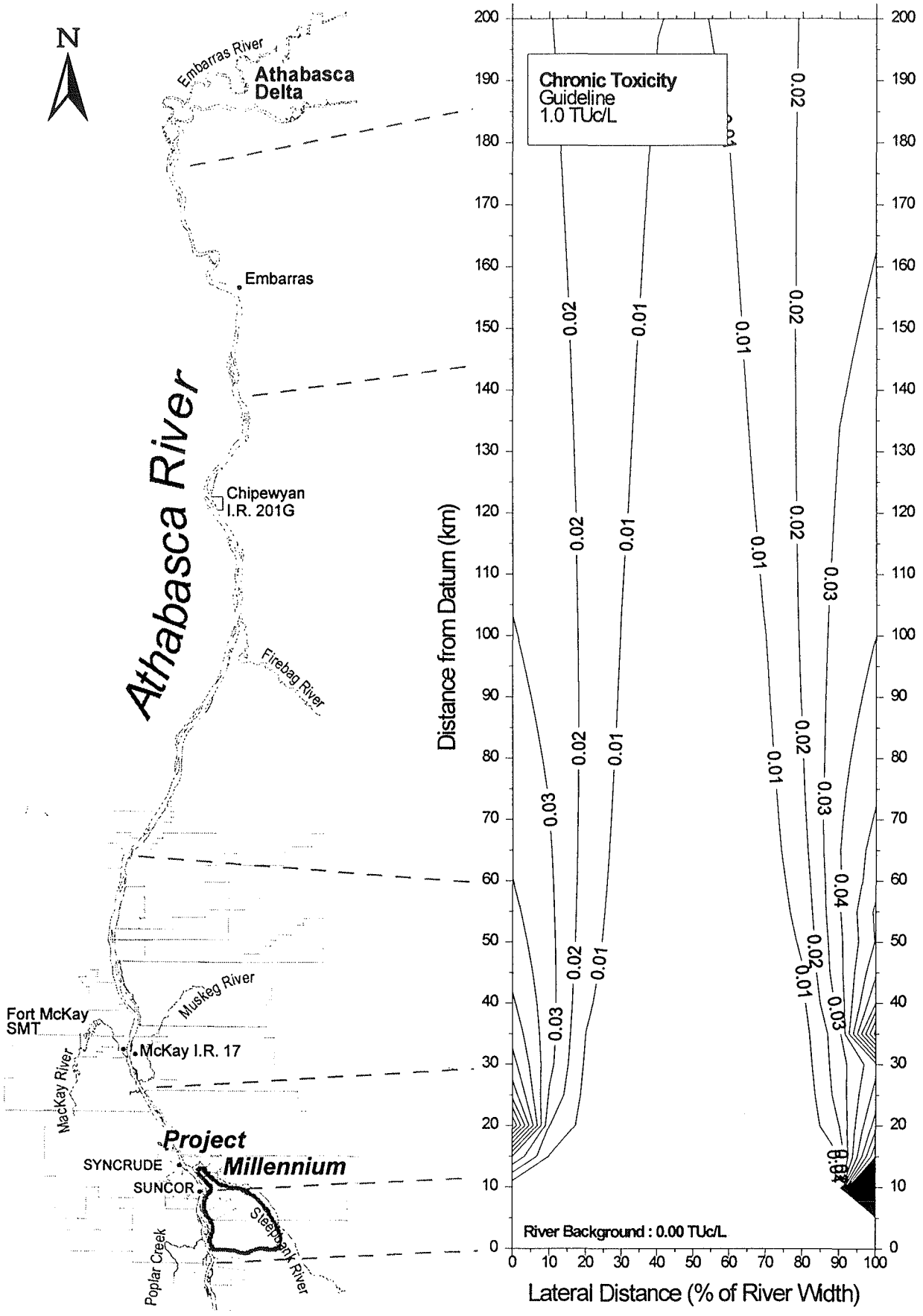

Figure V-21: Chronic Toxicity Concentrations in the Athabasca River 2045, annual 7Q10 flow (Project)

Figure V-22 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2005 (CEA)

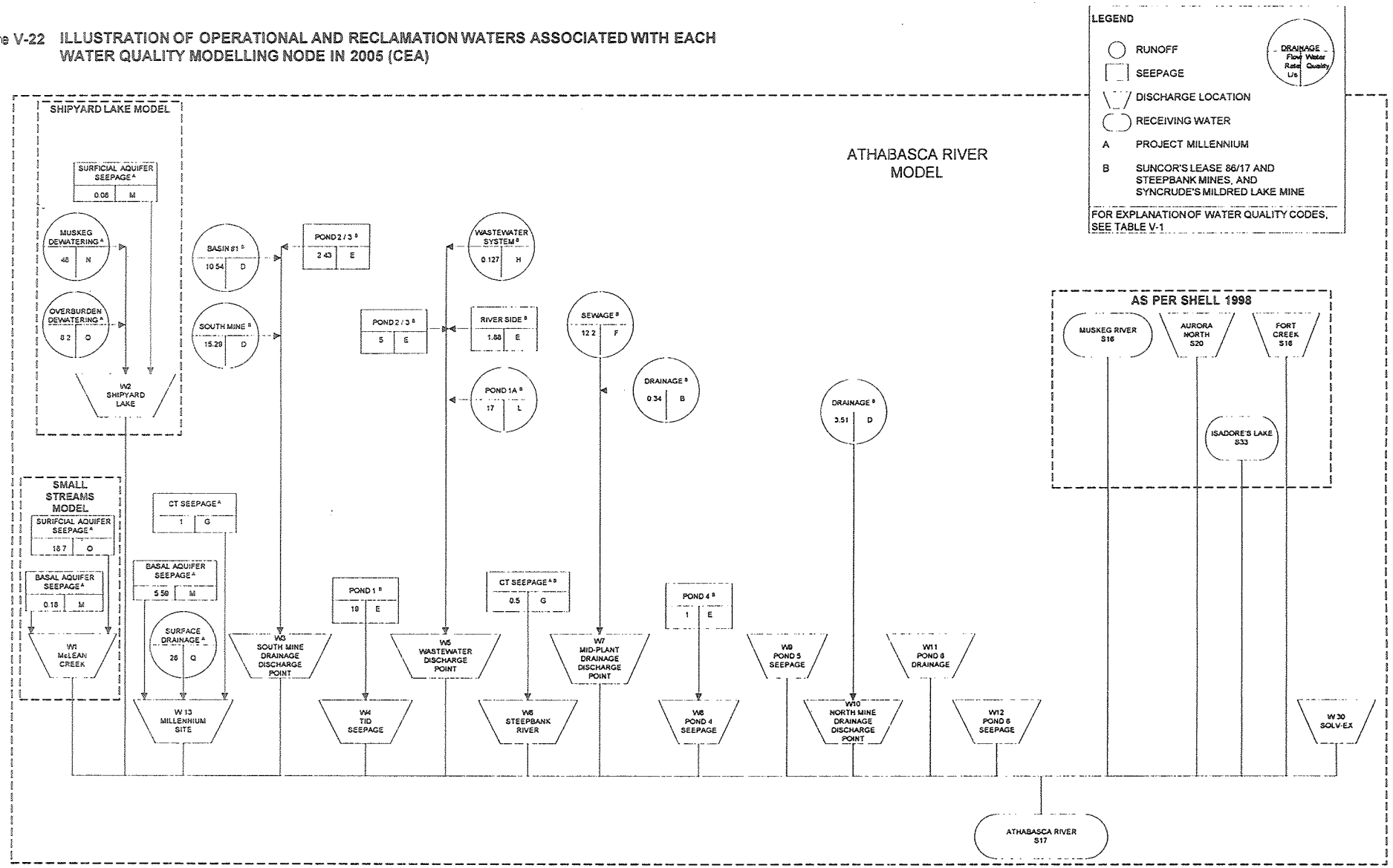

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Figure V-23 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2010 (CEA)

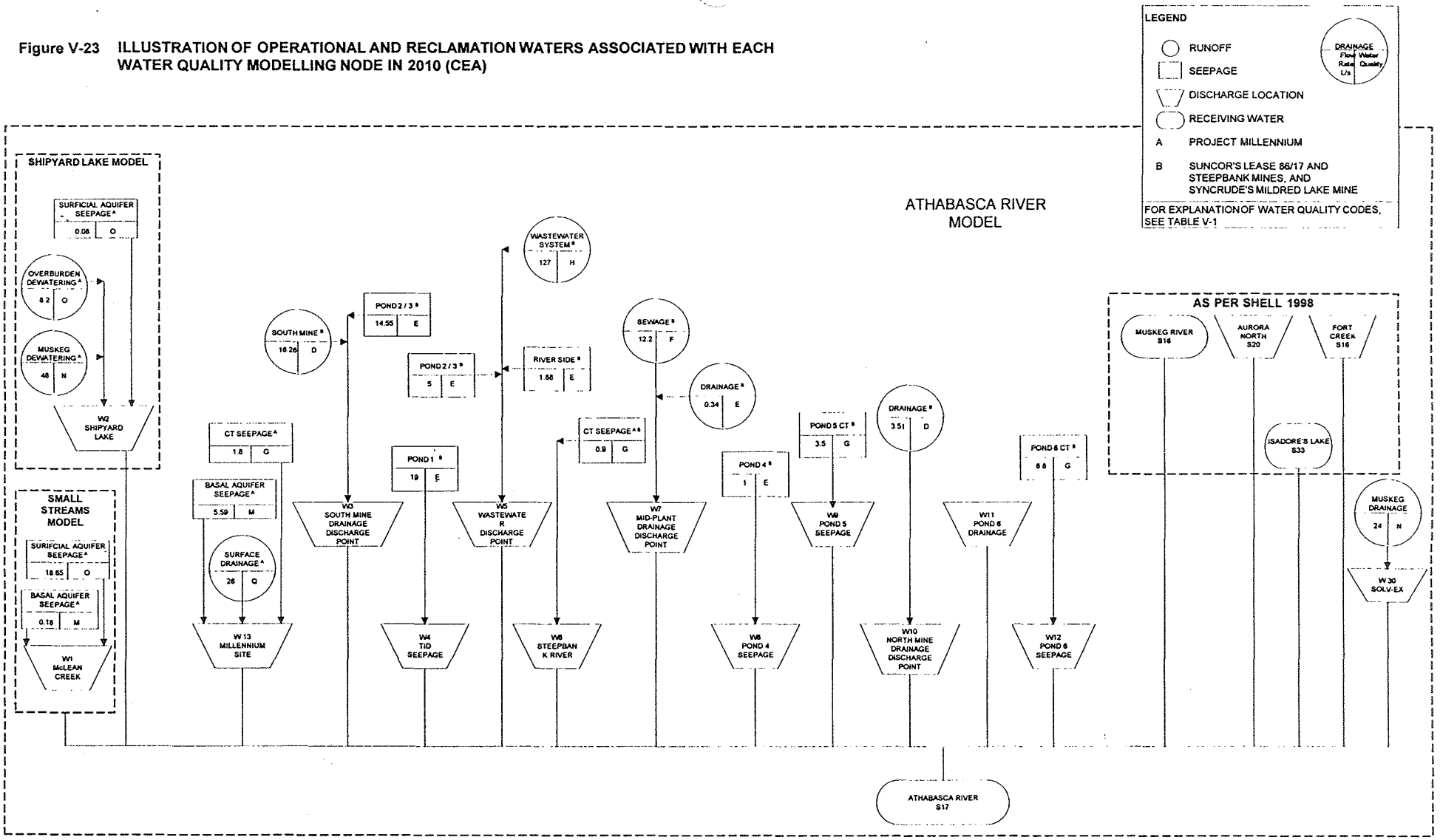

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Figure V-24 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2015 (CEA)

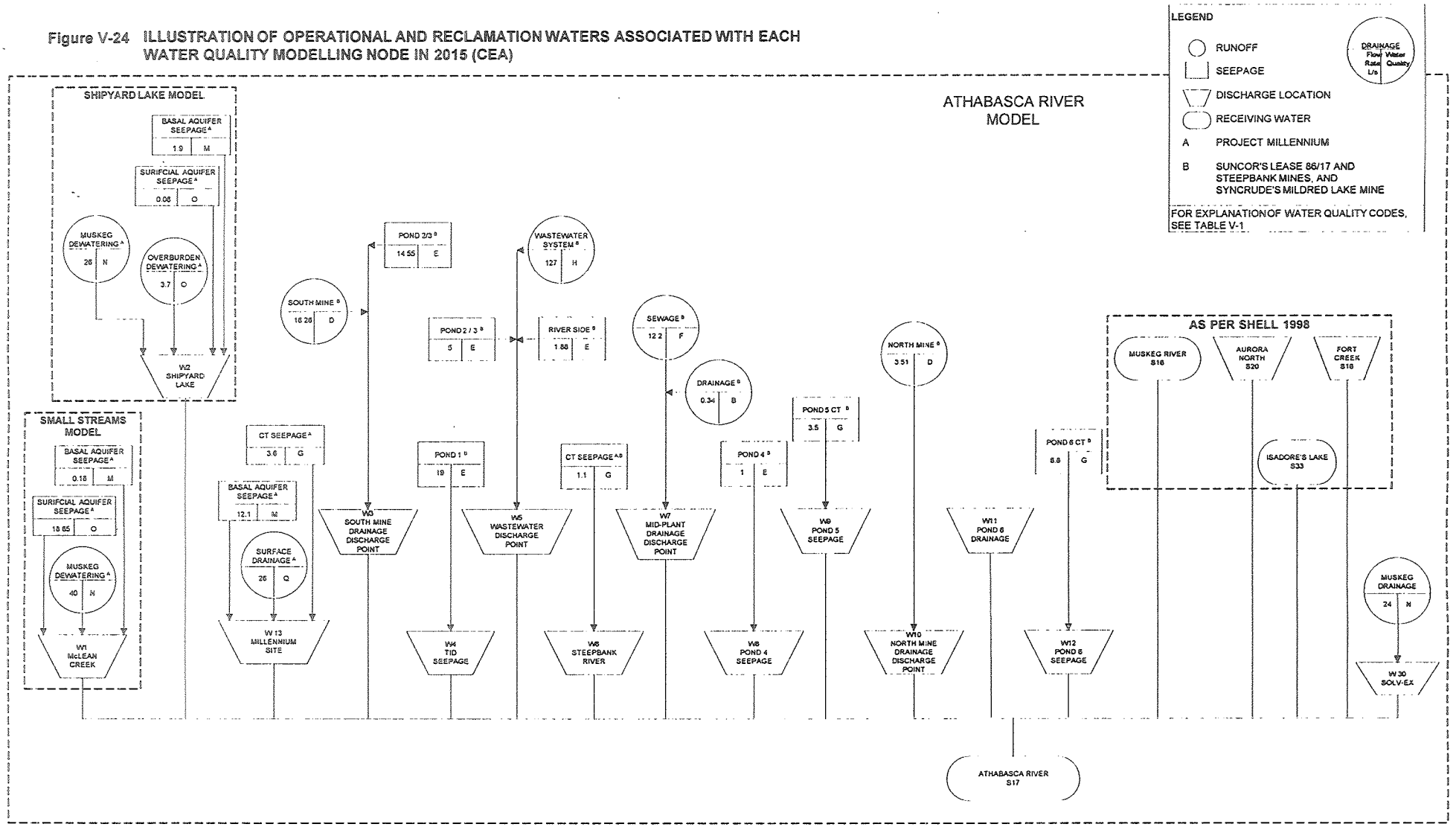

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Figure V-25 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2020 (CEA)

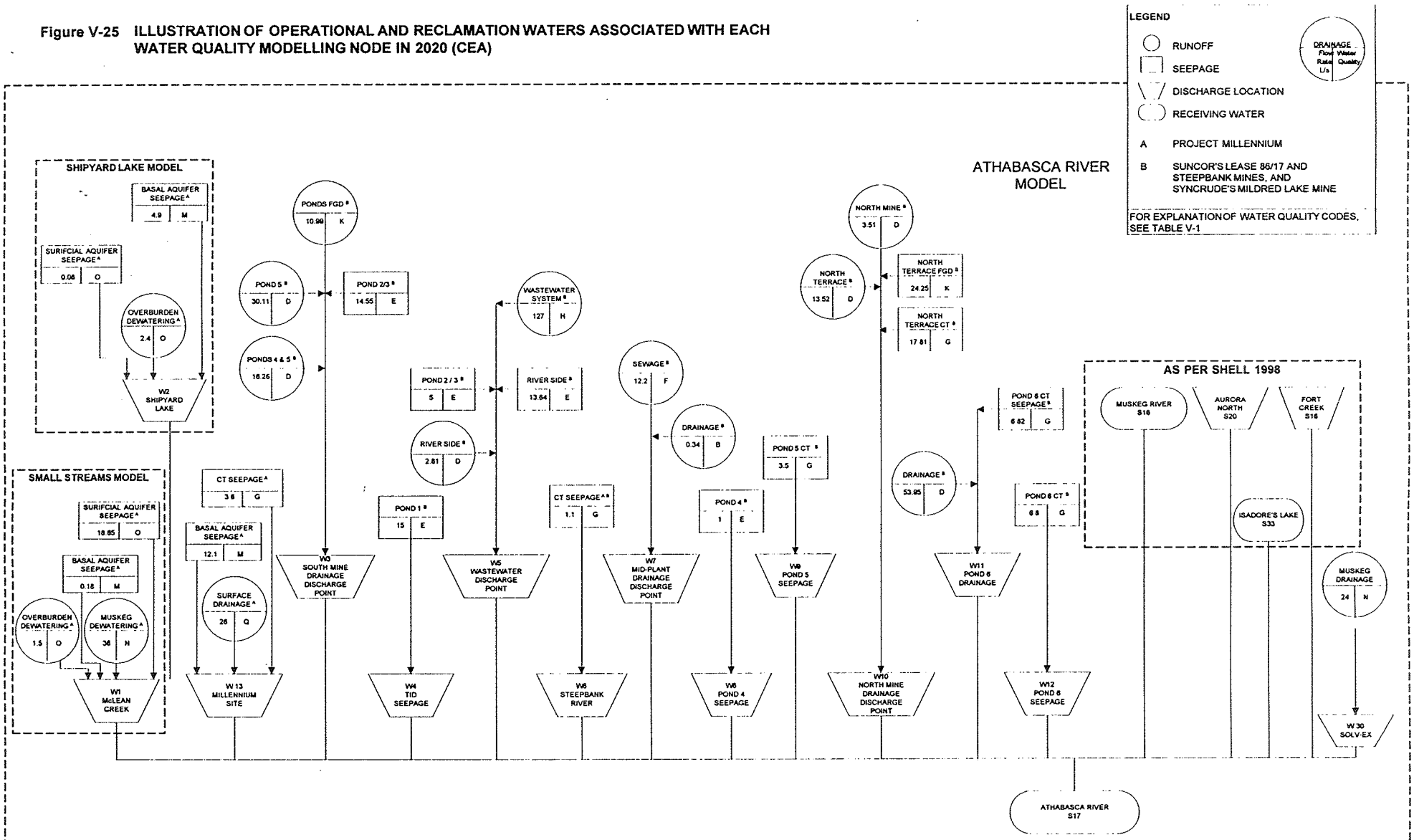

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Figure V-26 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2025 (CEA)

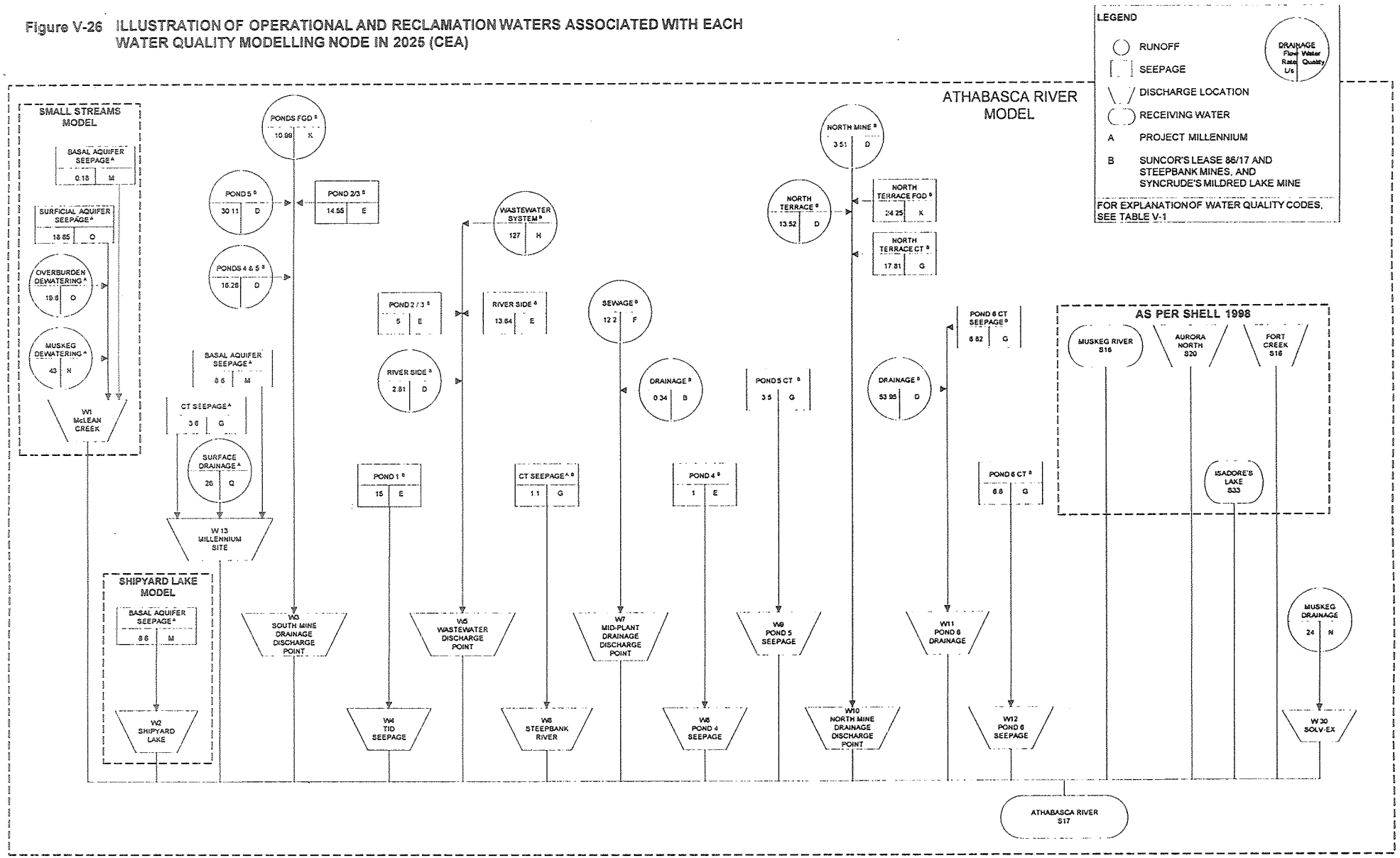

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Figure V-27 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2030 (CEA)

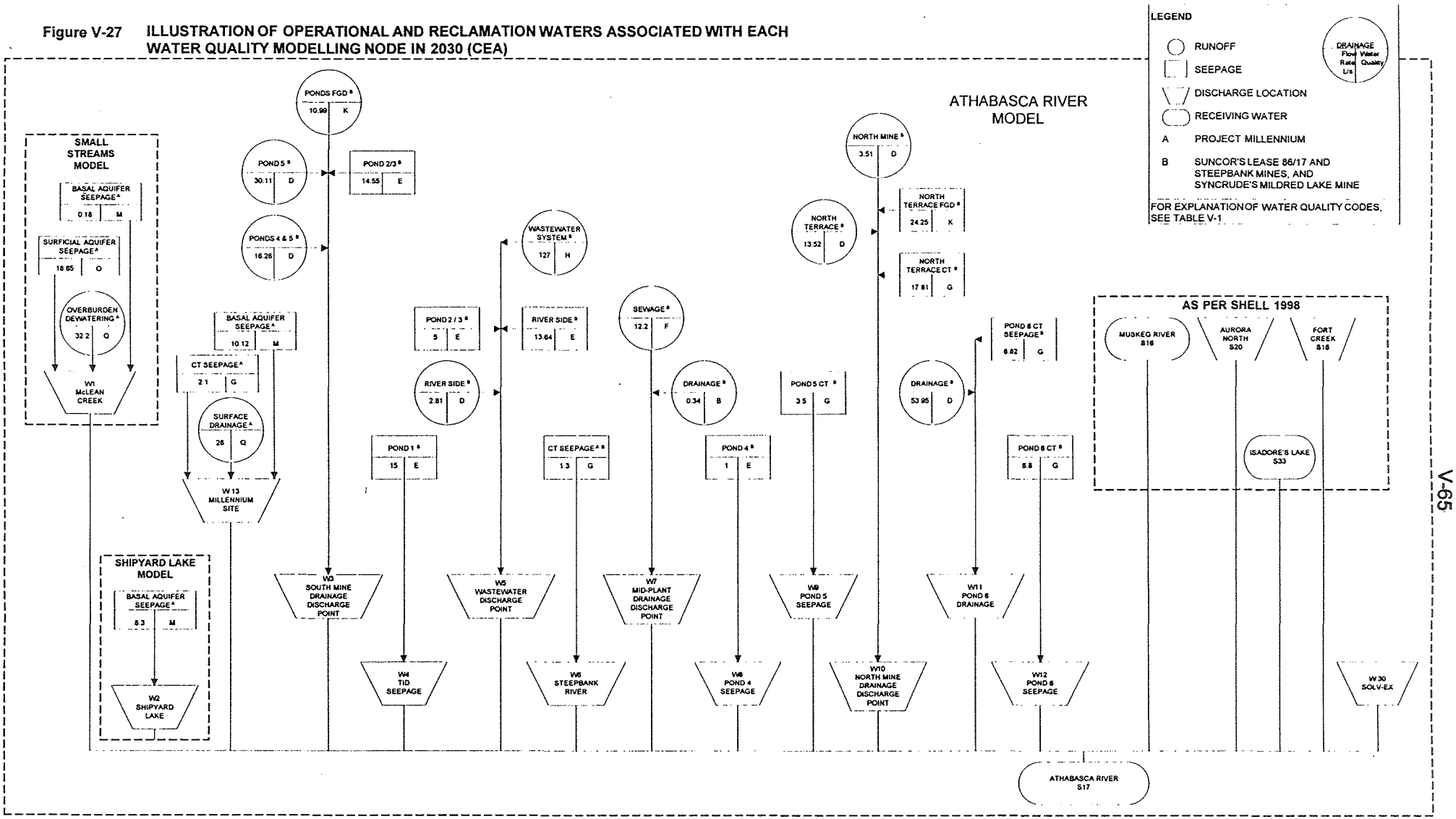

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Figure V-28 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN 2045 (CEA)

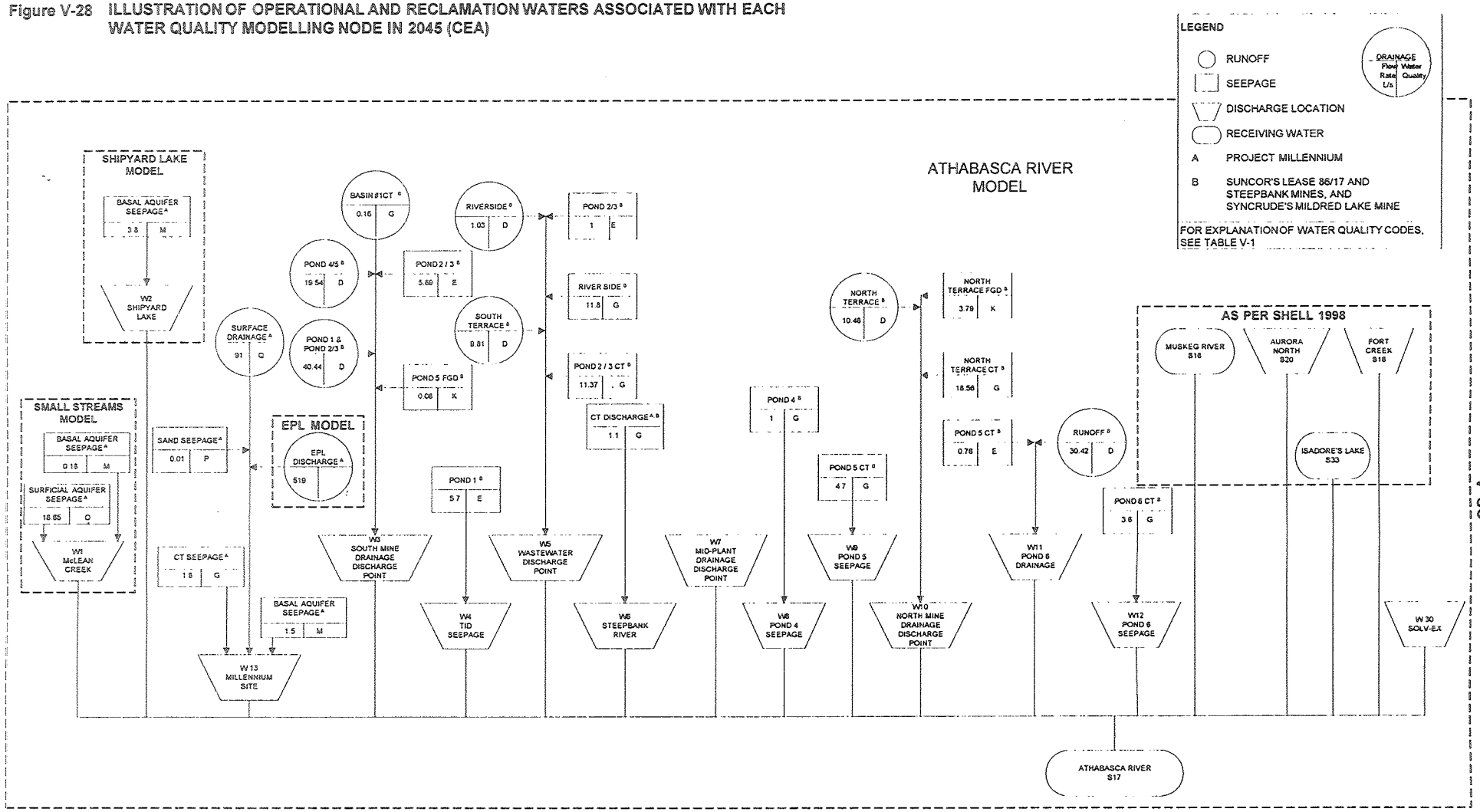

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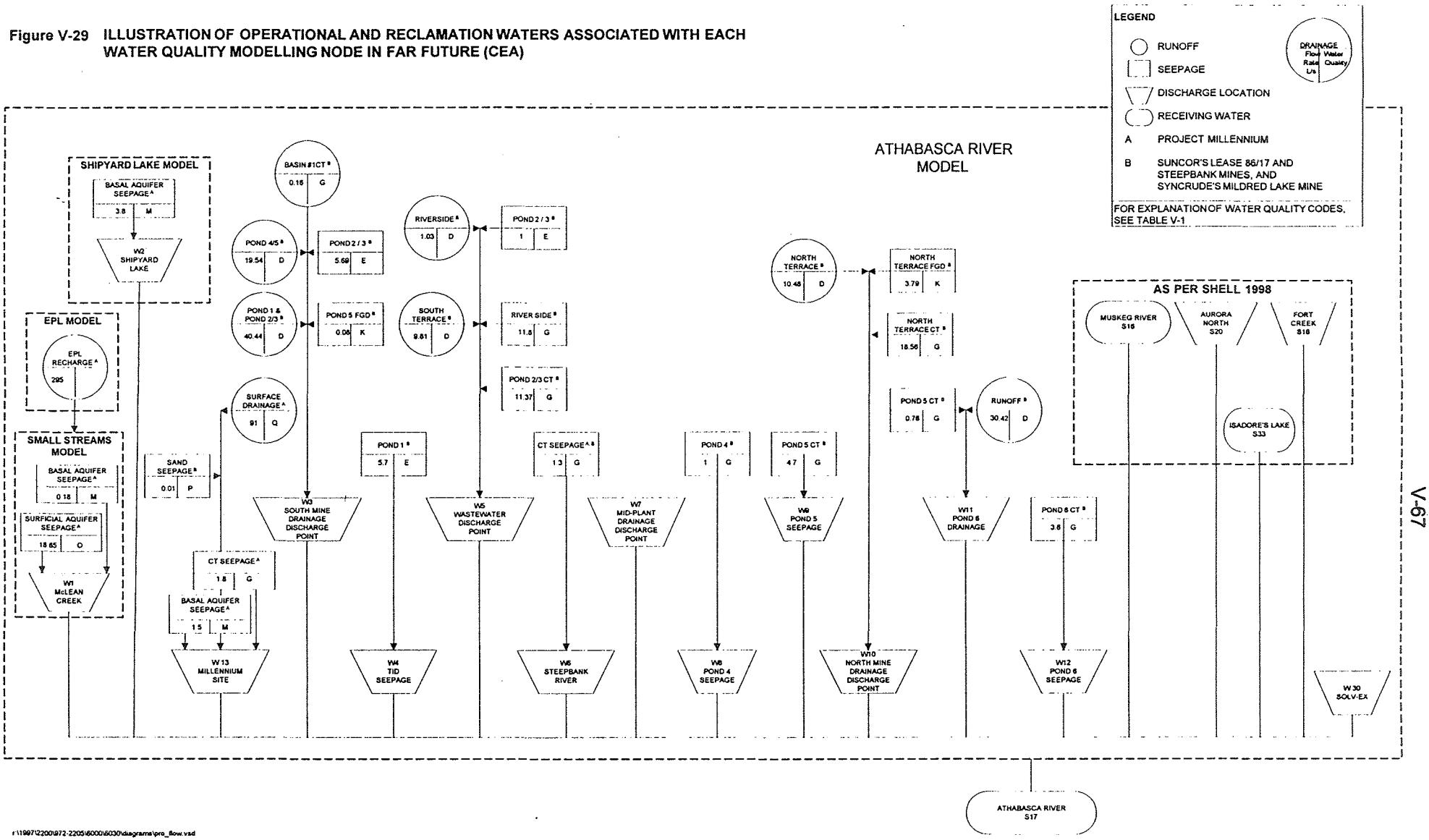
Figure V-29 ILLUSTRATION OF OPERATIONAL AND RECLAMATION WATERS ASSOCIATED WITH EACH WATER QUALITY MODELLING NODE IN FAR FUTURE (CEA)



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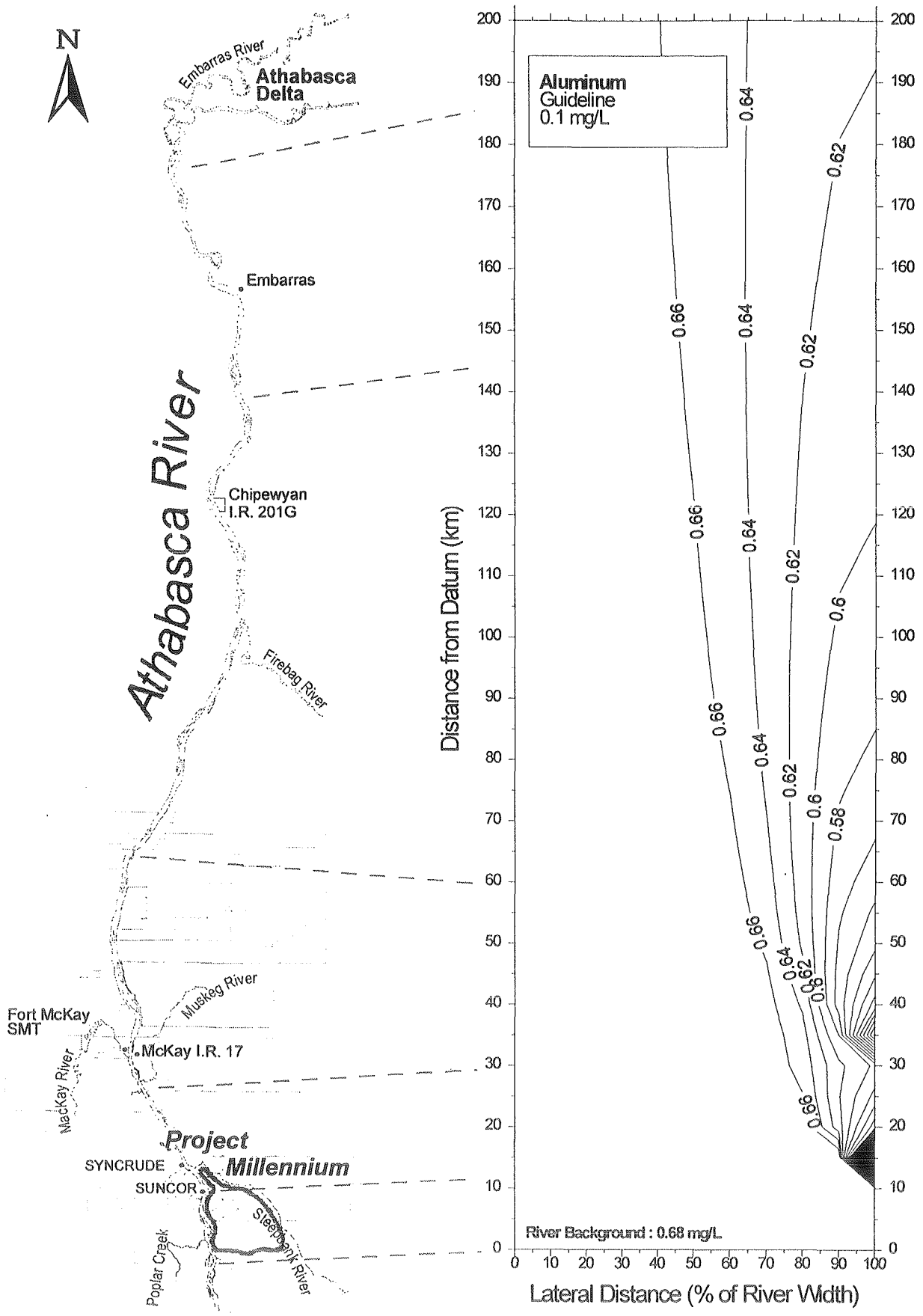


Figure V-30: Aluminum Concentrations in the Athabasca River 2045, mean open water flow (CEA)

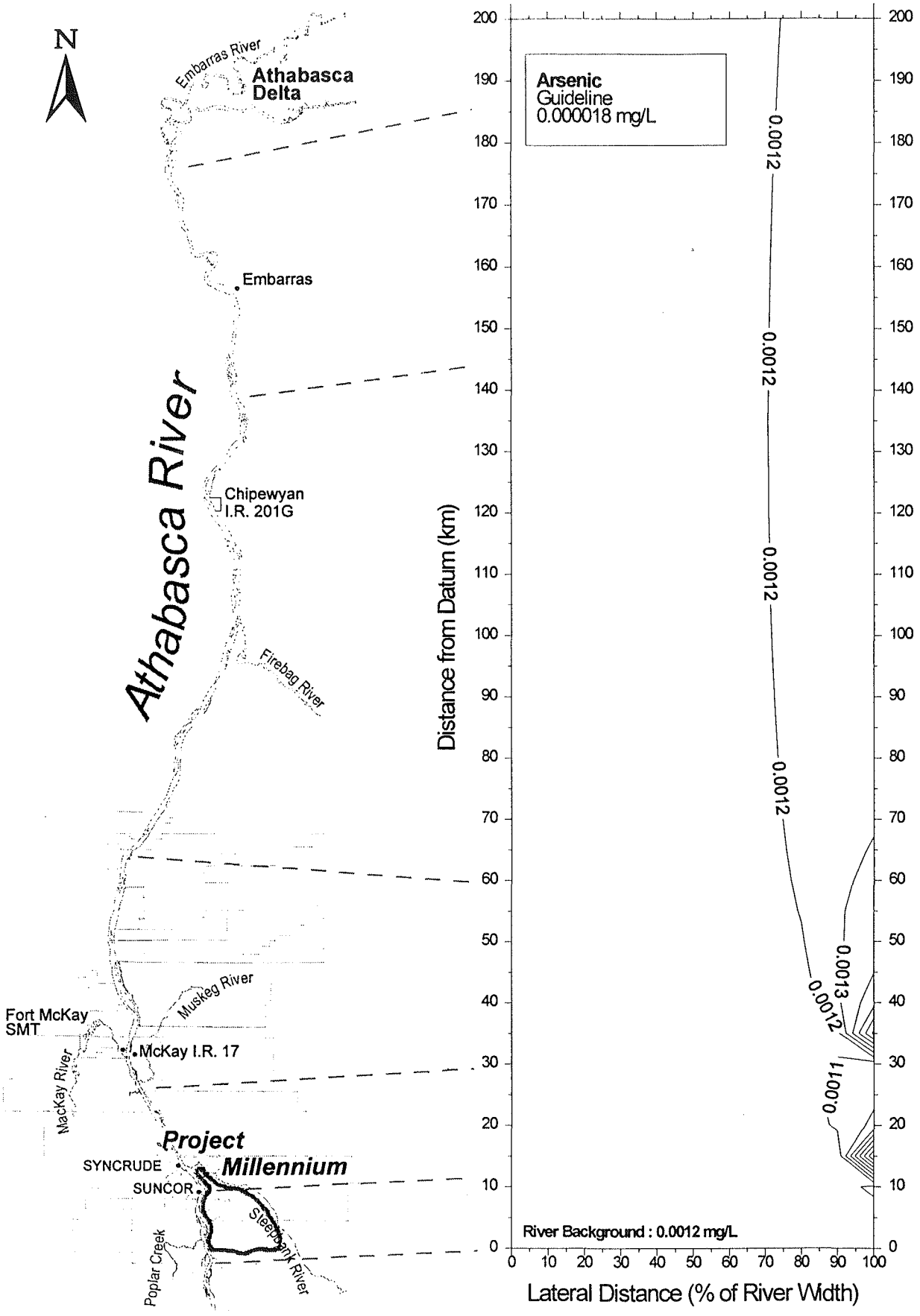


Figure V-31: Arsenic Concentrations in the Athabasca River 2045, mean open water flow (CEA)

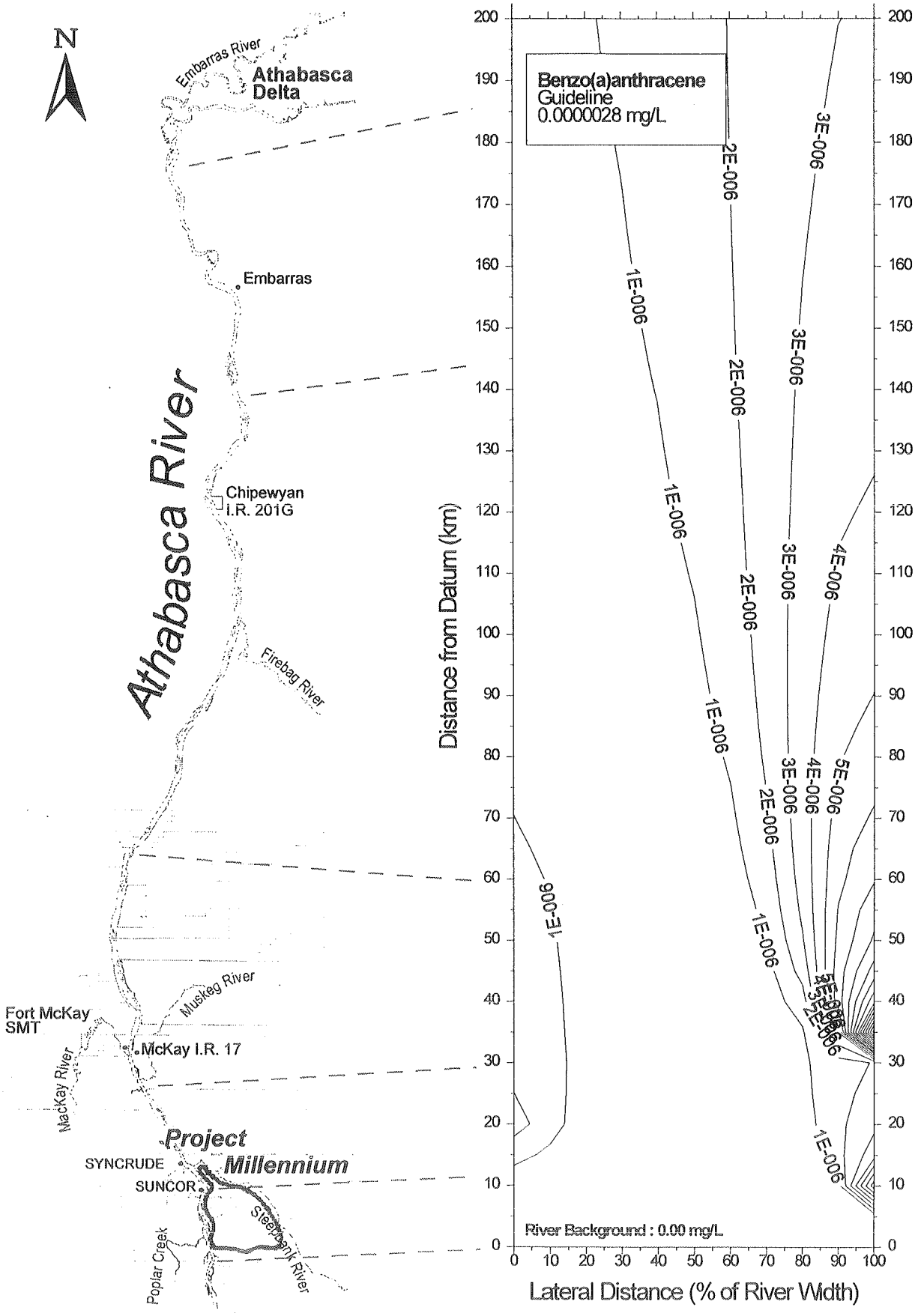


Figure V-32: Benzo(a)anthracene Group Concentrations in the Athabasca River 2045, mean open water flow (CEA)

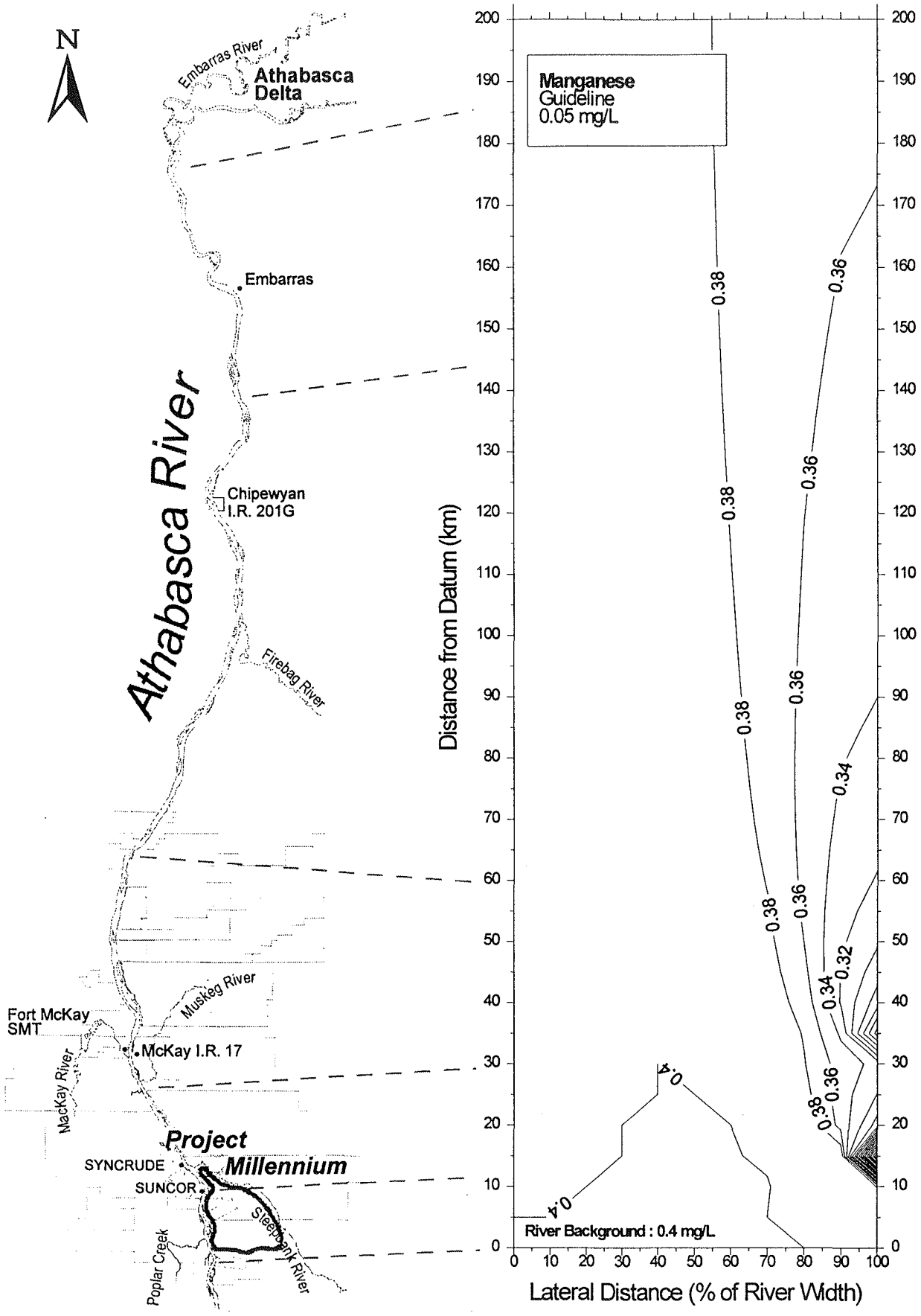


Figure V-33: Manganese Concentrations in the Athabasca River 2045, mean open water flow (CEA)

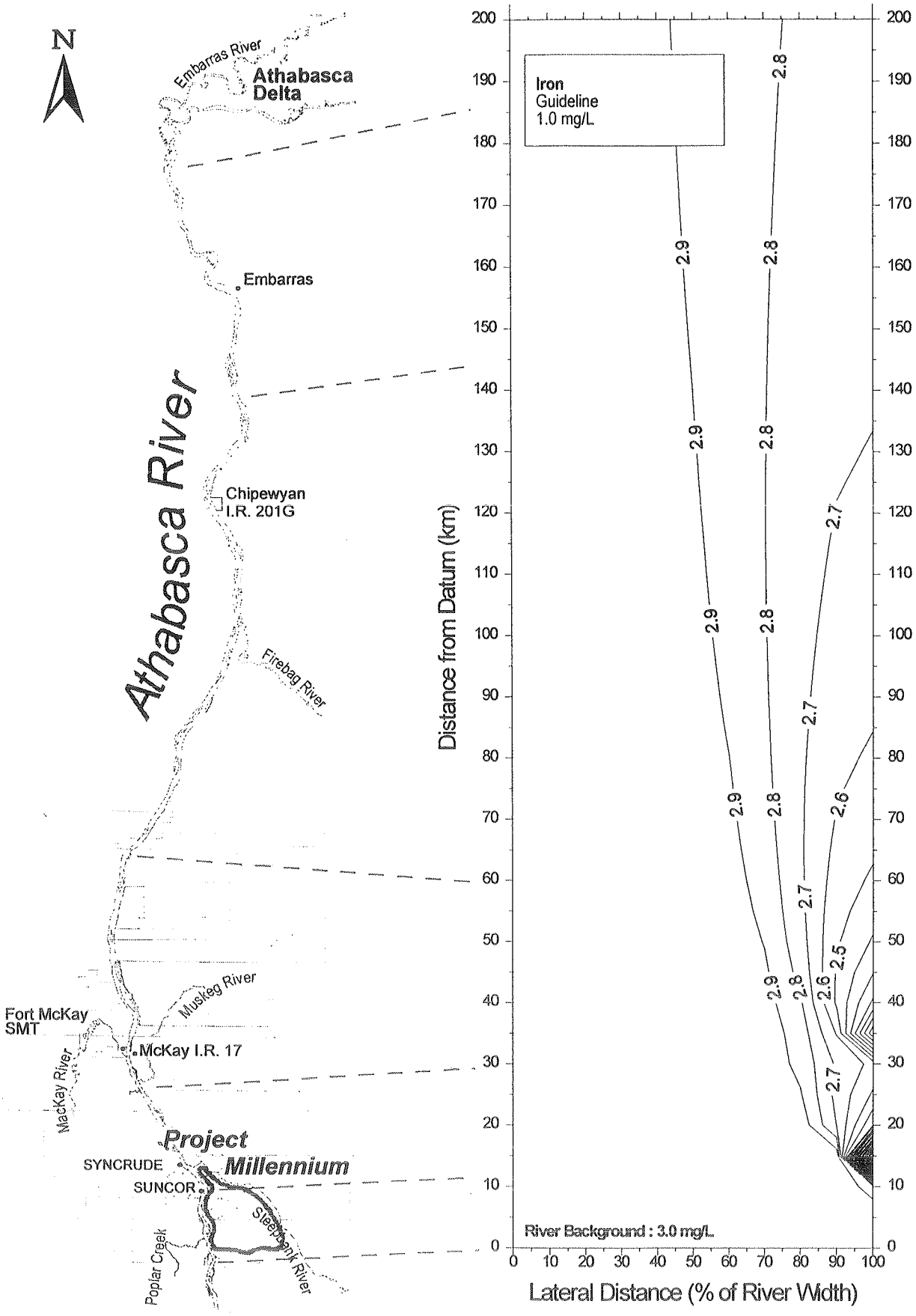


Figure V-34: Iron Concentrations in the Athabasca River 2045, mean open water flow (CEA)

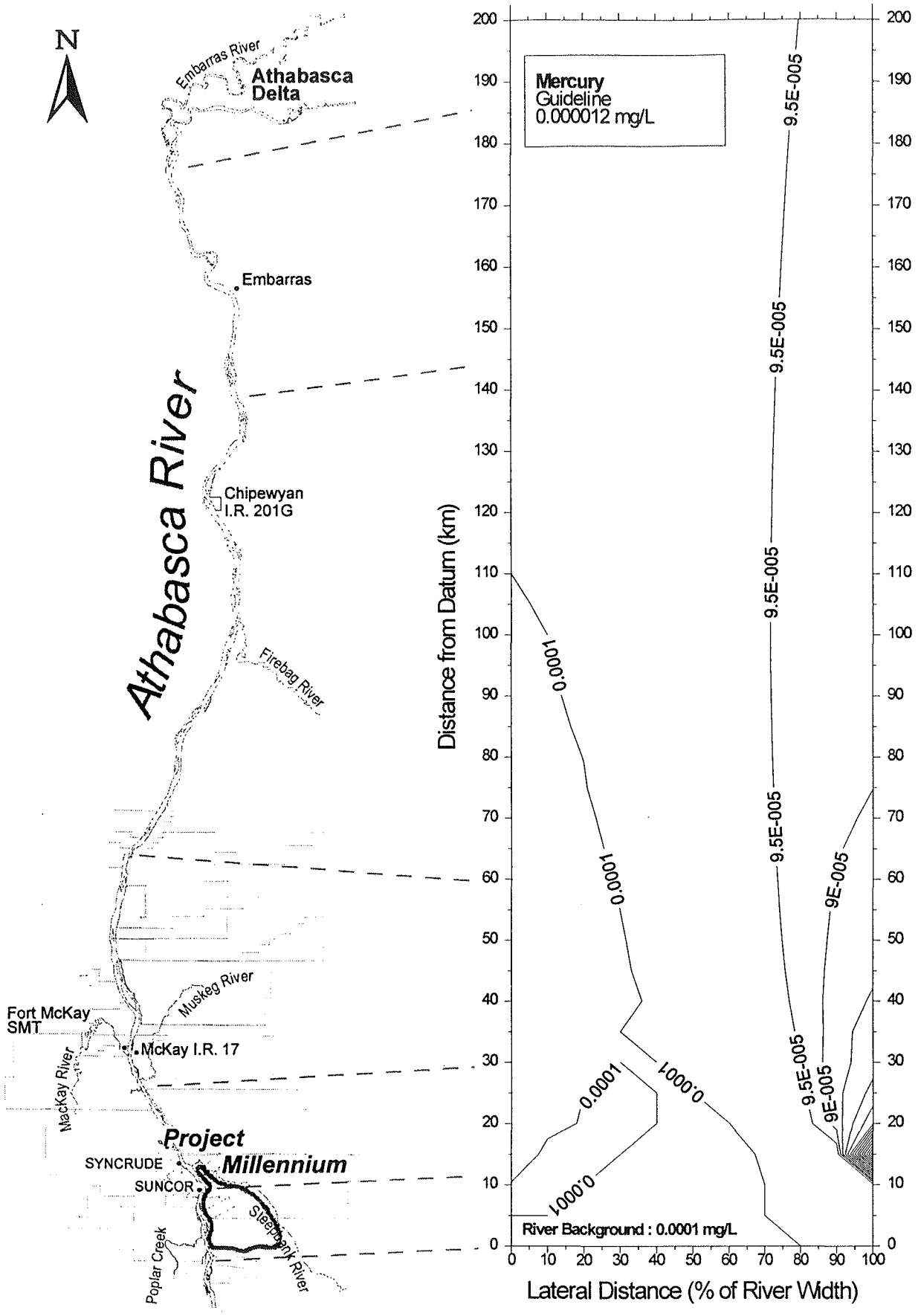


Figure V-35: Mercury Concentrations in the Athabasca River 2045, mean open water flow (CEA)

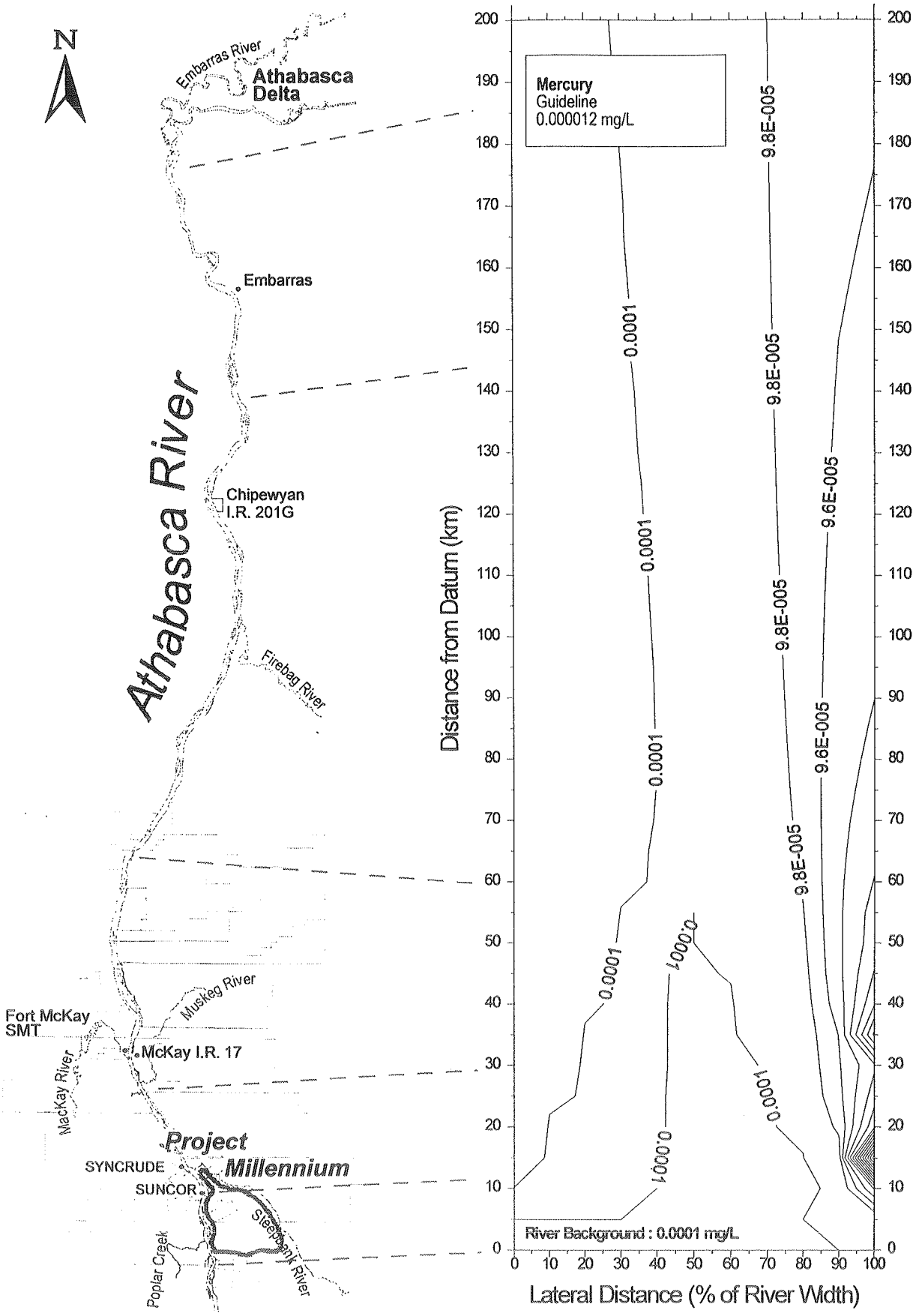


Figure V-36: Mercury Concentrations in the Athabasca River 2045, annual 7Q10 flow (CEA)

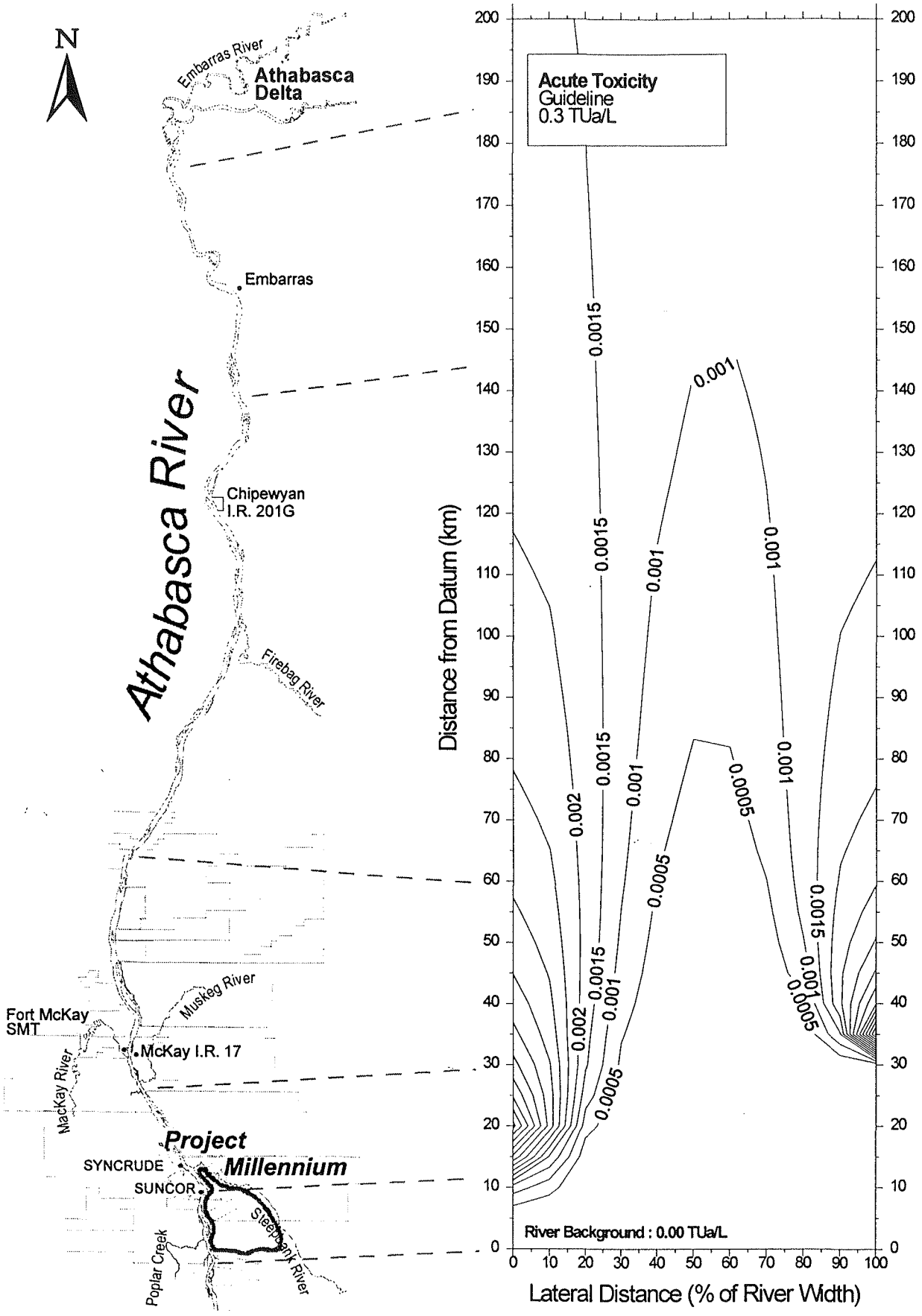


Figure V-37: Acute Toxicity Concentrations in the Athabasca River 2030, mean open water flow (CEA)

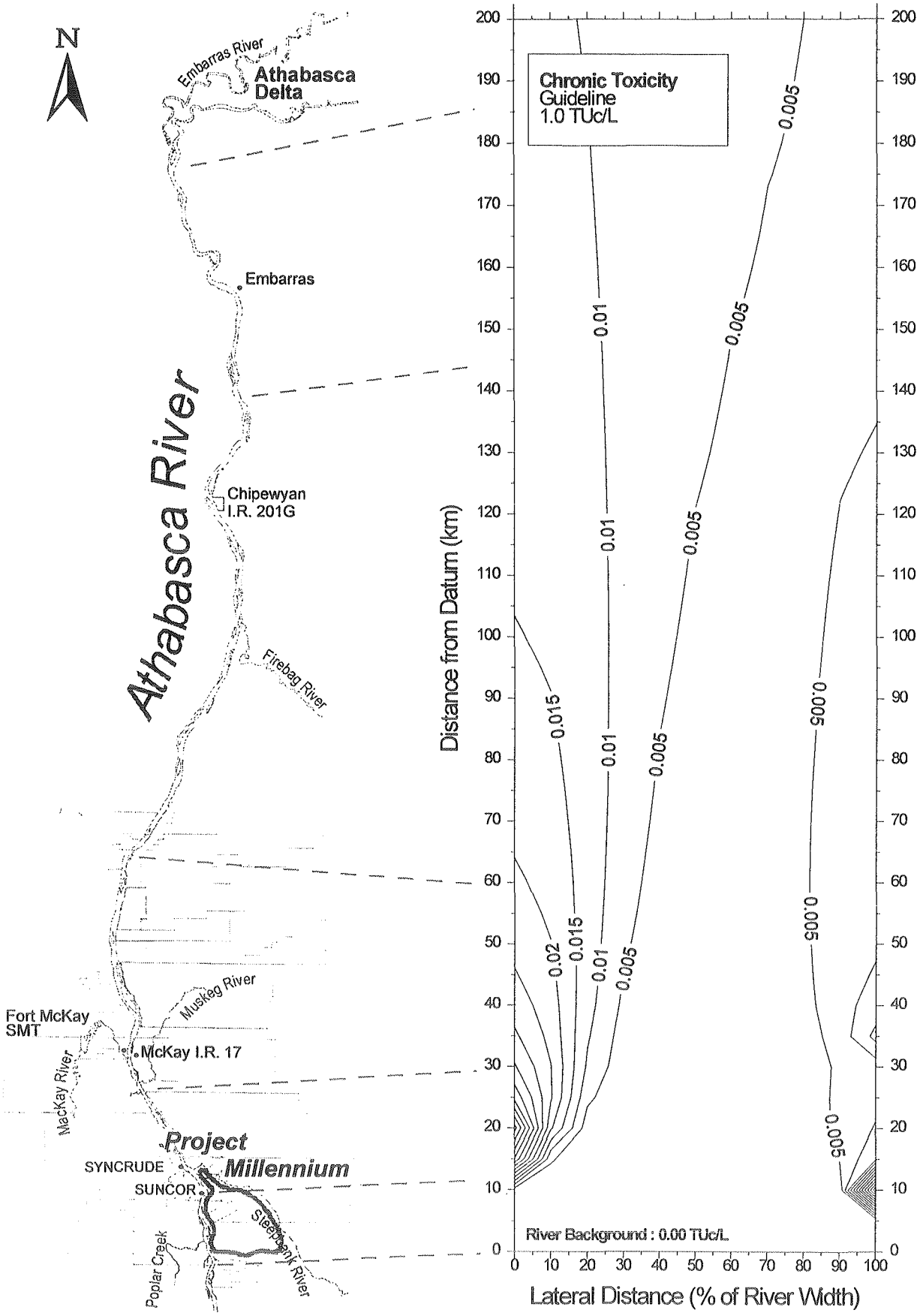


Figure V-38: Chronic Toxicity Concentrations in the Athabasca River 2030, mean open water flow (CEA)

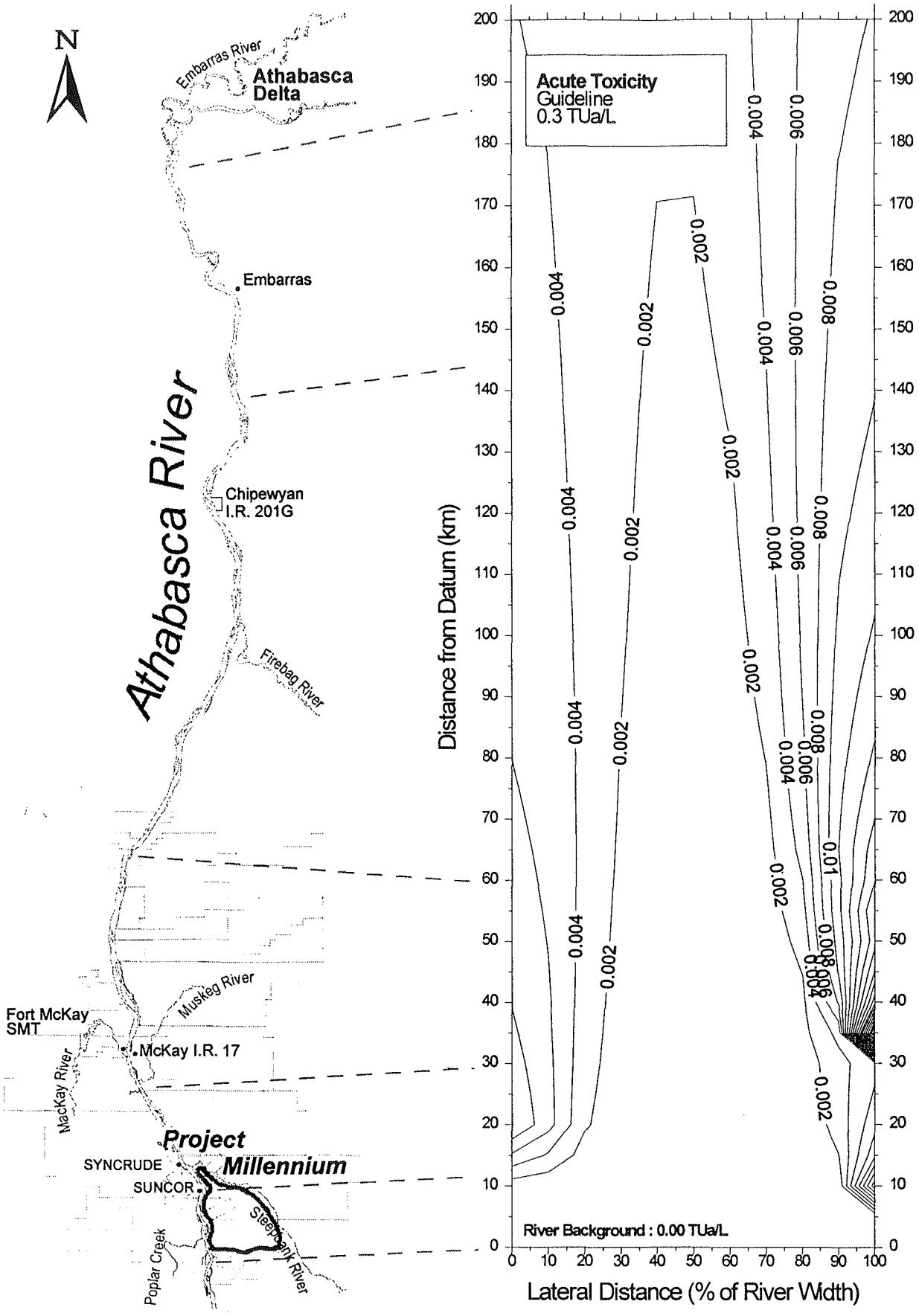


Figure V-39: Acute Toxicity Concentrations in the Athabasca River 2045, annual 7 Q10 flow (CEA)

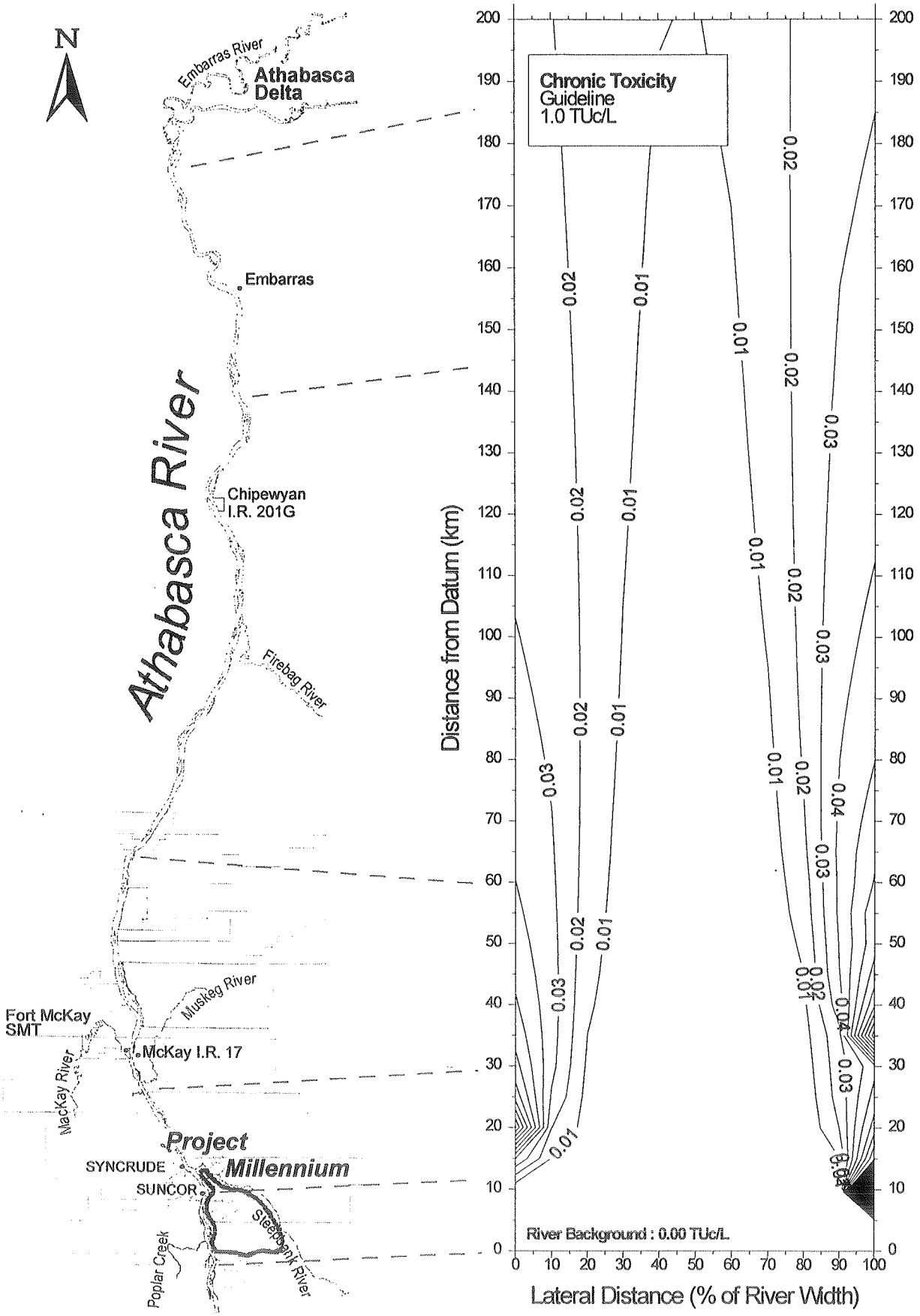


Figure V-40: Chronic Toxicity Concentrations in the Athabasca River 2045, annual 7Q10 flow (CEA)

APPENDIX VI

HUMAN AND WILDLIFE HEALTH

VI.1 CHEMICAL SCREENING

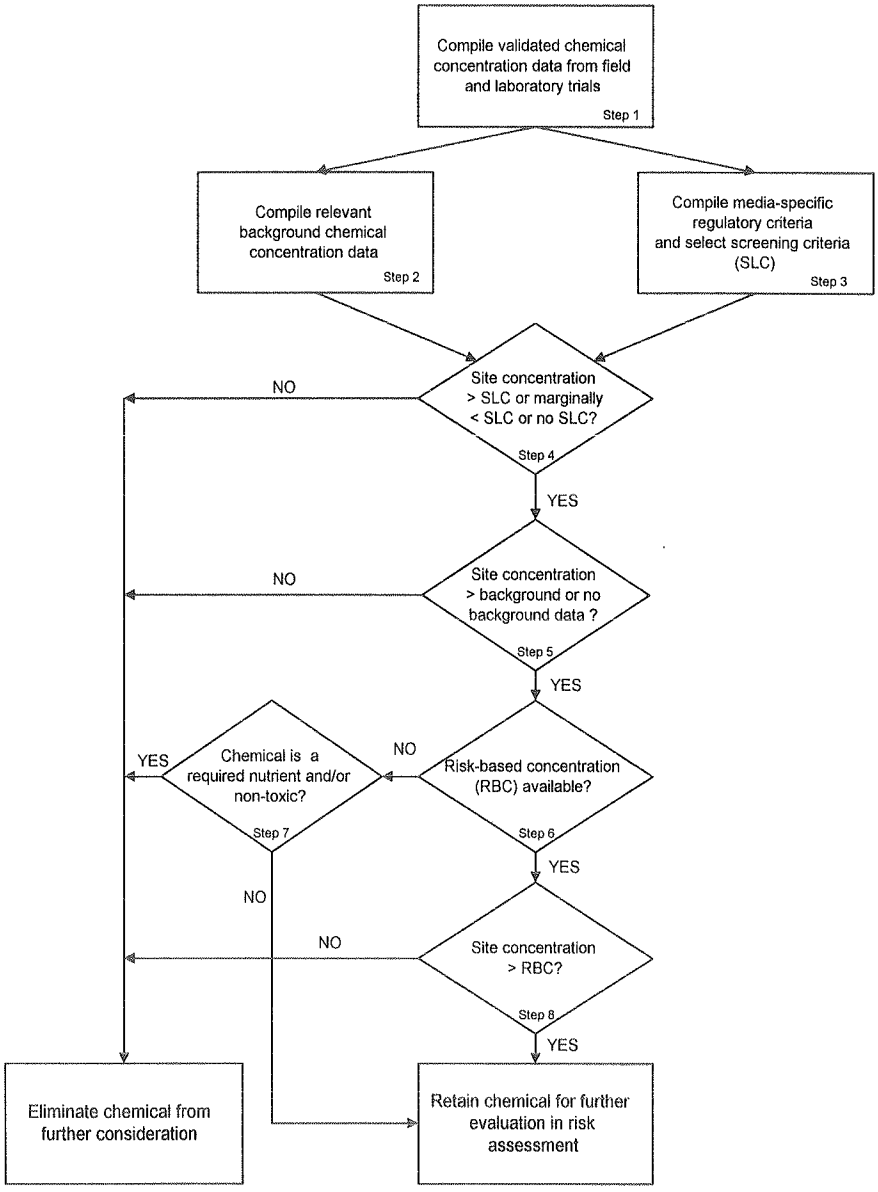
VI. HUMAN AND WILDLIFE HEALTH APPENDIX

VI.1 CHEMICAL SCREENING

The objective of screening chemicals is to focus the list of chemicals measured in various media (e.g., water, air, fish, plants, meat) to those chemicals that may be a concern because of their concentrations and their potential to cause adverse human or wildlife health effects. This list of chemicals of potential concern is used to assist in receptor and exposure pathway screening, and the chemicals identified here are carried forward into the Risk Analysis phase.

The screening process used for both the human and wildlife health risk assessments followed a methodical, step-wise process, as shown schematically in Figure VI.1-1, and outlined in Sections VI.1.2 (wildlife health) and VI.1.3 (human health).

Figure VI.1-1 Process for Chemical Screening



Note: See text below for explanation of the steps involved in chemical screening

VI.1.1 Grouping of PAHs for Screening

All detected PAHs were classified and grouped for screening purposes according to their structure and physical/chemical and toxicological properties.

Closely-related chemicals were combined to form chemical groups when insufficient human and/or ecological toxicity data were available to evaluate them individually. Maximum detected concentrations for each member of a chemical group were summed to provide a total concentration for each group in each sampling media. Within each chemical group, chemicals that were not detected in a particular media did not contribute to the overall group concentration.

For example, a chemical group designated the Naphthalene Group includes naphthalene, methyl naphthalene as well as the C_2, C_3, and C_4 substituted naphthalenes. Details of chemical grouping are summarized in Table VI.1-1.

VI.1.1.1 Selection of Surrogate Toxicity Values for Screening Purposes

For the purpose of risk-based screening, all PAHs within a group were assumed to have the same toxicological properties. Therefore, the quantitative toxicity value of a single compound (*i.e.,* the toxicity surrogate) was used to characterize the toxicity of the group. In selecting a toxicity surrogate for a group, the first choice was the parent compound found within that group. For example, naphthalene was chosen as the toxicity surrogate for the Naphthalene Group. For the Benzo(a)anthracene Group, sufficient data existed for two parent compounds (benzo(a)anthracene and chrysene). In this case, the chemical with the more protective toxicity value (benzo(a)anthracene) was selected as the toxicity surrogate.

When adequate toxicity data were not available or a more protective toxicity value was desired, a toxicity surrogate not present within the chemical group was chosen. For example, pyrene was chosen as a toxicity surrogate for the Phenanthrene and Dibenzothiophene Groups. Pyrene was selected as a surrogate for these groups for the following reasons:

- Pyrene and the constituents of these three groups are classified as noncarcinogens; and
- Of the PAHs with sufficient toxicity data, pyrene has the second lowest reference dose (RfD). Naphthalene has the lowest RfD; however, there is greater uncertainty associated with the naphthalene RfD compared to the pyrene RfD.

Therefore, the use of pyrene as a toxicity surrogate for noncarcinogenic PAHs for which insufficient toxicity data was available is assumed to be sufficiently protective.

In some cases, toxicity surrogates were used for individual compounds (not groups of compounds) that have insufficient toxicity data. For example, acenaphthene was chosen as a surrogate for acenaphthylene based on their similar chemical structures and similar physio-chemical properties.

The toxicity surrogates used in the risk analysis for each group of PAHs are listed in Table VI.1-1.

Table VI.1-1 Chemical Groupings and Toxicity Surrogates

Chemical / Chemical Groups	Contains Following Compounds	Toxicity Surrogate
Acenaphthene Group	acenapthene methyl acenaphthene	acenaphthene
Acenaphthylene	acenaphthylene	acenaphthene
Benzo(a)anthracene Group	benzo(a)anthracene/chrysene methyl benzo(a)anthracene/chrysene C_2 substituted benzo(a)anthracene/chrysene	benzo(a)anthracene[(a)]
Benzo(ghi)perylene	benzo(ghi)perylene	pyrene[(b)]
Benzo(a)pyrene Group	benzo(a)pyrene methyl benzo(b or k)fluoranthene/methyl benzo(a)pyrene C_3 substituted benzo(b or k)fluoranthene/benzo(a)pyrene	benzo(a)pyrene
Biphenyl Group	biphenyl methyl biphenyl C2 substituted biphenyl	biphenyl
Dibenzothiophene Group	dibenzothiophene methyl dibenzothiophene C_2, C_3, and C_4 substituted dibenzothiophenes	pyrene[(c)]
Fluoranthene Group	fluoranthene methyl fluoranthene/pyrene	fluoranthene
Fluorene Group	fluorene methyl fluorene C_2 substituted fluorene	fluorene
Naphthalene Group	naphthalene C_2, C_3, and C_4 substituted naphthalenes methyl naphthalene	naphthalene
Phenanthrene Group	phenanthrene/anthracene methyl phenanthrene/anthracene C_2, C_3, and C_4 substituted phenanthrene/anthracene	pyrene[(c)]
Acridine Group	acridine methyl acridine	anthracene
Quinoline Group	quinoline 7-methyl quinoline C_2 alkyl substituted quinolines	pyridine

(a) Based on B(a)P and toxicity equivalent factors for ecological receptors due to lack of data for benzo(a)anthracene.

(b) Based on B(a)P and toxicity equivalent factors for ecological receptors due to lack of data for benzo(ghi)perylene.

(c) Based on pyrene as there was sufficient laboratory data for ecological receptors.

VI.1.2 Chemical Screening for Wildlife Health

Site-specific data were collected and evaluated, and appropriate concentrations were selected for the screening process. For this assessment, the maximum measured concentrations were selected as a conservative estimate of the chemical concentrations.

Steps 1 and 2: Compile Validated Site and Background Chemical Concentration Data

Site and background data used in chemical screening for wildlife health are listed below under each key question. Background data are defined as data collected in areas outside the zone of influence of oil sands activities and emissions.

W-2: Operational Exposure

Water - Since operational release waters from Project Millennium were not available, water chemistry data from existing oil sands operations (i.e., Suncor and Syncrude) were used for water quality modelling. Predicted concentrations in the Athabasca River, McLean Creek and Shipyard Lake during the operational phase were used for chemical screening. For more details on water quality, refer to Section C3. Maximum measured or reasonable worst-case predicted concentrations were used for screening purposes. Background water quality data included water samples that were collected in the Athabasca River upstream of existing oil sands operations.

Fish Tissues - Fish tissue data were obtained from walleye, goldeye and longnose sucker collected during spring and summer of 1995 (Golder 1996c). These data were considered to be representative of baseline conditions. In addition, tissue analyses were performed on trout held in 10% TID water and refinery effluent in the laboratory and these data were considered to represent a worst-case scenario (HydroQual 1996a,b). Maximum concentrations were used for screening purposes.

Background fish tissue data were obtained from laboratory experiments in which walleye and rainbow trout were exposed to Athabasca River water collected upstream of the site (HydroQual 1996a). For more details on fish quality, refer to Section C4.

Aquatic Invertebrates - Measured tissue concentrations in benthic invertebrates collected from potentially impacted areas of the Athabasca River in 1995 were used for chemical screening (Golder 1996c). Background data were obtained in 1983 upstream from existing oil sands facilities (Beak Associates Consulting Ltd. 1988).

Plants - Plant tissue data were obtained from a vegetation sampling program conducted on Suncor Lease 25 within the zone of air deposition of existing oil sands facilities, on the Muskeg River Mine Project site (pre-development) and in control areas. Three types of plants consumed by local First Nations residents were selected for analysis: blueberries; Labrador tea leaves and cattail root. Maximum concentrations on the Project site and on the Muskeg River Mine Project site were used in the chemical screening. Plant tissue concentrations from control areas were used as background data for chemical screening purposes.

W-3: Reclaimed Landscape Exposure

Water - Predicted water concentrations in the Athabasca River, Shipyard Lake, McLean Creek and the end pit lake at closure and in the far future were used for chemical screening. For more details on water quality, refer to Section C3. Reasonable worst-case predicted concentrations were used for screening purposes.

Terrestrial Plants - Xu (1997) measured uptake of metals into the leaves, stems and roots of poplar, willow and reed canary grass from reclamation materials of various composition. Metal concentrations in plants growing on CT, capped with 20 cm of tailings sand and 5 cm of muskeg, were used as conservative estimates of the potential concentrations of plants on the Project Millennium reclaimed landscape. The geometric mean of these data were used for chemical screening for plants growing on top of capped CT deposits. Since no measured data were available for PAHs in plants growing on reclaimed landscapes, plant tissue concentrations were estimated based on the chemistry of tailings sand and bioconcentration factors (BCF) for plant uptake (Travis and Arms 1988). These predicted PAH concentrations were used in chemical screening.

Aquatic Invertebrates - Nix (1995) investigated the use of constructed wetlands as a method of treatment of oil sands wastewater. In that study, metal residue concentrations were reported for benthic invertebrates and emergent insects from two types of constructed wetlands including: (1) experimental control (i.e., surface runoff from a nearby lake), (2) seepage water from tailings ponds dykes. Reference data were also collected from a reference drainage ditch. Residue data from invertebrates found in the seepage water were used as a basis for chemical screening of prey tissue that might be consumed by wildlife species (e.g., mallard). Residue data from the experimental control, natural wetlands and a reference drainage ditch were used as background data. The maximum residue concentrations were used for screening.

Aquatic Plants - Data from Nix (1994) and Golder (1997g) were used for concentrations in aquatic plants. Nix (1994) studied the uptake of oil sands related inorganic chemicals into cattail and bulrush shoots growing in a constructed wetland. In that study, metal residue concentrations were

reported for aquatic plants from two types of constructed wetlands including: (1) experimental control (i.e., surface runoff from a nearby lake), (2) seepage water from tailings ponds dykes. Reference data were also collected from a reference drainage ditch. Golder (1997g) measured tissue concentrations in cattail and Carex sp. from the Suncor hummock wetlands and Pond 5 in 1996. These data were used as a basis for chemical screening for wildlife species (e.g., moose, mallard, beaver) that may consume aquatic plants as part of their diet. Residue data from the experimental control, natural wetlands and a reference drainage ditch were used as background data. The maximum residue concentrations were used for screening.

Step 3: Compile Relevant Environmental Criteria and Select SLC

Water - Drinking water criteria included:

- Canadian Council of Resource and Environment Ministers (CCREM) Water Quality Guidelines. Guidelines for Livestock Drinking Water Quality (CCREM 1987); and,
- BC Environment (BCE) Contaminated Sites Regulation. Schedule 6. Generic Numerical Water Standards. Livestock. (BCE 1997).

The lowest available value of the two criteria was chosen as the SLC for drinking water (Table VI.1-4).

Fish, Invertebrates and Plants - No regulatory SLC were available.

Step 4: Comparison of Maximum Observed or Predicted Concentrations to SLC

Site concentrations were compared to SLC. If chemical concentrations were greater than or equal to the SLC, the chemicals were carried forward to Step 5. If chemical concentrations were much less than the SLC, they were eliminated from further consideration in the risk assessment. However, if chemical concentrations were marginally less than the SLC, these chemicals were conservatively carried forward to Step 5. If no SLC were available, chemicals were carried forward to Step 5.

Step 5: Comparison of Maximum Observed or Predicted Concentrations to Background Concentrations

Site concentrations were compared to background chemical concentrations, where background data were available. If chemical concentrations were less than or equal to background concentrations, they were eliminated from further consideration in the risk assessment, since these chemical concentrations were assumed to be natural in origin and not Project-related.

If chemical concentrations exceeded background concentrations or if no background data were available, they were carried forward to Step 6.

Step 6: Identification of Risk-Based Concentrations (RBCs) for Remaining Chemicals

At this stage, risk-based concentrations (RBCs) were identified for all chemicals for which site concentrations exceeded both SLC and background concentrations. Receptor-specific mammalian wildlife NOAELS were calculated for water, plants and prey, based on estimated No-Observed-Adverse-Effect-Levels (NOAELs) or Lowest-Observed-Adverse-Effect-Levels (LOAELs) reported for laboratory animals, using dose-scaling techniques recommended by Sample et al. (1996), which are briefly described below.

NOAELs and LOAELs are daily dose levels normalized to body weight (i.e., expressed as mg of chemical per kg body weight per day) to allow comparison between test species and wildlife species, with consideration of differences in body weight. Smaller animals have higher metabolic rates and may be more resistant to toxic chemicals because of faster detoxification rates. Several studies have been conducted to investigate the relationship between body size and responses to toxic chemicals. For avian species, extrapolation of NOAELs and LOAELs from test species to wildlife species (i.e., dose-scaling) based on body weight has been shown to be appropriate. However, for mammals, body surface area dose-scaling between test and wildlife species may be more appropriate than dose-scaling according to body weight. Dose-scaling according to body surface area results in more conservative wildlife NOAELs and LOAELs for larger mammals (Sample et al. 1996). Receptor-specific NOAELs for wildlife species used in this assessment were derived based on these dose-scaling techniques. In addition to dose-scaling, a 10-fold uncertainty factor was applied to LOAELs to derive conservative NOAELs, where none were reported in the study. The receptor-specific wildlife NOAELs are presented in Table VI.1-2, along with details of the laboratory studies used to derive these NOAELs.

Receptor-specific RBCs were then calculated based on receptor-specific NOAELs, ingestion rates and dietary preferences (e.g., RBC for water = 0.1 x (NOAEL x body weight)/ingestion rate for water). In general, adverse effects are observed at levels ten times greater than the NOAEL; therefore, an RBC based on a chronic NOAEL is considered to be conservative (Sample et al. 1996). To be consistent with screening methods for human health, the target hazard quotient of the RBCs was conservatively set at 0.1, assuming an animal could only receive one-tenth of its daily exposure from each media. Receptor-specific RBCs are presented in Table VI.1-3.

If RBCs were not available and could not be derived, chemicals were retained and evaluated for nutrient and/or non-toxic status under Step 7. If RBCs were available, chemicals were retained and evaluated for exceedance of RBCs in Step 8.

Step 7: Evaluation of Nutritional or Non-Toxic Status

Certain constituents may be eliminated from further consideration based on their importance as a dietary component, status as an essential nutrient, or general lack of toxic effects. Calcium, magnesium, potassium, iron and sodium can generally be eliminated from an evaluation at the screening stage based on dietary and nutritional status (NAS 1980). Therefore, these chemicals were eliminated from further consideration. Other chemicals may be considered non-toxic under certain conditions of exposure. These are described below.

Aluminum

Aluminum is the third most abundant element in the earth's crust and is present in all rock types and most geologic materials, especially clays (CCREM 1987). Total aluminum measurements in soil reflect the natural abundance of aluminum silicate in soils, which are less thatn 1% bioavailable by the oral route. The daily intake of aluminum is largely from food. For these reasons, the elevated aluminum concentrations in reclamation soils were not evaluated further in the risk assessment.

Ammonia

Although considered an odour nuisance at low concentrations in water, ammonia was not considered an ecological health concern via the ingestion pathway (HSDB 1995).

Chloride

Chloride is an essential nutrient for the growth of plants (CCREM 1987) and is an essential nutrient for animals, which functions to ensure proper fluid-electrolyte balance (NAS 1980). Typically, when animals suffer from sodium and chloride deficiency, they will be drawn to salt licks (NAS 1980). Given that chloride is essential for plant and animal health and that there is no anthropogenic source for this chemical, chloride was eliminated from further consideration.

Phosphorus

Phosphorus is a natural element that may be removed from igneous and other types of rock by leaching or weathering (CCREM 1987).

Environmental concentrations in western Canada range from 0.003 to 3 mg/L for total phosphorus. Given that phosphorus occurs naturally and that concentrations at the site fall within concentrations reported for western Canada, phosphorus was eliminated from further consideration.

Silicon

Silicon is important in the formation of bone in young animals and birds and toxicity does not appear to be a serious problem in animals (NAS 1980). In addition, silicon is insufficiently bioavailable to be absorbed following intake (HSDB 1995). Therefore, it is considered non-hazardous and was eliminated from further consideration.

Sulphate

High sulphate concentrations in water can be tolerated in livestock, but a loss in agricultural production (i.e., decreased water and food consumption and weight loss) can be expected at concentrations above 1000 mg/L. Given that sulphate is a major ion, and that measured concentrations fall within the reported range for environmental concentrations, sulphate was not considered to be an wildlife health concern via the ingestion pathway and was eliminated from further consideration.

Step 8: Comparison of Maximum Observed or Predicted Concentration to Risk-Based Concentration

In this step, the maximum chemical concentrations measured in water, invertebrates, fish and plants were compared to the RBCs. If the maximum concentration of a chemical ws greater than or equal to the RBC, the chemical was retained for further evaluation in the risk assesssment. If the concentrations was less than the RBC, the chemical was eliminated from further consideration.

Chemical screening tables for the baseline are presented in Tables VI.1-5 to VI.1-13, with a summary list in Table VI.1-14. Screening tables for project impacts and the CEA are presented in Tables VI.1-15 to VI.1-34, with a summary list in Table VI.1-35. All chemicals that were identified in one or more media were evaluated in all media for each key question. This was done to determine the combined exposure to these chemicals from all potentially affected media (i.e., water, invertebrates, fish and plants) during operation (W-2) and following closure (W-3).

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Water Shrew							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	0.013	21.6	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	0.013	21.6	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	0.013	123.3	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	0.013	12.3	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	0.013	1.23	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	0.013	123.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	0.013	61.6	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	0.013	9.2	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	0.013	15.4	U.S. EPA 1989c.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes	0.03	0.013	15.4	U.S. EPA 1988
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	0.013	16.4	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	0.013	4.93	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	0.013	9.2	U.S. EPA 1989d.
Phenol	laboratory rats	60	reproduction	0.35	0.013	136.7	NTP 1983.
Acridine	laboratory mice	100	reproduction	0.03	0.013	123.3	Based on anthracene.
Quinoline	laboratory rat	1	increased liver weight	0.35	0.013	2.28	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	0.013	34.2	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	0.013	22.1	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	0.013	32.0	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	0.013	2.54	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	0.013	6.2	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	0.013	640.3	Based on o-cresol.
Aluminum	laboratory mice	1.93	reproduction	0.03	0.013	2.4	Ondreicka et al. 1966
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	0.013	0.154	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	0.013	0.155	Schroeder et al. 1971
Barium	laboratory rat	5.1	growth, hypertension	0.435	0.013	12.2	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	0.013	1.5	Schroeder and Mitchner 1975
Boron	laboratory rat	28.0	reproduction	0.35	0.013	63.8	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	0.013	2.2	Sutou et al. 1980b
Cobalt	cattle	0.24	maximum tolerable level	318	0.013	3.0	NAS 1980.
Copper	mink	11.7	reproduction	1	0.013	34.6	Aulerich et al. 1982
Chromium (III)	laboratory rat	2737.0	reproduction; longevity	0.35	0.013	6234.6	Ivankovic and Preussmann 1975
Cyanide	laboratory rat	6.9	reproduction	1	0.013	20.3	Tewe and Maner 1981
Lead	laboratory rat	8.0	reproduction	0.35	0.013	18.2	Azar et al. 1973
Lithium	laboratory rat	9.4	reproduction	0.35	0.013	21.4	Marathe and Thomas 1986
Manganese	laboratory rat	88	reproduction	0.35	0.013	200.5	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	0.013	3.0	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	0.013	0.32	Schroeder and Mitchener 1971
Nickel	laboratory rat	40.00	reproduction	0.35	0.013	91.12	Ambrose et al. 1976
Selenium	laboratory rat	0.20	reproduction	0.35	0.013	0.46	Rosenfeld and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	0.013	599.1	Skornya 1981.
Tin	laboratory rat	0.6	kidney and liver effects	0.35	0.013	1.4	NTP 1982.
Uranium	laboratory mice	3.1	reproduction	0.028	0.013	3.72	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	0.013	0.44	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	0.013	364.46	Schlicker and Cox 1968
Zirconium	laboratory mice	1.7	lifespan; longevity	0.03	0.013	2.14	Schroeder et al. 1968.
River Otter							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	7.698	4.4	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	7.698	4.4	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	7.698	25.0	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	7.698	2.5	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	7.698	0.25	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	7.698	25.0	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	7.698	12.5	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	7.698	1.9	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	7.698	3.1	U.S. EPA 1989c.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes	0.03	7.698	3.1	U.S. EPA 1988
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	7.698	3.3	Shopp et al. 1984.
Phenanthrene	laboratory mice	4.0	mortality, clinical signs	0.03	7.698	1.0	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	7.698	1.9	U.S. EPA 1989d.
Phenol	laboratory rats	60	reproduction	0.35	7.698	27.7	NTP 1983.
Acridine	laboratory mice	100	reproduction	0.03	7.698	25.0	Based on anthracene.
Quinoline	laboratory rat	1.0	increased liver weight	0.35	7.698	0.46	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	7.698	6.9	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	7.698	4.5	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	7.698	6.5	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	7.698	0.51	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5.0	clinical signs and blood changes	0.03	7.698	1.2	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	7.698	129.8	Based on o-cresol.
Aluminum	laboratory mice	1.93	reproduction	0.03	7.698	0.5	Ondreicka et al. 1966
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	7.698	0.031	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	7.698	0.031	Schroeder et al. 1971
Barium	laboratory rat	5.1	growth, hypertension	0.435	7.698	2.5	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	7.698	0.3	Schroeder and Mitchner 1975

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Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Boron	laboratory rat	28.0	reproduction	0.35	7.698	12.9	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	7.698	0.4	Sutou et al. 1980b
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	7.698	1263.9	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	7.698	0.6	NAS 1980.
Copper	mink	11.7	reproduction	1	7.698	7.0	Aulerich et al. 1982.
Cyanide	laboratory rat	6.9	reproduction	1	7.698	4.1	Tewe and Maner 1981
Lead	laboratory rat	8.0	reproduction	0.35	7.698	3.7	Azar et al. 1973
Lithium	laboratory rat	9.4	reproduction	0.35	7.698	4.3	Marathe and Thomas 1986
Manganese	laboratory rat	88	reproduction	0.35	7.698	40.6	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	7.698	0.6	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	7.698	0.06	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	7.698	18.5	Ambrose et al. 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	7.698	0.1	Rosenfeld and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	7.698	121.4	Skornya 1981.
Tin	laboratory rat	0.60	kidney and liver effects	0.35	7.698	0.3	NTP 1982
Uranium	laboratory mouse	3.1	reproduction	0.028	7.698	0.75	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	7.698	0.09	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	7.698	73.9	Schlicker and Cox 1968.
Zirconium	laboratory mouse	1.7	lifespan; longevity	0.03	7.698	0.43	Schroeder et al. 1968.
Killdeer							
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	22.6	Peakall et al. 1982.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0989	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	0.0989	0.011	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	0.0989	1.1	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	22.6	Based on anthracene.
Aluminum	ringed dove	109.7	reproduction	0.155	0.0989	109.7	Carriere et al. 1986
Arsenic	mallard ducks	5.1	mortality	1	0.0989	5.1	USFWS 1964
Barium	day-old chicks	21	mortality	0.121	0.0989	21	Johnson et al. 1960.
Cadmium	mallard	1.45	reproduction	1.153	0.0989	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.0989	1	Haseltine et al. 1985.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.0989	0.7	NAS 1980.
Copper	day-old chicks	47	growth, mortality	0.534	0.0989	47	Mehring et al. 1960
Manganese	Japanese quail	977	growth, behaviour	0.072	0.0989	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.0989	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.0989	3.5	Lepore and Miller 1965
Nickel	mallard	77.4	mortality, growth, behaviour	0.782	0.0989	77.4	Cain and Pafford 1981
Selenium	mallard	0.5	reproduction	1	0.0989	0.5	Heinz et al. 1987
Uranium	black duck	16	mortality, body weight, liver/kidney effe	1.25	0.0989	16	Haseltine and Silco 1983.
Vanadium	mallard	11.4	mortality, body weight	1.17	0.0989	11.4	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.0989	14.5	Stahl et al. 1990
Great Blue Heron							
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	22.6	Patton and Dieter 1980.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	2.204	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	2.204	0.011	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	2.204	1.1	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	22.6	Based on anthracene.
Aluminum	ringed dove	109.7	reproduction	0.155	2.204	109.7	Carriere et al. 1986
Arsenic	mallard	5.1	mortality	1	2.204	5.1	USFWS 1964
Barium	day-old chicks	21	mortality	0.121	2.204	21	Johnson et al. 1960.
Cadmium	mallard	1.45	reproduction	1.153	2.204	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	2.204	1	Haseltine et al., unpub. data.
Copper	day-old chicks	33.2	growth, mortality	0.534	2.204	33.2	Mehring et al. 1960.
Manganese	Japanese quail	977	growth, behaviour	0.072	2.204	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	2.204	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	2.204	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behaviour	0.782	2.204	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	2.204	0.5	Heinz et al. 1987
Uranium	black duck	16	mortality, body weight, liver/kidney effe	1.25	2.204	16	Haseltine and Silco 1983.
Vanadium	mallard	11.4	mortality, body weight	1.17	2.204	11.4	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	2.204	14.5	Stahl et al. 1990
Deer Mouse							

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	0.0187	19.7	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	0.0187	19.7	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	0.0187	112.5	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	0.0187	11.3	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	0.0187	1.1	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	0.0187	11.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	0.0187	104.0	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	0.0187	584.6	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	0.0187	584.6	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	0.0187	0.23	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	0.0187	8.4	Based on pyrene.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	0.0187	5.6	U.S. EPA 1989c.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	0.0187	20.2	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	0.0187	14.1	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	0.0187	14.1	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	0.0187	15.0	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	0.0187	4.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	0.0187	124.8	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	0.0187	8.4	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	0.0187	2.1	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	0.0187	2.3	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	0.0187	2.2	Ondreicka et al. 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	0.0187	0.14	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	0.0187	0.14	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	0.0187	11.1	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	0.0187	1.4	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	0.0187	58.2	Weir and Fisher 1972
Cadmium	laboratory rat	1	reproduction	0.35	0.0187	2.1	Sutou et al. 1980
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	0.0187	6.8	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	0.0187	5692.9	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	0.0187	2.7	NAS 1980.
Copper	mink	11.71	reproduction	1	0.0187	31.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	0.0187	13.4	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	0.0187	16.6	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	0.0187	25.4	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	0.0187	183.0	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	0.0187	2.7	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	0.0187	0.29	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	0.0187	83.2	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	0.0187	0.4	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	0.0187	547.0	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	0.0187	0.016	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	0.0187	3.4	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	0.0187	0.41	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	0.0187	332.8	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	0.0187	2.0	Schroeder et al. 1968.
Snowshoe hare							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	1.505	6.6	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	1.505	6.6	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	1.505	37.6	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	1.505	3.8	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	1.505	0.38	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	1.505	3.8	Based on benzo(a)pyrene and TEFS.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	1.505	37.6	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	1.505	34.7	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	1.505	195.2	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	1.505	195.2	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	1.505	0.08	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	1.505	1.9	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	1.505	2.8	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	1.505	6.7	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	1.505	4.7	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	1.505	4.7	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	1.505	5.0	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	1.505	1.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	1.505	41.7	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	1.505	2.8	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	1.505	0.69	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	1.505	0.77	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	1.505	0.73	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	1.505	0.047	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	1.505	0.047	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	1.505	3.7	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	1.505	0.5	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	1.505	19.4	Weir and Fisher 1972

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Cadmium	laboratory rat	1.0	reproduction	0.303	1.505	0.7	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	1.505	2.3	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	1.505	1900.7	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	1.505	0.92	NAS 1980.
Copper	mink	11.71	reproduction	1	1.505	10.6	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	1.505	4.5	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	1.505	5.6	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	1.505	8.5	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	1.505	61.1	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	1.505	0.9	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	1.505	0.10	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	1.505	27.8	Ambrose et al. 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	1.505	0.14	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	1.505	182.6	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	1.505	0.005	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	1.505	1.1	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	1.505	0.14	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	1.505	111.1	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	1.505	0.65	Schroeder et al. 1968.
Beaver							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	18.275	3.5	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	18.275	3.5	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	18.275	20.1	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	18.275	2.0	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	18.275	0.20	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	18.275	2.0	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	18.275	18.6	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	18.275	104.6	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	18.275	104.6	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	18.275	0.040	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	18.275	1.0	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	18.275	1.5	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	18.275	3.6	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	18.275	2.5	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	18.275	2.5	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	18.275	2.7	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	18.275	0.81	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	18.275	22.3	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	18.275	1.5	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	18.275	0.37	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	18.275	0.41	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	18.275	0.39	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	18.275	0.025	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	18.275	0.025	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	18.275	2.0	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	18.275	0.2	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	18.275	10.4	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	18.275	0.4	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	18.275	1.2	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	18.275	1018.2	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	18.275	0.49	NAS 1980.
Copper	mink	11.71	reproduction	1	18.275	5.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	18.275	2.4	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	18.275	3.0	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	18.275	4.5	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	18.275	32.7	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	18.275	0.5	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	18.275	0.05	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	18.275	14.9	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	18.275	0.07	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	18.275	97.8	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	18.275	0.003	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	18.275	0.61	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	18.275	0.07	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	18.275	59.5	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	1.505	0.65	Schroeder et al. 1968.
Moose							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	381	1.6	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	381	1.6	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	381	9.4	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	381	0.94	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	381	0.09	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	381	0.94	Based on benzo(a)pyrene and TEFS.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	381	9.4	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	381	8.7	Ambrose et al. 1960.

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
m-cresol	mink	216.2	reproduction	1	381	48.9	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	381	48.9	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	381	0.019	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	381	0.47	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	381	0.71	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	381	1.7	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	381	1.2	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	381	1.2	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	381	1.3	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	381	0.38	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	381	10.4	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	381	0.71	U.S. EPA 1989c.
Quinoline	laboratory rat	1	increased liver weight	0.35	381	0.17	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	381	0.19	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	381	0.18	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	381	0.012	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	381	0.012	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	381	0.93	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	381	0.1	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	381	4.9	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	381	0.2	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	381	0.57	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	381	476.5	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	381	0.23	NAS 1980.
Copper	mink	11.71	reproduction	1	381	2.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	381	1.1	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	381	1.4	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	381	2.1	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	381	15.3	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	381	0.2	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	381	0.024	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	381	7.0	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	381	0.035	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	381	45.8	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	381	0.001	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	381	0.28	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	381	0.034	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	381	27.9	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	381	0.16	Schroeder et al. 1968.
Black Bear							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	130	2.2	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	130	2.2	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	130	12.3	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	130	1.2	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	130	0.12	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	130	1.2	Based on benzo(a)pyrene and TEFS.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	130	12.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	130	11.4	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	130	64.0	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	130	64.0	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	130	0.02	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	130	0.6	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	130	0.9	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	130	2.2	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	130	1.5	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	130	1.5	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	130	1.6	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	130	0.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	130	13.7	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	130	0.9	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	130	0.23	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	130	0.25	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	130	0.24	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	130	0.015	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	130	0.016	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	130	1.2	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	130	0.2	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	130	6.4	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	130	0.2	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	130	0.7	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	130	623.5	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	130	0.30	NAS 1980.
Copper	mink	11.71	reproduction	1	130	3.5	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	130	1.5	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	130	1.8	Azar et al. 1973.

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Lithium	laboratory rat	9.39	reproduction	1	130	2.8	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	130	20.0	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	130	0.3	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	130	0.03	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	130	9.1	Ambrose et al. 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	130	0.05	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	130	59.9	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	130	0.002	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	130	0.4	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	130	0.04	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	130	36.4	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	130	0.21	Schroeder et al. 1968.
American robin							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0836	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	0.0836	0.0112	Peakall et al. 1982.
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0836	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Phenanthrene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	0.0836	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	0.0836	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	0.0836	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	0.0836	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	0.0836	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	0.0836	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.0836	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.0836	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	0.0836	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	0.0836	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	0.0836	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.0836	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.0836	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	0.0836	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	0.0836	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	0.0836	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	0.0836	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	0.0836	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.0836	14.5	Stahl et al. 1990
Ruffed grouse							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.54285	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	0.54285	0.0112	Peakall et al. 1982.
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	0.54285	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Phenanthrene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	0.54285	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	0.54285	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	0.54285	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	0.54285	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	0.54285	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	0.54285	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.54285	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.54285	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	0.54285	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	0.54285	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	0.54285	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.54285	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.54285	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	0.54285	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	0.54285	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	0.54285	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	0.54285	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	0.54285	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.54285	14.5	Stahl et al. 1990
Mallard							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	1.107	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	1.107	0.0112	Peakall et al. 1982.

TABLE VI.1-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR WILDLIFE RECEPTORS

Chemicals	Test Species	Test[a] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[b] Species Body Weight (kg)	Estimated[c] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	1.107	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Phenanthrene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	1.107	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	1.107	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	1.107	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	1.107	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	1.107	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	1.107	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	1.107	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	1.107	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	1.107	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	1.107	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	1.107	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	1.107	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	1.107	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	1.107	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	1.107	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	1.107	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	1.107	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	1.107	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	1.107	14.5	Stahl et al. 1990

[a] No-Observed Adverse Effect Level (NOAEL) based on the toxicological literature and the method by Sample et al. 1996.

[b] Based on literature derived values. Please see Appendix VIII.4.1.

[c] For mammalian species, estimated wildlife NOAEL = $NOAEL_{test}$ (body $weight_{test}$ / body $weight_{wildlife}$)$^{1/4}$. Based on method by Sample et al. (1996).
For avian species, estimated wildlife NOAEL = test NOAEL. Based on method by Sample et al. (1996).

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

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Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Water Shrew								
Acenaphthylene	21.6	0.013	-	0.01235	0.001987	-	2.3	14.1
Acenaphthene	21.6	0.013	-	0.01235	0.001987	-	2.3	14.1
Anthracene	123.3	0.013	-	0.01235	0.001987	-	13.0	80.7
Benzo(a)anthracene	12.3	0.013	-	0.01235	0.001987	-	1.3	8.0
Benzo(a)pyrene	1.23	0.013	-	0.01235	0.001987	-	0.1	0.8
Benzo(ghi)perylene	123.3	0.013	-	0.01235	0.001987	-	13.0	80.7
Biphenyl	61.6	0.013	-	0.01235	0.001987	-	6.5	40.3
Dibenzothiophene	9.24	0.013	-	0.01235	0.001987	-	1.0	6.0
Fluorene	15.41	0.013	-	0.01235	0.001987	-	1.6	10.1
Fluoranthene	15.41	0.013	-	0.01235	0.001987	-	1.6	10.1
Naphthalene	16.39	0.013	-	0.01235	0.001987	-	1.7	10.7
Phenanthrene	4.93	0.013	-	0.01235	0.001987	-	0.5	3.2
Pyrene	9.24	0.013	-	0.01235	0.001987	-	1.0	6.0
Phenol	136.70	0.013	-	0.01235	0.001987	-	14.4	89.4
Acridine	123.25	0.013	-	0.01235	0.001987	-	13.0	80.6
Quinoline	2.28	0.013	-	0.01235	0.001987	-	0.2	1.5
Chloroform	34.17	0.013	-	0.01235	0.001987	-	3.6	22.4
Ethylbenzene	22.12	0.013	-	0.01235	0.001987	-	2.3	14.5
Toluene	32.02	0.013	-	0.01235	0.001987	-	3.4	20.9
Xylenes	2.54	0.013	-	0.01235	0.001987	-	0.3	1.7
2,4-Dimethylphenol	6.16	0.013	-	0.01235	0.001987	-	0.6	4.0
m-cresol	640.28	0.013	-	0.01235	0.001987	-	67.4	418.9
Aluminum	2.4	0.013	-	0.01235	0.001987	-	0.3	1.6
Antimony	0.15	0.013	-	0.01235	0.001987	-	0.0	0.1
Arsenic	0.155	0.013	-	0.01235	0.001987	-	0.0	0.1
Barium	12.17	0.013	-	0.01235	0.001987	-	1.3	8.0
Beryllium	1.5	0.013	-	0.01235	0.001987	-	0.2	1.0
Boron	63.8	0.013	-	0.01235	0.001987	-	6.7	41.7
Cadmium	2.2	0.013	-	0.01235	0.001987	-	0.2	1.4
Chromium (III)	6234.6	0.013	-	0.01235	0.001987	-	656.3	4079.0
Cobalt	3	0.013	-	0.01235	0.001987	-	0.3	2.0
Copper	34.6	0.013	-	0.01235	0.001987	-	3.6	22.6
Cyanide	20.3	0.013	-	0.01235	0.001987	-	2.1	13.3
Lead	18.2	0.013	-	0.01235	0.001987	-	1.9	11.9
Lithium	21.4	0.013	-	0.01235	0.001987	-	2.3	14.0
Manganese	200.45	0.013	-	0.01235	0.001987	-	21.1	131.1
Mercury (inorganic)	3	0.013	-	0.01235	0.001987	-	0.3	2.0
Molybdenum	0.32	0.013	-	0.01235	0.001987	-	0.03	0.2
Nickel	91.12	0.013		0.01235	0.001987	-	9.6	59.6
Selenium	0.46	0.013	-	0.01235	0.001987	-	0.0	0.3
Strontium	599.08	0.013	-	0.01235	0.001987	-	63.1	392.0
Tin	1.37	0.013	-	0.01235	0.001987	-	0.1	0.9
Uranium	3.72	0.013	-	0.01235	0.001987	-	0.4	2.4
Vanadium	0.44	0.013	-	0.01235	0.001987	-	0.05	0.3
Zinc	364.46	0.013		0.01235	0.001987	-	38.4	238.4
Zirconium	2.14	0.013	-	0.01235	0.001987	-	0.2	1.4
River Otter								
Acenaphthylene	4.37	7.698	-	0.3678	0.6214	-	9.2	5.4
Acenaphthene	4.37	7.698	-	0.3678	0.6214	-	9.2	5.4

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Anthracene	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Benzo(a)anthracene	2.50	7.698	-	0.3678	0.6214	-	5.2	3.1
Benzo(a)pyrene	0.25	7.698	-	0.3678	0.6214	-	0.5	0.3
Benzo(ghi)perylene	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Biphenyl	12.49	7.698	-	0.3678	0.6214	-	26.1	15.5
Dibenzothiophene	1.87	7.698	-	0.3678	0.6214	-	3.9	2.3
Fluorene	3.12	7.698	-	0.3678	0.6214	-	6.5	3.9
Fluoranthene	3.12	7.698	-	0.3678	0.6214	-	6.5	3.9
Naphthalene	3.32	7.698	-	0.3678	0.6214	-	7.0	4.1
Phenanthrene	1.00	7.698	-	0.3678	0.6214	-	2.1	1.2
Pyrene	1.87	7.698	-	0.3678	0.6214	-	3.9	2.3
Phenol	27.7	7.698	-	0.3678	0.6214	-	58.0	34.3
Acridine	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Quinoline	0.46	7.698	-	0.3678	0.6214	-	1.0	0.6
Chloroform	6.93	7.698	-	0.3678	0.6214	-	14.5	8.6
Ethylbenzene	4.48	7.698	-	0.3678	0.6214	-	9.4	5.6
Toluene	6.49	7.698	-	0.3678	0.6214	-	13.6	8.0
Xylenes	0.51	7.698	-	0.3678	0.6214	-	1.1	0.6
2,4-Dimethylphenol	1.25	7.698	-	0.3678	0.6214	-	2.6	1.5
m-cresol	129.80	7.698	-	0.3678	0.6214	-	271.7	160.8
Aluminum	0.50	7.698	-	0.3678	0.6214	-	1.0	0.6
Antimony	0.03	7.698	-	0.3678	0.6214	-	0.1	0.04
Arsenic	0.03	7.698	-	0.3678	0.6214	-	0.1	0.04
Barium	2.47	7.698	-	0.3678	0.6214	-	5.2	3.1
Beryllium	0.3	7.698	-	0.3678	0.6214	-	0.6	0.4
Boron	12.9	7.698	-	0.3678	0.6214	-	27.0	16.0
Cadmium	0.4	7.698	-	0.3678	0.6214	-	0.8	0.5
Chromium (III)	1263.9	7.698	-	0.3678	0.6214	-	2645.3	1565.7
Cobalt	0.6	7.698	-	0.3678	0.6214	-	1.3	0.7
Copper	7.03	7.698	-	0.3678	0.6214	-	14.7	8.7
Cyanide	4.1	7.698	-	0.3678	0.6214	-	8.6	5.1
Lead	3.7	7.698	-	0.3678	0.6214	-	7.7	4.6
Lithium	4.34	7.698	-	0.3678	0.6214	-	9.1	5.4
Manganese	40.64	7.698	-	0.3678	0.6214	-	85.0	50.3
Mercury (inorganic)	0.60	7.698	-	0.3678	0.6214	-	1.3	0.7
Molybdenum	0.06	7.698	-	0.3678	0.6214	-	0.1	0.1
Nickel	18.47	7.698	-	0.3678	0.6214	-	38.7	22.9
Selenium	0.09	7.698	-	0.3678	0.6214	-	0.2	0.1
Strontium	121.44	7.698	-	0.3678	0.6214	-	254.2	150.4
Tin	0.28	7.698	-	0.3678	0.6214	-	0.6	0.3
Uranium	0.75	7.698	-	0.3678	0.6214	-	1.6	0.9
Vanadium	0.09	7.698	-	0.3678	0.6214	-	0.2	0.1
Zinc	73.88	7.698	-	0.3678	0.6214	-	154.6	91.5
Zirconium	0.43	7.698	-	0.3678	0.6214	-	0.9	0.5
Killdeer								
Acenaphthylene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Acenaphthene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Benzo(a)anthracene	0.11	0.0989	-	0.0154	0.02179	-	0.1	0.05
Benzo(a)pyrene	0.011	0.0989	-	0.0154	0.02179	-	0.01	0.005
Benzo(ghi)perylene	1.1	0.0989	-	0.0154	0.02179	-	0.71	0.50

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Dibenzothiophene	22.6	0.0989	-	0.0154	0.02179	-	14.5	10.3
Fluoranthene	22.6	0.0989	-	0.0154	0.02179	-	14.5	10.3
Fluorene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Phenanthrene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Pyrene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Acridine	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Aluminum	109.7	0.0989	-	0.0154	0.02179	-	70.5	49.8
Arsenic	5.1	0.0989	-	0.0154	0.02179	-	3.3	2.3
Barium	21	0.0989	-	0.0154	0.02179	-	13.5	9.5
Cadmium	1.45	0.0989	-	0.0154	0.02179	-	0.9	0.7
Chromium	1	0.0989	-	0.0154	0.02179	-	0.6	0.5
Cobalt	0.7	0.0989	-	0.0154	0.02179	-	0.4	0.3
Copper	47	0.0989	-	0.0154	0.02179	-	30.2	21.3
Lead	3.85	0.0989	-	0.0154	0.02179	-	2.5	1.7
Manganese	977	0.0989	-	0.0154	0.02179	-	627.4	443.4
Mercury (inorganic)	0.45	0.0989	-	0.0154	0.02179	-	0.3	0.2
Molybdenum	3.5	0.0989	-	0.0154	0.02179	-	2.2	1.6
Nickel	77.4	0.0989	-	0.0154	0.02179	-	49.7	35.1
Selenium	0.5	0.0989	-	0.0154	0.02179	-	0.3	0.2
Uranium	16	0.0989	-	0.0154	0.02179	-	10.3	7.3
Vanadium	11.4	0.0989	-	0.0154	0.02179	-	7.3	5.2
Zinc	14.5	0.0989	-	0.0154	0.02179	-	9.3	6.6
Great Blue Heron								
Acenaphthylene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Acenaphthene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Benzo(a)anthracene	0.11	2.204	-	0.09757	0.2223	-	0.2	0.1
Benzo(a)pyrene	0.011	2.204	-	0.09757	0.2223	-	0.0	0.0
Benzo(ghi)perylene	1.1	2.204	-	0.09757	0.2223	-	2.48	1.09
Dibenzothiophene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Fluoranthene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Fluorene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Phenanthrene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Pyrene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Acridine	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Aluminum	109.7	2.204	-	0.09757	0.2223	-	247.8	108.8
Arsenic	5.1	2.204	-	0.09757	0.2223	-	11.5	5.1
Barium	21	2.204	-	0.09757	0.2223	-	47.4	20.8
Cadmium	1.4	2.204	-	0.09757	0.2223	-	3.2	1.4
Chromium	1	2.204	-	0.09757	0.2223	-	2.3	1.0
Cobalt	0.7	2.204	-	0.09757	0.2223	-	1.6	0.7
Copper	47	2.204	-	0.09757	0.2223	-	106.2	46.6
Lead	3.85	2.204	-	0.09757	0.2223	-	8.7	3.8
Manganese	977	2.204	-	0.09757	0.2223	-	2206.9	968.6
Molybdenum	3.5	2.204	-	0.09757	0.2223	-	7.9	3.5
Mercury (inorganic)	0.45	2.204	-	0.09757	0.2223	-	1.0	0.4
Nickel	77.4	2.204	-	0.09757	0.2223	-	174.8	76.7
Selenium	0.5	2.204	-	0.09757	0.2223	-	1.1	0.5
Uranium	16	2.204	-	0.09757	0.2223	-	36.1	15.9
Vanadium	11.4	2.204	-	0.09757	0.2223	-	25.8	11.3
Zinc	14.5	2.204	-	0.09757	0.2223	-	32.8	14.4

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Deer Mouse								
Acenaphthene	19.7	0.0187	0.00188	0.00136	0.00276	19.6	27.1	13.3
Acenaphthylene	19.7	0.0187	0.00188	0.00136	0.00276	19.6	27.1	13.3
Anthracene	112.5	0.0187	0.00188	0.00136	0.00276	111.9	154.7	76.2
Benzo(a)anthracene	11.3	0.0187	0.00188	0.00136	0.00276	11.2	15.5	7.7
Benzo(a)pyrene	1.1	0.0187	0.00188	0.00136	0.00276	1.1	1.5	0.7
Benzo(b,k)fluoranthene	11.3	0.0187	0.00188	0.00136	0.00276	11.2	15.5	7.7
Biphenyl	104	0.0187	0.00188	0.00136	0.00276	103.4	143.0	70.5
m-cresol	584.6	0.0187	0.00188	0.00136	0.00276	581.5	803.8	396.1
o-cresol	584.6	0.0187	0.00188	0.00136	0.00276	581.5	803.8	396.1
Dibenzo(a,h)anthracene	0.23	0.0187	0.00188	0.00136	0.00276	0.2	0.3	0.2
Dibenzothiophene	8.4	0.0187	0.00188	0.00136	0.00276	8.4	11.6	5.7
2,4-Dimethylphenol	5.6	0.0187	0.00188	0.00136	0.00276	5.6	7.7	3.8
Ethylbenzene	20.2	0.0187	0.00188	0.00136	0.00276	20.1	27.8	13.7
Fluoranthene	14.1	0.0187	0.00188	0.00136	0.00276	14.0	19.4	9.6
Fluorene	14.1	0.0187	0.00188	0.00136	0.00276	14.0	19.4	9.6
Naphthalene	15	0.0187	0.00188	0.00136	0.00276	14.9	20.6	10.2
Phenanthrene	4.5	0.0187	0.00188	0.00136	0.00276	4.5	6.2	3.0
Phenol	124.8	0.0187	0.00188	0.00136	0.00276	124.1	171.6	84.6
Pyrene	8.4	0.0187	0.00188	0.00136	0.00276	8.4	11.6	5.7
Quinoline	2.1	0.0187	0.00188	0.00136	0.00276	2.1	2.9	1.4
Xylene	2.3	0.0187	0.00188	0.00136	0.00276	2.3	3.2	1.6
Aluminum	2.2	0.0187	0.00188	0.00136	0.00276	2.2	3.0	1.5
Antimony	0.14	0.0187	0.00188	0.00136	0.00276	0.1	0.2	0.1
Arsenic	0.14	0.0187	0.00188	0.00136	0.00276	0.1	0.2	0.1
Barium	11.1	0.0187	0.00188	0.00136	0.00276	11.0	15.3	7.5
Beryllium	1.4	0.0187	0.00188	0.00136	0.00276	1.4	1.9	0.9
Boron	58.2	0.0187	0.00188	0.00136	0.00276	57.9	80.0	39.4
Cadmium	2.1	0.0187	0.00188	0.00136	0.00276	2.1	2.9	1.4
Chromium (hexavalent)	6.8	0.0187	0.00188	0.00136	0.00276	6.8	9.4	4.6
Chromium (trivalent)	5692.9	0.0187	0.00188	0.00136	0.00276	5662.6	7827.7	3857.1
Cobalt	2.7	0.0187	0.00188	0.00136	0.00276	2.7	3.7	1.8
Copper	31.7	0.0187	0.00188	0.00136	0.00276	31.5	43.6	21.5
Cyanide	13.4	0.0187	0.00188	0.00136	0.00276	13.3	18.4	9.1
Lead	16.6	0.0187	0.00188	0.00136	0.00276	16.5	22.8	11.2
Lithium	25.4	0.0187	0.00188	0.00136	0.00276	25.3	34.9	17.2
Manganese	183	0.0187	0.00188	0.00136	0.00276	182.0	251.6	124.0
Mercury	2.7	0.0187	0.7236	0.00136	0.00276	0.0070	3.7	1.83
Molybdenum	0.29	0.0187	0.7236	0.00136	0.00276	0.001	0.4	0.2
Nickel	83.2	0.0187	0.7236	0.00136	0.00276	0.2	114.4	56.4
Selenium	0.4	0.0187	0.7236	0.00136	0.00276	0.001	0.6	0.3
Strontium	547	0.0187	0.7236	0.00136	0.00276	1.4	752.1	370.6
Thallium	0.016	0.0187	0.7236	0.00136	0.00276	0.00004	0.0	0.01
Uranium	3.4	0.0187	0.7236	0.00136	0.00276	0.009	4.7	2.3
Vanadium	0.41	0.0187	0.7236	0.00136	0.00276	0.001	0.6	0.3
Zinc	332.8	0.0187	0.7236	0.00136	0.00276	0.9	457.6	225.5
Zirconium	2	0.0187	0.7236	0.00136	0.00276	0.01	2.8	1.4
Snowshoe hare								
Acenaphthene	6.6	1.505	0.1178	-	0.143	8.4	-	6.9
Acenaphthylene	6.6	1.505	0.1178	-	0.143	8.4	-	6.9

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Anthracene	37.6	1.505	0.1178	-	0.143	48.0	-	39.6
Benzo(a)anthracene	3.8	1.505	0.1178	-	0.143	4.9	-	4.0
Benzo(a)pyrene	0.38	1.505	0.1178	-	0.143	0.5	-	0.4
Benzo(b,k)fluoranthene	3.8	1.505	0.1178	-	0.143	4.9	-	4.0
Benzo(ghi)perylene	37.6	1.505	0.1178	-	0.143	48.0	-	39.6
Biphenyl	34.7	1.505	0.1178	-	0.143	44.3	-	36.5
m-cresol	195.2	1.505	0.1178	-	0.143	249.4	-	205.4
n-cresol	195.2	1.505	0.1178	-	0.143	249.4	-	205.4
Dibenzo(a,h)anthracene	0.08	1.505	0.1178	-	0.143	0.1	-	0.1
Dibenzothiophene	2.8	1.505	0.1178	-	0.143	3.6	-	2.9
2,4-Dimethylphenol	1.9	1.505	0.1178	-	0.143	2.4	-	2.0
Ethylbenzene	6.7	1.505	0.1178	-	0.143	8.6	-	7.1
Fluoranthene	4.7	1.505	0.1178	-	0.143	6.0	-	4.9
Fluorene	4.7	1.505	0.1178	-	0.143	6.0	-	4.9
Naphthalene	5	1.505	0.1178	-	0.143	6.4	-	5.3
Phenanthrene	1.5	1.505	0.1178	-	0.143	1.9	-	1.6
Phenol	41.7	1.505	0.1178	-	0.143	53.3	-	43.9
Pyrene	2.8	1.505	0.1178	-	0.143	3.6	-	2.9
Quinoline	0.69	1.505	0.1178	-	0.143	0.9	-	0.7
Xylene	0.77	1.505	0.1178	-	0.143	1.0	-	0.8
Aluminum	0.73	1.505	0.1178	-	0.143	0.9	-	0.8
Antimony	0.047	1.505	0.1178	-	0.143	0.1	-	0.05
Arsenic	0.047	1.505	0.1178	-	0.143	0.1	-	0.05
Barium	3.7	1.505	0.1178	-	0.143	4.7	-	3.9
Beryllium	0.5	1.505	0.1178	-	0.143	0.6	-	0.5
Boron	19.4	1.505	0.1178	-	0.143	24.8	-	20.4
Cadmium	0.7	1.505	0.1178	-	0.143	0.9	-	0.7
Chromium (hexavalent)	2.3	1.505	0.1178	-	0.143	2.9	-	2.4
Chromium (trivalent)	1900	1.505	0.1178	-	0.143	2427.4	-	1999.7
Cobalt	0.92	1.505	0.1178	-	0.143	1.2	-	1.0
Copper	10.6	1.505	0.1178	-	0.143	13.5	-	11.2
Cyanide	4.5	1.505	0.1178	-	0.143	5.7	-	4.7
Lead	5.6	1.505	0.1178	-	0.143	7.2	-	5.9
Lithium	8.5	1.505	0.1178	-	0.143	10.9	-	8.9
Manganese	61.1	1.505	0.1178	-	0.143	78.1	-	64.3
Mercury	0.9	1.505	0.1178	-	0.143	1.1	-	0.9
Molybdenum	0.1	1.505	0.1178	-	0.143	0.1	-	0.1
Nickel	27.8	1.505	0.1178	-	0.143	35.5	-	29.3
Selenium	0.14	1.505	0.1178	-	0.143	0.2	-	0.1
Strontium	182.6	1.505	0.1178	-	0.143	233.3	-	192.2
Thallium	0.005	1.505	0.1178	-	0.143	0.0	-	0.01
Uranium	1.1	1.505	0.1178	-	0.143	1.4	-	1.2
Vanadium	0.14	1.505	0.1178	-	0.143	0.2	-	0.1
Zinc	111.1	1.505	0.1178	-	0.143	141.9	-	116.9
Zirconium	0.65	1.505	0.1178	-	0.143	0.8	-	0.7
Beaver								
Acenaphthene	3.5	18.275	0.7237	-	1.353	88.4	-	47.3
Acenaphthylene	3.5	18.275	0.7237	-	1.353	88.4	-	47.3
Anthracene	20.1	18.275	0.7237	-	1.353	507.6	-	271.5
Benzo(a)anthracene	2	18.275	0.7237	-	1.353	50.5	-	27.0

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Benzo(a)pyrene	0.2	18.275	0.7237	-	1.353	5.1	-	2.7
Benzo(b,k)fluoranthene	2	18.275	0.7237	-	1.353	50.5	-	27.0
Biphenyl	18.6	18.275	0.7237	-	1.353	469.7	-	251.2
m-cresol	104.6	18.275	0.7237	-	1.353	2641.4	-	1412.8
n-cresol	104.6	18.275	0.7237	-	1.353	2641.4	-	1412.8
Dibenzo(a,h)anthracene	0.04	18.275	0.7237	-	1.353	1.0	-	0.5
Dibenzothiophene	1.5	18.275	0.7237	-	1.353	37.9	-	20.3
2,4-Dimethylphenol	1	18.275	0.7237	-	1.353	25.3	-	13.5
Ethylbenzene	3.6	18.275	0.7237	-	1.353	90.9	-	48.6
Fluoranthene	2.5	18.275	0.7237	-	1.353	63.1	-	33.8
Fluorene	2.5	18.275	0.7237	-	1.353	63.1	-	33.8
Naphthalene	2.7	18.275	0.7237	-	1.353	68.2	-	36.5
Phenanthrene	0.81	18.275	0.7237	-	1.353	20.5	-	10.9
Phenol	22.3	18.275	0.7237	-	1.353	563.1	-	301.2
Pyrene	1.5	18.275	0.7237	-	1.353	37.9	-	20.3
Quinoline	0.37	18.275	0.7237	-	1.353	9.3	-	5.0
Xylene	0.41	18.275	0.7237	-	1.353	10.4	-	5.5
Aluminum	0.39	18.275	0.7237	-	1.353	9.8	-	5.3
Antimony	0.025	18.275	0.7237	-	1.353	0.6	-	0.3
Arsenic	0.025	18.275	0.7237	-	1.353	0.6	-	0.3
Barium	2	18.275	0.7237	-	1.353	50.5	-	27.0
Beryllium	0.2	18.275	0.7237	-	1.353	5.1	-	2.7
Boron	10.4	18.275	0.7237	-	1.353	262.6	-	140.5
Cadmium	0.4	18.275	0.7237	-	1.353	10.1	-	5.4
Chromium (hexavalent)	1.2	18.275	0.7237	-	1.353	30.3	-	16.2
Chromium (trivalent)	1018.2	18.275	0.7237	-	1.353	25711.8	-	13752.8
Cobalt	0.49	18.275	0.7237	-	1.353	12.4	-	6.6
Copper	5.7	18.275	0.7237	-	1.353	143.9	-	77.0
Cyanide	2.4	18.275	0.7237	-	1.353	60.6	-	32.4
Lead	3	18.275	0.7237	-	1.353	75.8	-	40.5
Lithium	4.5	18.275	0.7237	-	1.353	113.6	-	60.8
Manganese	32.7	18.275	0.7237	-	1.353	825.7	-	441.7
Mercury	0.5	18.275	0.7237	-	1.353	12.6	-	6.8
Molybdenum	0.05	18.275	0.7237	-	1.353	1.3	-	0.7
Nickel	14.9	18.275	0.7237	-	1.353	376.3	-	201.3
Selenium	0.07	18.275	0.7237	-	1.353	1.8	-	0.9
Strontium	97.8	18.275	0.7237	-	1.353	2469.7	-	1321.0
Thallium	0.003	18.275	0.7237	-	1.353	0.1	-	0.04
Uranium	0.61	18.275	0.7237	-	1.353	15.4	-	8.2
Vanadium	0.07	18.275	0.7237	-	1.353	1.8	-	0.9
Zinc	59.5	18.275	0.7237	-	1.353	1502.5	-	803.7
Zirconium	0.65	18.275	0.7237	-	1.353	16.4	-	8.8
Moose								
Acenaphthene	1.6	381	6.586	-	20.83	9.3	-	2.9
Acenaphthylene	1.6	381	6.586	-	20.83	9.3	-	2.9
Anthracene	9.4	381	6.586	-	20.83	54.4	-	17.2
Benzo(a)anthracene	0.94	381	6.586	-	20.83	5.4	-	1.7
Benzo(a)pyrene	0.09	381	6.586	-	20.83	0.5	-	0.2
Benzo(b,k)fluoranthene	0.94	381	6.586	-	20.83	5.4	-	1.7
Benzo(ghi)perylene	9.4	381	6.586	-	20.83	54.4	-	17.2

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

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Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Biphenyl	8.7	381	6.586	-	20.83	50.3	-	15.9
m-cresol	48.9	381	6.586	-	20.83	282.9	-	89.4
n-cresol	48.9	381	6.586	-	20.83	282.9	-	89.4
Dibenzo(a,h)anthracene	0.019	381	6.586	-	20.83	0.1	-	0.03
Dibenzothiophene	0.71	381	6.586	-	20.83	4.1	-	1.3
2,4-Dimethylphenol	0.47	381	6.586	-	20.83	2.7	-	0.9
Ethylbenzene	1.7	381	6.586	-	20.83	9.8	-	3.1
Fluoranthene	1.2	381	6.586	-	20.83	6.9	-	2.2
Fluorene	1.2	381	6.586	-	20.83	6.9	-	2.2
Naphthalene	1.3	381	6.586	-	20.83	7.5	-	2.4
Phenanthrene	0.38	381	6.586	-	20.83	2.2	-	0.7
Phenol	10.4	381	6.586	-	20.83	60.2	-	19.0
Pyrene	0.71	381	6.586	-	20.83	4.1	-	1.3
Quinoline	0.17	381	6.586	-	20.83	1.0	-	0.3
Xylene	0.19	381	6.586	-	20.83	1.1	-	0.3
Aluminum	0.18	381	6.586	-	20.83	1.0	-	0.3
Antimony	0.012	381	6.586	-	20.83	0.1	-	0.02
Arsenic	0.012	381	6.586	-	20.83	0.1	-	0.02
Barium	0.93	381	6.586	-	20.83	5.4	-	1.7
Beryllium	0.1	381	6.586	-	20.83	0.6	-	0.2
Boron	4.9	381	6.586	-	20.83	28.3	-	9.0
Cadmium	0.2	381	6.586	-	20.83	1.2	-	0.37
Chromium (hexavalent)	0.57	381	6.586	-	20.83	3.3	-	1.0
Chromium (trivalent)	476.5	381	6.586	-	20.83	2756.6	-	871.6
Cobalt	0.23	381	6.586	-	20.83	1.3	-	0.4
Copper	2.7	381	6.586	-	20.83	15.6	-	4.9
Cyanide	1.1	381	6.586	-	20.83	6.4	-	2.0
Lead	1.4	381	6.586	-	20.83	8.1	-	2.6
Lithium	2.1	381	6.586	-	20.83	12.1	-	3.8
Manganese	15.3	381	6.586	-	20.83	88.5	-	28.0
Mercury	0.2	381	6.586	-	20.83	1.2	-	0.4
Molybdenum	0.024	381	6.586	-	20.83	0.1	-	0.04
Nickel	7	381	6.586	-	20.83	40.5	-	12.8
Selenium	0.035	381	6.586	-	20.83	0.2	-	0.1
Strontium	45.8	381	6.586	-	20.83	265.0	-	83.8
Thallium	0.001	381	6.586	-	20.83	0.01	-	0.002
Uranium	0.28	381	6.586	-	20.83	1.6	-	0.5
Vanadium	0.034	381	6.586	-	20.83	0.2	-	0.1
Zinc	27.9	381	6.586	-	20.83	161.4	-	51.0
Zirconium	0.16	381	6.586	-	20.83	0.9	-	0.3
Black Bear								
Acenaphthene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Acenaphthylene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Anthracene	12.3	130	2.26	0.75	7.89	70.8	213.2	20.3
Benzo(a)anthracene	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Benzo(a)pyrene	0.12	130	2.26	0.75	7.89	0.7	2.1	0.2
Benzo(b,k)fluoranthene	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Benzo(ghi)perylene	12.3	130	2.26	0.75	7.89	70.8	213.2	20.3
Biphenyl	11.4	130	2.26	0.75	7.89	65.6	197.6	18.8
m-cresol	64	130	2.26	0.75	7.89	368.1	1109.3	105.4

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

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Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
n-cresol	64	130	2.26	0.75	7.89	368.1	1109.3	105.4
Dibenzo(a,h)anthracene	0.02	130	2.26	0.75	7.89	0.1	0.3	0.03
Dibenzothiophene	0.6	130	2.26	0.75	7.89	3.5	10.4	1.0
2,4-Dimethylphenol	0.9	130	2.26	0.75	7.89	5.2	15.6	1.5
Ethylbenzene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Fluoranthene	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5
Fluorene	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5
Naphthalene	1.6	130	2.26	0.75	7.89	9.2	27.7	2.6
Phenanthrene	0.5	130	2.26	0.75	7.89	2.9	8.7	0.8
Phenol	13.7	130	2.26	0.75	7.89	78.8	237.5	22.6
Pyrene	0.9	130	2.26	0.75	7.89	5.2	15.6	1.5
Quinoline	0.23	130	2.26	0.75	7.89	1.3	4.0	0.4
Xylene	0.25	130	2.26	0.75	7.89	1.4	4.3	0.4
Aluminum	0.24	130	2.26	0.75	7.89	1.4	4.2	0.4
Antimony	0.015	130	2.26	0.75	7.89	0.1	0.3	0.02
Arsenic	0.016	130	2.26	0.75	7.89	0.1	0.3	0.03
Barium	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Beryllium	0.2	130	2.26	0.75	7.89	1.2	3.5	0.3
Boron	6.4	130	2.26	0.75	7.89	36.8	110.9	10.5
Cadmium	0.2	130	2.26	0.75	7.89	1.2	3.5	0.33
Chromium (hexavalent)	0.7	130	2.26	0.75	7.89	4.0	12.1	1.2
Chromium (trivalent)	623.5	130	2.26	0.75	7.89	3586.5	10807.3	1027.3
Cobalt	0.3	130	2.26	0.75	7.89	1.7	5.2	0.5
Copper	3.5	130	2.26	0.75	7.89	20.1	60.7	5.8
Cyanide	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5
Lead	1.8	130	2.26	0.75	7.89	10.4	31.2	3.0
Lithium	2.8	130	2.26	0.75	7.89	16.1	48.5	4.6
Manganese	20	130	2.26	0.75	7.89	115.0	346.7	33.0
Mercury	0.3	130	2.26	0.75	7.89	1.7	5.2	0.5
Molybdenum	0.03	130	2.26	0.75	7.89	0.2	0.5	0.05
Nickel	9.1	130	2.26	0.75	7.89	52.3	157.7	15.0
Selenium	0.05	130	2.26	0.75	7.89	0.3	0.9	0.1
Strontium	59.9	130	2.26	0.75	7.89	344.6	1038.3	98.7
Thallium	0.002	130	2.26	0.75	7.89	0.012	0.035	0.003
Uranium	0.4	130	2.26	0.75	7.89	2.3	6.9	0.7
Vanadium	0.04	130	2.26	0.75	7.89	0.2	0.7	0.1
Zinc	36.4	130	2.26	0.75	7.89	209.4	630.9	60.0
Zirconium	0.21	130	2.26	0.75	7.89	1.2	3.6	0.3
American robin								
Acenaphthene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Acenaphthylene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Benzo(a)anthracene	0.11	0.0836	0.004884	0.01256	0.019227	0.2	0.1	0.05
Benzo(a)pyrene	0.0112	0.0836	0.004884	0.01256	0.019227	0.019	0.007	0.005
Benzo(b,k)fluoranthene	0.11	0.0836	0.004884	0.01256	0.019227	0.2	0.1	0.05
Dibenzothiophene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Fluorene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Phenanthrene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Pyrene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Aluminum	109.7	0.0836	0.004884	0.01256	0.019227	187.8	73.0	47.7
Antimony	2.46	0.0836	0.004884	0.01256	0.019227	4.2	1.6	1.1

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

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Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Arsenic	5.135	0.0836	0.004884	0.01256	0.019227	8.8	3.4	2.2
Barium	20.826	0.0836	0.004884	0.01256	0.019227	35.6	13.9	9.1
Boron	28.8	0.0836	0.004884	0.01256	0.019227	49.3	19.2	12.5
Cadmium	1.45	0.0836	0.004884	0.01256	0.019227	2.5	1.0	0.6
Chromium	1	0.0836	0.004884	0.01256	0.019227	1.7	0.7	0.4
Cobalt	0.7	0.0836	0.004884	0.01256	0.019227	1.2	0.5	0.3
Copper	47	0.0836	0.004884	0.01256	0.019227	80.5	31.3	20.4
Lead	3.85	0.0836	0.004884	0.01256	0.019227	6.6	2.6	1.7
Manganese	977	0.0836	0.004884	0.01256	0.019227	1672.3	650.3	424.8
Mercury	0.45	0.0836	0.004884	0.01256	0.019227	0.770	0.300	0.196
Molybdenum	3.5	0.0836	0.004884	0.01256	0.019227	6.0	2.3	1.5
Nickel	77.4	0.0836	0.004884	0.01256	0.019227	132.5	51.5	33.7
Selenium	0.5	0.0836	0.004884	0.01256	0.019227	0.9	0.3	0.2
Selenium	0.4	0.0836	0.004884	0.01256	0.019227	0.7	0.3	0.2
Uranium	16	0.0836	0.004884	0.01256	0.019227	27.4	10.6	7.0
Vanadium	11.38	0.0836	0.004884	0.01256	0.019227	19.5	7.6	4.9
Zinc	14.5	0.0836	0.004884	0.01256	0.019227	24.8	9.7	6.3
Ruffed Grouse								
Acenaphthene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Acenaphthylene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Benzo(a)anthracene	0.11	0.54285	0.0391	-	0.07776	0.2	-	0.1
Benzo(a)pyrene	0.0112	0.54285	0.0391	-	0.07776	0.016	-	0.008
Benzo(b,k)fluoranthene	0.11	0.54285	0.0391	-	0.07776	0.2	-	0.1
Dibenzothiophene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Fluorene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Phenanthrene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Pyrene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Aluminum	109.7	0.54285	0.0391	-	0.07776	152.3	-	76.6
Antimony	2.46	0.54285	0.0391	-	0.07776	3.4	-	1.7
Arsenic	5.135	0.54285	0.0391	-	0.07776	7.1	-	3.6
Barium	20.826	0.54285	0.0391	-	0.07776	28.9	-	14.5
Boron	28.8	0.54285	0.0391	-	0.07776	40.0	-	20.1
Cadmium	1.45	0.54285	0.0391	-	0.07776	2.0	-	1.0
Chromium	1	0.54285	0.0391	-	0.07776	1.4	-	0.7
Cobalt	0.7	0.54285	0.0391	-	0.07776	1.0	-	0.5
Copper	47	0.54285	0.0391	-	0.07776	65.3	-	32.8
Lead	3.85	0.54285	0.0391	-	0.07776	5.3	-	2.7
Manganese	977	0.54285	0.0391	-	0.07776	1356.4	-	682.1
Mercury	0.45	0.54285	0.0391	-	0.07776	0.625	-	0.314
Molybdenum	3.5	0.54285	0.0391	-	0.07776	4.9	-	2.4
Nickel	77.4	0.54285	0.0391	-	0.07776	107.5	-	54.0
Selenium	0.5	0.54285	0.0391	-	0.07776	0.7	-	0.3
Selenium	0.4	0.54285	0.0391	-	0.07776	0.6	-	0.3
Uranium	16	0.54285	0.0391	-	0.07776	22.2	-	11.2
Vanadium	11.38	0.54285	0.0391	-	0.07776	15.8	-	7.9
Zinc	14.5	0.54285	0.0391	-	0.07776	20.1	-	10.1
Mallard								
Acenaphthene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Acenaphthylene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Benzo(a)anthracene	0.11	1.107	0.01574	0.0464	0.13277	0.8	0.3	0.1

TABLE VI.1-3

RISK-BASED CONCENTRATIONS (RBC) FOR THE INGESTION OF PLANTS, PREY AND WATER FOR ECOLOGICAL RECEPTORS

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Chemicals	Estimated[a] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[b] Species Body Weight (kg)	Plant[b] Ingestion Rate (kg/day)	Prey[b] Ingestion Rate (kg/day)	Water[b] Ingestion Rate (L/day)	Risk-Based[c] Concentration (mg/kg plant)	Risk-Based[c] Concentration (mg/kg prey)	Risk-Based[c] Concentration (mg/L water)
Benzo(a)pyrene	0.0112	1.107	0.01574	0.0464	0.13277	0.1	0.03	0.01
Benzo(b,k)fluoranthene	0.11	1.107	0.01574	0.0464	0.13277	0.8	0.3	0.1
Dibenzothiophene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Fluorene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Phenanthrene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Pyrene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Aluminum	109.7	1.107	0.01574	0.0464	0.13277	771.5	261.7	91.5
Antimony	2.46	1.107	0.01574	0.0464	0.13277	17.3	5.9	2.1
Arsenic	5.135	1.107	0.01574	0.0464	0.13277	36.1	12.3	4.3
Barium	20.826	1.107	0.01574	0.0464	0.13277	146.5	49.7	17.4
Boron	28.8	1.107	0.01574	0.0464	0.13277	202.6	68.7	24.0
Cadmium	1.45	1.107	0.01574	0.0464	0.13277	10.2	3.5	1.2
Chromium	1	1.107	0.01574	0.0464	0.13277	7.0	2.4	0.8
Cobalt	0.7	1.107	0.01574	0.0464	0.13277	4.9	1.7	0.6
Copper	47	1.107	0.01574	0.0464	0.13277	330.6	112.1	39.2
Lead	3.85	1.107	0.01574	0.0464	0.13277	27.1	9.2	3.2
Manganese	977	1.107	0.01574	0.0464	0.13277	6871.3	2330.9	814.6
Mercury	0.45	1.107	0.01574	0.0464	0.13277	3.16	1.07	0.38
Molybdenum	3.5	1.107	0.01574	0.0464	0.13277	24.6	8.4	2.9
Nickel	77.4	1.107	0.01574	0.0464	0.13277	544.4	184.7	64.5
Selenium	0.5	1.107	0.01574	0.0464	0.13277	3.5	1.2	0.4
Selenium	0.4	1.107	0.01574	0.0464	0.13277	2.8	1.0	0.3
Uranium	16	1.107	0.01574	0.0464	0.13277	112.5	38.2	13.3
Vanadium	11.38	1.107	0.01574	0.0464	0.13277	80.0	27.2	9.5
Zinc	14.5	1.107	0.01574	0.0464	0.13277	102.0	34.6	12.1

[a] No-Observed Adverse Effect Level (NOAEL) based on the toxicological literature and the method by Sample et al. 1996. See Table VIII-2.

[b] Based on literature derived values. See Appendix VIII.4.1 for derivation and summary.

[c] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor). Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

TABLE VI.1-4

WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Chemicals	CCREM[a] (mg/L) (livestock)	BC MOE[b] (mg/L) (livestock/ wildlife)	Screening[c] Level Criteria (mg/L)
ORGANICS			
Acenaphthylene	(d)	(d)	(d)
Acenaphthene group[c]	(d)	(d)	(d)
Benzo(a)anthracene group[c]	(d)	(d)	(d)
Benzo(ghi)perylene	(d)	(d)	(d)
Benzo(a)pyrene group[c]	(d)	(d)	(d)
Biphenyl	(d)	(d)	(d)
Dibenzothiophene group[c]	(d)	(d)	(d)
Fluoranthene group[c]	(d)	(d)	(d)
Fluorene group[c]	(d)	(d)	(d)
Naphthalene group[c]	(d)	(d)	(d)
Phenanthrene group[c]	(d)	(d)	(d)
Pyrene	(d)	(d)	(d)
Naphthenic acids	(d)	(d)	(d)
Phenol	(d)	(d)	(d)
2,4-Dimethylphenol	(d)	(d)	(d)
m-cresol	(d)	(d)	(d)
o-cresol	(d)	(d)	(d)
INORGANICS			
Aluminum	5	5	5
Ammonia	(d)	(d)	(d)
Antimony	(d)	(d)	(d)
Arsenic	0.5	0.5	0.5
Barium	(d)	(d)	(d)
Beryllium	0.1	0.1	0.1
Boron	5	5	5
Cadmium	0.02	0.02	0.02
Calcium	1000	1000	1000
Chloride	(d)	(d)	(d)
Chromium	1	1	1
Cobalt	1	1	1
Copper	0.5	0.3	0.3
Cyanide	(d)	(d)	(d)
Iron	(d)	(d)	(d)
Lead	0.1	0.1	0.1
Lithium	-[4]	5	5
Magnesium	(d)	(d)	(d)
Manganese	(d)	(d)	(d)
Mercury	0.003	0.002	0.002
Molybdenum	0.5	0.05	0.05
Nickel	1	1	1
Phosphorus	(d)	(d)	(d)
Potassium	(d)	(d)	(d)
Selenium	0.05	0.05	0.05

TABLE VI.1-4

WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Chemicals	CCREM[a] (mg/L) (livestock)	BC MOE[b] (mg/L) (livestock/ wildlife)	Screening[c] Level Criteria (mg/L)
Silicon	(d)	(d)	(d)
Silver	(d)	(d)	(d)
Sodium	(d)	(d)	(d)
Strontium	(d)	(d)	(d)
Sulphate	1000	1000	1000
Tin	(d)	(d)	(d)
Titanium	(d)	(d)	(d)
Vanadium	0.1	0.1	0.1
Uranium	0.2	0.2	0.2
Zinc	50	50	50
Zirconium	(d)	(d)	(d)

(a) Canadian Council of Resource and Environment Ministers Water Quality Guidelines for Livestock Drinking Water Quality (CCREM 1987).

(b) British Columbia Ministry of Environment Water Quality Criteria for the protection of livestock and/or wildlife (BC Contam Sites Regulation, 1997).

(c) Screening Level Criteria are the lowest of the listed criteria values.

(d) No criterion

(e) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-5

BASELINE: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Baseline Concentrations 1997-2004[a]	RBC for [b] Water Shrew	RBC for [b] River Otter	RBC for [b] Killdeer	RBC for [b] Great Blue Heron	RBC for [b] Moose	RBC for [b] Snowshoe Hare	RBC for [b] Black Bear	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS									
Naphthenic Acids	0.5	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.002	89.4	34.3	[c]	[c]	19	43.9	22.6	Does not exceed.
INORGANICS									
Aluminum	0.58	1.6	0.6	49.8	108.8	0.3	0.8	0.4	EXCEEDS (moose, bear)[d]
Antimony	<0.0004	0.1	0.04	[c]	[c]	0.02	0.05	0.02	Does not exceed.
Arsenic	0.001	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.07	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.0008	1	0.4	[c]	[c]	0.2	0.5	0.3	Does not exceed.
Boron	0.19	41.7	16	[c]	[c]	9	20.4	10.5	Does not exceed.
Cadmium	0.001	1.4	0.5	0.7	1.4	1.2	0.9	1.2	Does not exceed.
Chromium	0.003	[c]	[c]	0.5	[c]	1	2.4	1.2	Does not exceed.
Copper	0.003	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.00005	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Manganese	0.33	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	<0.0002	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.000005	0.2	0.1	1.6	968.6	0.04	0.1	0.05	Does not exceed.
Nickel	0.001	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0002	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Silver	0.000006	[c]	[c]	[c]	[c]	[c]	[c]	[c]	Does not exceed.
Strontium	0.2	392	150.4	[c]	[c]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.003	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.03	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[a] Modelled water concentrations in Shipyard Lake for 1997-2004, based on inputs from existing and approved developments (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] Although aluminum theoretically exceeds the RBCs for some species, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

TABLE VI.1-6

BASELINE: COMPARISON OF MCLEAN CREEK CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Maximum Measured Concentrations 1995[a]	Predicted Baseline Concentrations 1997[b]	RBC for [c] Water Shrew	RBC for [c] River Otter	RBC for [c] Killdeer	RBC for [c] Great Blue Heron	RBC for [c] Moose	RBC for [c] Snowshoe Hare	RBC for [c] Black Bear	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS										
Naphthenic Acids	[d]	0.89	[d]	[d]	[d]	[d]	[d]	[d]	[d]	No RBC
Total Phenolics (evaluated as phenol)	[d]	0.002	89.4	34.3	[d]	[d]	19	43.9	22.6	Does not exceed.
INORGANICS										
Aluminum	0.29	0.31	1.6	0.6	49.8	108.8	0.3	0.8	0.4	Does not exceed.
Arsenic	0.0008	0.0007	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.04	0.04	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.001	0.0002	1	0.4	[d]	[d]	0.2	0.5	0.3	Does not exceed.
Boron	0.12	0.13	41.7	16	[d]	[d]	9	20.4	10.5	Does not exceed.
Cadmium	0.003	0.003	1.4	0.5	0.7	1.4	1.2	0.9	1.2	Does not exceed.
Chromium	0.008	0.001	[d]	[d]	0.5	[d]	1	2.4	1.2	Does not exceed.
Cobalt	0.005	[d]	2	0.7	0.3	0.7	0.4	1	0.5	Does not exceed.
Copper	0.002	0.002	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lithium	0.016	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	Does not exceed.
Manganese	0.061	0.11	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Molybdenum	0.004	0.0013	0.2	0.1	1.6	968.6	0.04	0.1	0.05	Does not exceed.
Selenium	0.0003	0.00005	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Strontium	0.18	0.1	392	150.4	[d]	[d]	83.8	192.2	98.7	Does not exceed.
Titanium	0.007	[d]	[d]	[d]	[d]	[d]	[d]	[d]	[d]	Does not exceed.
Vanadium	0.007	0.001	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.066	0.03	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[a] Maximum of the measured concentrations in McLean Creek (1995); n=3.

[b] Modelled water concentrations in McLean Creek for 1997 based on inputs from existing and approved developments (refer to Section C3 for details).

[c] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[d] No data or criterion.

TABLE VI.1-7

BASELINE: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Baseline[a] 1997	Baseline[a] 2000-2025	Baseline[a] 2030	Baseline[a] Far Future	RBC for[b] Water Shrew	RBC for[b] River Otter	RBC for[b] Killdeer	RBC for[b] Great Blue Heron	RBC for[b] Moose	RBC for[b] Snowshoe Hare	RBC for[b] Black Bear	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS												
Benzo(a)anthracene group[e]	0.0000015	0.0000044	0.0000048	0.0000048	8	3.1	10.2	22.4	1.7	4	2	Does not exceed.
Benzo(a)pyrene group[e]	0.00000072	0.0000014	0.0000013	0.0000006	0.8	0.3	0.05	0.1	0.2	0.4	0.2	Does not exceed.
Naphthenic Acids	0.02	0.49	0.55	0.55	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC
Total Phenolics Iphenol)	0.002	0.002	0.002	0.002	89.4	34.3	[c]	[c]	19	43.9	22.6	Does not exceed.
INORGANICS												
Aluminum	0.68	0.68	0.68	0.68	1.6	0.6	49.8	108.8	0.3	0.8	0.4	EXCEEDS (otter, moose, bear)[d]
Antimony	0.00001	0.00001	0.0000077	0.0000019	0.1	0.04	[c]	[c]	0.02	0.05	0.02	Does not exceed.
Arsenic	0.0012	0.0017	0.0014	0.0013	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.07	0.07	0.07	0.07	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.001	0.001	0.001	0.001	1	0.4	[c]	[c]	0.2	0.5	0.3	Does not exceed.
Boron	0.05	0.05	0.06	0.06	41.7	16	[c]	[c]	9	20.4	10.5	Does not exceed.
Cadmium	0.001	0.001	0.001	0.001	1.4	0.5	0.7	1.4	1.2	0.9	1.2	Does not exceed.
Chromium	0.004	0.004	0.004	0.004	[c]	[c]	0.5	[c]	1	2.4	1.2	Does not exceed.
Copper	0.004	0.004	0.004	0.004	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.000077	0.00009	0.000073	0.000073	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Manganese	0.4	0.4	0.4	0.4	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	0.0001	0.0001	0.0001	0.0001	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.0028	0.0049	0.0049	0.0015	0.2	0.1	1.6	968.6	0.04	0.1	0.05	Does not exceed.
Nickel	0.00081	0.00055	0.00055	0.00017	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0002	0.0004	0.0002	0.0002	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Silver	0.00001	0.00001	0.00001	0.0000046	100	100	100	100	100	100	100	Does not exceed.
Strontium	0.22	0.22	0.22	0.22	392	150.4	[c]	[c]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.01	0.007	0.007	0.004	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.012	0.016	0.013	0.012	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[a] Maximum predicted concentrations in the Athabasca River for existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] Although aluminum theoretically exceeds the RBCs for some species, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-8

BASELINE: COMPARISON OF GROUNDWATER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Maximum Measured Concentrations 1995[a]	RBC for[b] Water Shrew	RBC for[b] River Otter	RBC for[b] Killdeer	RBC for[b] Great Blue Heron	RBC for[b] Moose	RBC for[b] Snowshoe Hare	RBC for[b] Black Bear	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs									
Acenaphthene group[d]	0.00016	14.1	5.4	10.2	22.4	2.9	6.9	3.6	Does not exceed.
Benzo(a)anthracene group[d]	0.00015	8	3.1	0.05	0.1	1.7	4	2	Does not exceed.
Biphenyl	0.00015	40.3	15.5	[c]	[c]	15.9	36.5	18.8	Does not exceed.
Dibenzothiophene group[d]	0.0014	6	2.3	10.3	22.4	1.3	2.9	1	Does not exceed.
Fluoranthene group[d]	0.00006	10.1	3.9	10.3	22.4	2.2	4.9	2.5	Does not exceed.
Fluorene group[d]	0.00047	10.1	3.9	10.3	22.4	2.2	4.9	2.5	Does not exceed.
Naphthalene group[d]	0.00176	10.7	4.1	[c]	[c]	2.4	5.3	2.6	Does not exceed.
Phenanthrene group[d]	0.00125	3.2	1.2	10.3	22.4	0.7	1.6	0.8	Does not exceed.
Pyrene	0.00003	6	2.3	10.3	22.4	1.3	2.9	1.5	Does not exceed.
PHENOLICS									
Cresol	0.0004	419	161	[c]	[c]	89.4	205.4	105.4	Does not exceed.
2,4-dimethylphenol	0.0002	4	1.5	[c]	[c]	0.9	2	1.5	Does not exceed.
INORGANICS									
Aluminum	0.5	1.6	0.6	49.8	108.8	0.3	0.8	0.4	Does not exceed.
Arsenic	0.0016	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	3	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.002	1	0.4	[c]	[c]	0.2	0.5	0.3	Does not exceed.
Boron	4.45	41.7	16	[c]	[c]	9	20.4	10.5	Does not exceed.
Cadmium	0.004	1.4	0.5	0.7	1.4	1.2	0.9	1.2	Does not exceed.
Chromium	0.018	[c]	[c]	0.5	[c]	1	2.4	1.2	Does not exceed.
Cobalt	0.031	2	0.7	0.3	0.7	0.4	1	0.5	Does not exceed.
Copper	0.008	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.04	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Manganese	4.02	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	0.0016	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.019	0.2	0.1	1.6	968.6	0.04	0.1	0.05	Does not exceed.
Nickel	0.113	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0008	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Strontium	14.7	392	150.4	[c]	[c]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.009	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.014	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[a] Maximum measured concentration in groundwater within study area; used to represent hypothetical concentrations in mineral licks used by wildlife (1995); maximum used where limited data

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-9

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN BLUEBERRIES TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES

Chemical	Site Concentrations		Background Concentrations	Comments
	Muskeg River Mine Project Site[a] (ug/g) Max	Suncor Lease 25[b] (ug/g) Max	Mariana Lakes Region[c] (ug/g) Max	
INORGANICS				
Aluminum	<0.2	40	88	Does not exceed
Antimony	<0.04	<0.04	<0.04	Does not exceed
Arsenic	<0.2	<0.2	<0.2	Does not exceed
Barium	15.5	7.4	18	Does not exceed
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	7	6	6	EXCEEDS
Cadmium	0.09	<0.08	<0.08	EXCEEDS
Calcium	1140	973	1170	Does not exceed
Chromium	<0.5	<0.2	<0.2	Does not exceed
Cobalt	<0.08	<0.08	<0.08	Does not exceed
Copper	4.18	4.6	2.2	EXCEEDS
Iron	20	13	24	Does not exceed
Lead	<0.4	0.3	<0.1	EXCEEDS
Magnesium	488	363	500	Does not exceed
Manganese	576	292	374	EXCEEDS
Mercury	0.02	0.02	0.02	Does not exceed
Molybdenum	<0.4	0.11	0.36	Does not exceed
Nickel	0.99	0.66	0.56	EXCEEDS
Phosphorus	851	750	1070	Does not exceed
Potassium	4590	2930	4830	Does not exceed
Selenium	<0.2	<0.2	<0.2	Does not exceed
Silver	<0.08	<1	<1	Does not exceed
Sodium	17	6	<2	EXCEEDS[d]
Strontium	1.48	1.3	1.4	EXCEEDS
Sulphur	654	707	708	Does not exceed
Thallium	<0.04	<0.04	<0.04	Does not exceed
Tin	<0.08	<0.1	0.3	Does not exceed
Vanadium	<0.08	<0.08	<0.08	Does not exceed
Zinc	1	11	5	EXCEEDS

[a] Blueberries collected on Muskeg River Mine Project Site by Golder during 1997.

[b] Blueberries collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] Blueberries collected near Mariana Lakes, approximately 40 km south of Fort McMurray. These are considered to be background samples.

[d] Sodium was not evaluated in the risk assessment since it is a required nutrient.

< These compounds were not detected above detection limits.

TABLE VI.1-10

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN LABRADOR TEA TO BACKGROUND CONCENTRATIONS

Chemical	Site Concentrations		Background Concentrations	Comments
	Muskeg River Mine Project Site[a] (ug/g) Max	Suncor Lease 25[b] (ug/g) Max	Mariana Lakes Region and West of Syncrude[c] (ug/g) Max	
PAHS AND SUBSTITUTED PAHS				
Naphthalene group[d]	0.2	0.25	0.1	EXCEEDS
INORGANICS				
Aluminum	14.7	35	43	Does not exceed
Antimony	<0.04	0.68	0.53	EXCEEDS
Arsenic	<0.2	<0.2	<0.2	Does not exceed
Barium	120	112	80.1	EXCEEDS
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	21	25	22	EXCEEDS
Cadmium	0.08	0.09	<0.08	EXCEEDS
Calcium	5710	5890	5870	EXCEEDS[e]
Chromium	<0.5	0.4	<0.2	EXCEEDS
Cobalt	0.31	0.13	0.11	EXCEEDS
Copper	74	23.2	13.7	EXCEEDS
Iron	104	313	49	EXCEEDS[e]
Lead	2.9	0.8	0.3	EXCEEDS
Magnesium	1250	1530	1420	EXCEEDS[e]
Manganese	1070	1010	864	EXCEEDS
Mercury	0.03	0.05	0.04	EXCEEDS
Molybdenum	<0.4	0.12	0.12	Does not exceed
Nickel	6.92	4.67	3.36	EXCEEDS
Phosphorus	1060	1120	1280	Does not exceed
Potassium	5401	5500	5310	EXCEEDS[e]
Selenium	<0.2	<0.2	<0.2	Does not exceed
Silver	<0.08	<0.08	<0.08	Does not exceed
Sodium	12	43	33	EXCEEDS[e]
Strontium	8.58	19.9	13.9	EXCEEDS
Sulphur	1090	1210	1250	Does not exceed
Thallium	<0.04	<0.04	<0.04	Does not exceed
Tin	0.18	0.3	0.3	Does not exceed
Vanadium	<0.08	0.15	<0.08	EXCEEDS
Zinc	54.5	34	27	EXCEEDS

[a] Labrador tea leaves collected on Muskeg River Mine Project by Golder during 1997.

[b] Labrador tea leaves collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] Labrador tea leaves collected near Mariana Lakes, approximately 40 km south of Fort McMurray and west of Syncrude, outside the zone of influence of air emissions. These are considered to be background samples.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These compounds were not detected above detection limits.

TABLE VI.1-11

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN CATTAIL ROOT TO BACKGROUND CONCENTRATIONS

Chemical	Site Concentrations		Background Concentrations	Comments
	Muskeg River Mine Project Site[a] (ug/g) Max	Suncor Lease 25[b] (ug/g) Max	Mariana Lakes Region and West of Syncrude[c] (ug/g) Max	
INORGANICS				
Aluminum	693	611	245	EXCEEDS
Antimony	<0.04	<0.04	<0.04	Does not exceed
Arsenic	0.9	1.1	1.9	Does not exceed
Barium	46.9	47.3	20.7	EXCEEDS
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	29	13	12	EXCEEDS
Cadmium	0.17	0.09	<0.08	EXCEEDS
Calcium	40000	10700	4490	EXCEEDS[d]
Chromium	1	1.2	0.7	EXCEEDS
Cobalt	5.24	1.37	1.04	EXCEEDS
Copper	3.36	14.4	11.2	EXCEEDS
Iron	8340	5160	4160	EXCEEDS[d]
Lead	1.4	2.5	2.1	EXCEEDS
Magnesium	4060	2180	1910	EXCEEDS[d]
Manganese	225	541	717	Does not exceed
Mercury	0.04	0.07	0.06	EXCEEDS
Molybdenum	<0.4	1.7	1.53	EXCEEDS
Nickel	6.43	3.98	3.19	EXCEEDS
Phosphorus	893	2040	3190	Does not exceed
Potassium	15600	26300	34100	Does not exceed
Selenium	0.2	0.7	0.4	EXCEEDS
Silver	<0.08	<1	<1	Does not exceed
Sodium	1330	3340	3670	Does not exceed
Strontium	36.4	38.5	16.6	EXCEEDS
Sulphur	4100	2830	1350	EXCEEDS[d]
Thallium	0.04	<0.04	0.14	Does not exceed
Tin	<0.08	<0.08	0.3	Does not exceed
Vanadium	7.16	6.07	0.82	EXCEEDS
Zinc	59.2	26	45	EXCEEDS

[a] Cattail root collected on Muskeg River Mine Project by Golder during 1997.

[b] Cattail root collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] Cattail root collected near Mariana Lakes, approximately 40 km south of Fort McMurray and west of Syncrude, outside the zone of influence of air emissions. These are considered to be background samples.

[d] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These compounds were not detected above detection limits.

TABLE VI.1-12

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN BLUEBERRIES AND LABRADOR TEA TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Muskeg River Mine Project Site[a] (ug/g) Max	Suncor Lease 25[b] (ug/g) Max	Moose RBC for[c] Plant Ingestion (ug/g)	Hare RBC for[c] Plant Ingestion (ug/g)	Bear RBC for [c] Plant Ingestion (ug/g)	Grouse RBC for[c] Plant Ingestion (ug/g)	Comments
Blueberries							
Cadmium	0.09	<0.08	0.104	0.089	0.115	2	Does not exceed
Copper	4.15	3.14	15.6	13.5	20.1	65.3	Does not exceed
Lead	<0.4	0.3	8.1	7.2	10.4	5.3	Does not exceed
Manganese	194	315	88.5	78.1	115	1356.4	EXCEEDS (moose, hare, bear)
Nickel	0.99	0.66	40.5	35.5	52.3	107.5	Does not exceed
Strontium	1.48	1.3	265	233.3	345	[d]	Does not exceed
Zinc	1	11	161.4	141.9	209	20.1	Does not exceed
Labrador Tea							
Naphthalene group	0.2	0.25	7.5	6.4	9.2	[d]	Does not exceed
Antimony	<0.04	0.68	0.069	0.01	0.09	3.4	EXCEEDS (moose, hare, bear)
Barium	120	112	5.4	4.7	6.9	28.9	EXCEEDS (moose, hare, bear, grouse)
Boron	21	25	28	25	37	40	Does not exceed
Cadmium	0.08	0.09	0.10	0.09	0.12	2	Does not exceed
Chromium	<0.5	0.4	2757	2427	3587	1.4	Does not exceed
Cobalt	0.31	0.13	1.3	1.2	1.7	1	Does not exceed
Copper	74	23.2	15.6	13.5	20.1	65.3	EXCEEDS (moose, hare, bear, grouse)
Lead	2.9	0.8	8.1	7.2	10.4	5.3	Does not exceed
Manganese	1070	1010	88.5	78.1	115	1356.4	EXCEEDS (moose, hare, bear)
Mercury	0.03	0.05	1.2	1.1	1.7	0.625	Does not exceed
Nickel	6.92	4.67	40.5	35.5	52.3	107.5	Does not exceed
Strontium	8.58	19.9	265	233.3	345	[d]	Does not exceed
Vanadium	<0.08	0.15	0.2	0.18	0.23	15.8	Does not exceed
Zinc	54.5	34	161.4	141.9	209	20.1	Does not exceed

[a] Samples collected on Muskeg River Mine Project by Golder during 1997.

[b] Samples collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[d] No data

TABLE VI.1-13

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN CATTAILS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Muskeg River Mine Project Site[a] (ug/g) Max[1]	Suncor Lease 25[b] (ug/g) Max[2]	Moose RBC for[c] Plant Ingestion (ug/g)	Mallard RBC for[c] Plant Ingestion (ug/g)	Comments
Cattail Root					
Aluminum	693	611	1	771.5	EXCEEDS (moose)[e]
Barium	46.9	47.3	5.4	147	EXCEEDS (moose)
Boron	29	13	28	203	EXCEEDS (moose)
Cadmium	0.17	0.09	0.1	10	EXCEEDS (moose)
Chromium	1	1.2	2757	7	Does not exceed
Cobalt	5	1.37	1.3	5	EXCEEDS (moose)
Copper	3.36	14.4	15.6	330.6	Does not exceed
Lead	1.4	2.5	8.1	27	Does not exceed
Mercury	0.04	0.07	1.2	3.2	Does not exceed
Molybdenum	<0.4	1.7	0.1	24.6	EXCEEDS (moose)
Selenium	0.2	0.7	0.2	3.5	EXCEEDS (moose)
Strontium	36.4	38.5	265	[d]	Does not exceed
Vanadium	7.16	6.07	0.2	80	EXCEEDS (moose)
Zinc	59.2	26	161	102	Does not exceed

[a] Samples collected on Muskeg River Mine Project by Golder during 1997.

[b] Samples collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).Note that for the screening, assessment the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[d] No data

[e] Although aluminum exceeds the RBC for plant ingestion, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route.

Therefore, aluminum was excluded from further consideration

TABLE VI.1-14

BASELINE: LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR WILDLIFE

Chemical	Moose	Snowshoe Hare	Black Bear	Ruffed Grouse
Baseline Exposure to Plants				
Antimony	x	x	x	
Barium	x	x	x	x
Boron	x			
Cadmium	x			
Cobalt	x			
Copper	x	x	x	x
Manganese	x	x	x	
Molybdenum	x			
Selenium	x			
Vanadium	x			

Note: No chemicals of concern were retained following chemical screening of baseline concentrations in local water bodies.

TABLE VI.1-15

PROJECT IMPACTS: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2045[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Naphthenic acids	1.05	0.74	0.47	[c]	No criterion
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	[c]	No criterion
INORGANICS					
Aluminum	0.64	0.61	0.58	5	Does not exceed
Ammonia	0.02	0.02	0.02	[c]	No criterion [e]
Arsenic	0.001	0.001	0.001	0.5	Does not exceed
Barium	0.08	0.07	0.06	[c]	No criterion
Beryllium	0.0009	0.0009	0.0008	0.1	Does not exceed
Boron	0.27	0.25	0.19	5	Does not exceed
Cadmium	0.001	0.001	0.001	0.02	Does not exceed
Calcium	52	51.2	50.7	1000	Does not exceed
Chloride	219	168.5	106	[c]	No criterion [e]
Chromium	0.004	0.003	0.003	1	Does not exceed
Copper	0.003	0.003	0.003	0.3	Does not exceed
Iron	2.8	2.6	2.5	[c]	No criterion [e]
Lead	0.000029	2.90E-19	5.60E-32	0.1	Does not exceed
Magnesium	15	16	15	[c]	No criterion [e]
Manganese	0.37	0.35	0.32	[c]	No criterion
Mercury	0.000092	0.000085	0.000078	0.002	Does not exceed
Molybdenum	0.00045	4.50E-18	8.90E-31	0.05	Does not exceed
Nickel	0.001	0.001	0.001	1	Does not exceed
Selenium	0.0002	0.0002	0.0002	0.05	Does not exceed
Silver	0.00012	0.0000079	0.0000048	[c]	No criterion
Sodium	177	140	91	[c]	No criterion [e]
Strontium	0.4	0.3	0.2	[c]	No criterion
Sulphate	19	18	17	1000	Does not exceed
Vanadium	0.004	0.003	0.003	0.1	Does not exceed
Zinc	0.03	0.03	0.03	50	Does not exceed

[a] Modelled concentrations in Shipyard Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These chemicals were not detected above detection limits

TABLE VI.1-16

PROJECT IMPACTS: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2044[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Shrew (mg/L)	RBC for[b] River Otter (mg/L)	RBC for[b] Killdeer (mg/L)	RBC for[b] Great Blue Heron (mg/L)	RBC for[b] Deer Mouse (mg/L)	RBC for[b] Beaver (mg/L)	RBC for[b] Moose (mg/L)	RBC for[b] Snowshoe Hare (mg/L)	RBC for[b] Black Bear (mg/L)	Comments
ORGANICS													
Naphthenic Acids	1.16	0.53	0.64	[d]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	89.4	34.3	[c]	[c]	85	301	19	43.9	22.6	Does not exceed.
INORGANICS													
Arsenic	0.001	0.001	0.001	0.1	0.04	10.2	22.4	0.1	0.3	0.02	0.05	0.03	Does not exceed.
Barium	0.08	0.07	0.06	8	3.1	2.3	5.1	7.5	27	1.7	3.9	2	Does not exceed.
Manganese	0.37	0.35	0.32	131.1	50.3	21.3	32.9	124	442	28	64.3	33	Does not exceed.
Molybdenum	0.00045	4.50E-18	8.90E-31	0.2	0.1	1.6	968.6	0.2	0.7	0.04	0.1	0.05	Does not exceed.
Silver	0.00012	0.0000079	0.0000048	100	100	100	100	100	100	100	100	100	Does not exceed.
Strontium	0.4	0.3	0.2	392	150.4	[c]	[c]	371	1321	83.8	192.2	98.7	Does not exceed.

[a] Modelled concentrations in Shipyard Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-17

PROJECT IMPACTS: COMPARISON OF MCLEAN CREEK CONCENTRATIONS TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2045[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Benzo(a)anthracene group[d]	nd	nd	2.60E-18	[c]	No criterion
Benzo(a)pyrene group[d]	nd	nd	1.20E-22	[c]	No criterion
Naphthenic acids	0.62	0.98	0.35	[c]	No criterion
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	[c]	No criterion
INORGANICS					
Aluminum	0.32	0.31	0.37	5	Does not exceed
Ammonia	0.11	0.03	0.01	[c]	No criterion [e]
Antimony	0.000049	nd	0.000079	[c]	No criterion
Arsenic	0.0025	0.0008	0.0009	0.5	Does not exceed
Barium	0.06	0.06	0.05	[c]	No criterion
Beryllium	0.0004	0.0006	0.0005	0.1	Does not exceed
Boron	0.15	0.19	0.36	5	Does not exceed
Cadmium	0.003	0.003	0.002	0.02	Does not exceed
Calcium	49	44.5	54.5	1000	Does not exceed
Chloride	12.8	15.8	14.4	[c]	No criterion [e]
Chromium	0.003	0.002	0.002	1	Does not exceed
Copper	0.004	0.003	0.004	0.3	Does not exceed
Iron	1.3	0.7	0.9	[c]	No criterion [e]
Lead	0.00025	0.000097	0.00091	0.1	Does not exceed
Magnesium	12.2	12.6	14.1	[c]	No criterion [e]
Manganese	0.17	0.12	0.08	[c]	No criterion
Mercury	nd	nd	0.000002	0.002	Does not exceed
Molybdenum	0.0013	0.0015	0.063	0.05	EXCEEDS (far future)
Nickel	0.002	0.004	0.002	1	Does not exceed
Selenium	0.0012	0.00006	0.0002	0.05	Does not exceed
Silver	0.0003	0.0004	0.0002	[c]	No criterion
Sodium	30	41	58	[c]	No criterion [e]
Strontium	0.1	0.1	0.2	[c]	No criterion
Sulphate	19	25	70	1000	Does not exceed
Vanadium	0.002	0.002	0.008	0.1	Does not exceed
Zinc	0.04	0.03	0.03	50	Does not exceed

[a] Modelled concentrations in McLean Creek based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

nd = predicted to be less than detection limit

TABLE VI.1-18

PROJECT IMPACTS: COMPARISON OF MCLEAN CREEK CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2045[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Shrew (mg/L)	RBC for[b] River Otter (mg/L)	RBC for[b] Killdeer (mg/L)	RBC for[b] Great Blue Heron (mg/L)	RBC for[b] Deer Mouse (mg/L)	RBC for[b] Beaver (mg/L)	RBC for[b] Moose (mg/L)	RBC for[b] Snowshoe Hare (mg/L)	RBC for[b] Black Bear (mg/L)	Comments
ORGANICS													
Benzo[a]anthracene group[d]	nd	nd	2.60E-18	8	3.1	10.2	22.4	7.7	27	1.7	4	2	Does not exceed.
Benzo[a]pyrene group[d]	nd	nd	1.20E-22	0.8	0.3	0.05	0.1	0.7	2.7	0.2	0.4	0.2	Does not exceed.
Naphthenic Acids	0.62	0.98	0.35	[d]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	89.4	34.3	[c]	[c]	85	301	19	43.9	22.6	Does not exceed.
INORGANICS													
Arsenic	0.0025	0.0008	0.0009	0.1	0.04	10.2	22.4	0.1	0.3	0.02	0.05	0.03	Does not exceed.
Antimony	0.000049	nd	0.000079	0.1	0.04	[c]	[c]	0.1	0.3	0.02	0.05	0.02	Does not exceed.
Barium	0.06	0.06	0.05	8	3.1	2.3	5.1	7.5	27	1.7	3.9	2	Does not exceed.
Manganese	0.17	0.12	0.08	131.1	50.3	21.3	32.9	124	442	28	64.3	33	Does not exceed.
Molybdenum	0.0013	0.0015	0.063	0.2	0.1	1.6	968.6	0.2	0.7	0.04	0.1	0.05	EXCEEDS(moose, black bear)
Silver	0.0003	0.0004	0.0002	100	100	100	100	100	100	100	100	100	Does not exceed.
Strontium	0.1	0.1	0.2	392	150.4	[c]	[c]	371	1321	83.8	192.2	98.7	Does not exceed.

[a] Modelled concentrations in McLean Creek based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

nd = predicted to be less than detection limit

TABLE VI.1-19

PROJECT IMPACTS: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2045[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Background Athabasca River[c]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS						
Benzo(a)anthracene group[e]	(f)	0.0000057	(f)	(d)	<0.00004	No criterion; EXCEEDS BACKGROUND
Naphthenic acids	(f)	0.57	(f)	(d)	<1	No criterion; EXCEEDS BACKGROUND
INORGANICS						
Antimony	(f)	(f)	0.0000023	(d)	0.0002	No criterion; Does not exceed background
Boron	(f)	0.07	(f)	5	0.09	Does not exceed.
Chloride	5.2	5.3	(f)	(d)	14.8	No criterion; Does not exceed background
Lead	(f)	0.00014	0.000077	0.1	(d)	Does not exceed
Molybdenum	(f)	0.0063	0.002	0.05	0.01	Does not exceed
Nickel	(f)	(f)	0.00018	1	0.01	Does not exceed.
Strontium	(f)	0.23	(f)	(d)	0.36	No criterion; Does not exceed background
Sulphate	(f)	24.5	(f)	1000	58	Does not exceed

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[c] Measured concentrations in the Athabasca River upstream of Lease 19 sampled by Golder in 1995 and NAQUADAT 1985-1995.

[d] No data or criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[f] Data not included because predicted concentrations for Project Millennium are not greater than baseline Athabasca River concentrations; chemicals not listed are not included for the same reason

< These chemicals were not detected above detection limits

TABL -20

PROJECT IMPACTS: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2044[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Shrew (mg/L)	RBC for[b] River Otter (mg/L)	RBC for[b] Killdeer (mg/L)	RBC for[b] Great Blue Heron (mg/L)	RBC for[b] Deer Mouse (mg/L)	RBC for[b] Beaver (mg/L)	RBC for[b] Moose (mg/L)	RBC for[b] Snowshoe Hare (mg/L)	RBC for[b] Black Bear (mg/L)	Comments
ORGANICS													
Benzo(a)anthracene group[d]	0.0000014	0.0000057	0.0000047	8	3.1	10.2	22.4	7.7	27	1.7	4	2	Does not exceed.
Naphthenic Acids	0.49	0.57	0.55	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-21

PROJECT IMPACTS: COMPARISON OF END PIT LAKE CONCENTRATIONS TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2045[a] (mg/L)	Predicted Concentrations 2052[a] (mg/L)	Predicted Concentrations Far Future[a] 2130 (mg/L)	Screening Level Criteria[b] (mg/L)	Comments
ORGANICS					
Benzo(a)anthracene group[d]	0.00016	0.000099	4.00E-18	[c]	No criterion
Benzo(a)pyrene group[d]	0.000035	0.000024	1.84E-22	[c]	No criterion
Naphthenic acids	2.6	2.5	0.07	[c]	No criterion
Total Phenolics (evaluated as phenol)	0.0091	0.0087	0.0027	[c]	No criterion
INORGANICS					
Aluminum	1.3	1.2	0.4	5	Does not exceed
Ammonia	0.14	0.14	0.0073	[c]	No criterion [e]
Antimony	0.0009	0.0009	0.0001	[c]	No criterion
Arsenic	0.0044	0.0041	0.001	0.5	Does not exceed
Barium	0.115	0.109	0.05	[c]	No criterion
Beryllium	0.0035	0.0033	0.00052	0.1	Does not exceed
Boron	2.34	2.17	0.45	5	Does not exceed
Cadmium	0.0042	0.0039	0.0007	0.02	Does not exceed
Calcium	105	103	60	1000	Does not exceed
Chloride	41	39	13.7	[c]	No criterion [e]
Chromium	0.012	0.012	0.0016	1	Does not exceed
Copper	0.013	0.013	0.0038	0.3	Does not exceed
Iron	1.22	1.15	0.94	[c]	No criterion [e]
Lead	0.01	0.01	0.0013	0.1	Does not exceed
Magnesium	21.1	20.9	15	[c]	No criterion [e]
Manganese	0.079	0.074	0.064	[c]	No criterion
Mercury	0.000026	0.000025	0.0000033	0.002	Does not exceed
Molybdenum	0.74	0.71	0.095	0.05	EXCEEDS
Nickel	0.015	0.015	0.002	1	Does not exceed
Selenium	0.0019	0.0018	0.0003	0.05	Does not exceed
Silver	0.001	0.001	0.00013	[c]	No criterion
Sodium	332	307	67.5	[c]	No criterion [e]
Strontium	1.19	1.14	0.3	[c]	No criterion
Sulphate	670	641	94	1000	Does not exceed
Vanadium	0.09	0.086	0.012	0.1	Does not exceed
Zinc	0.05	0.05	0.04	50	Does not exceed

[a] Modelled concentrations for End Pit Lake based on inputs from Project Millennium plus existing developments (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE VI.1-22

PROJECT IMPACTS: COMPARISON OF END PIT LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Concentrations 2045[a] (mg/L)	Predicted Concentrations 2052[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for [b] Water Shrew (mg/L)	RBC for [b] River Otter (mg/L)	RBC for [b] Killdeer (mg/L)	RBC for [b] Great Blue Heron (mg/L)	RBC for [b] Deer Mouse (mg/L)	RBC for [b] Beaver (mg/L)	RBC for [b] Moose (mg/L)	RBC for [b] Snowshoe Hare (mg/L)	RBC for [b] Black Bear (mg/L)	Comments
ORGANICS													
Benzo[a]anthracene group[d]	0.000154989	9.86802E-05	3.97052E-18	8	3.1	10.2	22.4	7.7	27	1.7	4	2	Does not exceed.
Benzo[a]pyrene group[d]	3.51334E-05	2.41157E-05	1.84322E-22	0.8	0.3	0.05	0.1	0.7	2.7	0.2	0.4	0.2	Does not exceed.
Naphthenic Acids	2.5998	2.4953	0.0733	[d]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.0091	0.0087	0.0027	89.4	34.3	[c]	[c]	85	301	19	43.9	22.6	Does not exceed.
INORGANICS													
Antimony	0.0009	0.0009	0.0001	0.1	0.04	[c]	[c]	0.1	0.3	0.02	0.05	0.02	Does not exceed.
Arsenic	0.0044	0.0041	0.001	0.1	0.04	10.2	22.4	0.1	0.3	0.02	0.05	0.03	Does not exceed.
Barium	0.115	0.109	0.05	8	3.1	2.3	5.1	7.5	27	1.7	3.9	2	Does not exceed.
Manganese	0.079	0.074	0.064	131.1	50.3	21.3	32.9	124	442	28	64.3	33	Does not exceed.
Molybdenum	0.74	0.71	0.095	0.2	0.1	1.6	968.6	0.2	0.7	0.04	0.1	0.05	EXCEEDS (all species except killdeer and heron)
Silver	0.001	0.001	0.00013	100	100	100	100	100	100	100	100	100	Does not exceed.
Strontium	1.19	1.14	0.3	392	150.4	[c]	[c]	371	1321	83.8	192.2	98.7	Does not exceed.

[a] Modelled concentrations for End Pit Lake based on inputs from Project Millennium plus existing developments (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-23
PROJECT IMPACTS: COMPARISON OF CHEMICAL CONCENTRATIONS IN INVERTEBRATE TISSUE TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES

Chemical	Site Concentrations Athabasca River Downstream (1995)[a] (ug/g) Max	Background Concentrations Athabasca River Upstream (1983)[b] (ug/g) Max	Comments
PAHS AND SUBSTITUTED PAHS			
Naphthalene group[c]	0.08	[d]	No background
INORGANICS			
Aluminum	1070	1260	Does not exceed
Barium	29	13.4	EXCEEDS
Calcium	3030	3610	Does not exceed
Chromium	10.5	10	EXCEEDS
Cobalt	1.4	[d]	No background
Copper	45	5.5	EXCEEDS
Iron	2400	972	EXCEEDS[e]
Lithium	1.3	[d]	No Background
Magnesium	1530	426	EXCEEDS[e]
Manganese	314	51.2	EXCEEDS
Mercury	0.055	0.12	Does not exceed
Molybdenum	0.9	2.3	Does not exceed
Nickel	8.8	5.3	EXCEEDS[e]
Phosphorus	5620	3850	EXCEEDS[e]
Potassium	6640	621	EXCEEDS[e]
Silicon	546	[d]	No background[e]
Silver	0.4	[d]	No background
Sodium	5140	405	EXCEEDS[e]
Strontium	16.4	10.3	EXCEEDS
Titanium	16.4	26.6	Does not exceed
Vanadium	3.6	3.2	EXCEEDS
Zinc	133	30.1	EXCEEDS

[a] Data from benthic invertebrates sampled by Golder during 1995 (Golder 1996b).
[b] Data from benthic invertebrates sampled by Beak during 1983 upstream of Suncor and Syncrude (Beak 1988).
[c] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.
[d] No data
[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE VI.1-24

PROJECT IMPACTS: COMPARISON OF CHEMICAL CONCENTRATIONS IN INVERTEBRATE TISSUE TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Athabasca River[a] (ug/g) Max	RBC for Water Shrew Invertebrate Ingestion[b] (ug/g)	RBC for Killdeer Invertebrate Ingestion[b] (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS				
Naphthalene group[c]	0.08	1.7	[d]	Does not exceed
INORGANICS				
Barium	29	1.3	13.5	EXCEEDS (shrew, killdeer)
Chromium	10.5	656.3	0.6	EXCEEDS (killdeer)
Cobalt	1.4	0.3	0.4	EXCEEDS (shrew, killdeer)
Copper	45	3.6	30.2	EXCEEDS (shrew, killdeer)
Lithium	1.3	2.3	[d]	Does not exceed
Manganese	314	21.1	627.4	EXCEEDS (shrew)
Nickel	8.8	9.6	49.7	Does not exceed
Silver	0.4	[d]	[d]	No RBC
Strontium	16.4	63.1	[d]	Does not exceed
Vanadium	3.6	0.0467	7.3	Does not exceed
Zinc	133	38.4	9.3	EXCEEDS (shrew, killdeer)

[a] Data from benthic invertebrates sampled by Golder during 1995 (Golder 1996b).

[b] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors w

[c] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[d] No data

TABLE VI.1-25

PROJECT IMPACTS: COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO BACKGROUND CONCENTRATIONS

Chemical	Site Concentrations					Background Concentrations		Comments
	Muskeg River[a] Longnose Sucker (ug/g) Max	Athabasca River[a] Walleye (ug/g) Max	Athabasca River[a] Goldeye (ug/g) Max	TID Exposed[b] Walleye (ug/g) Max - Lab	Refinery Effluent[b] Exposed Trout (ug/g) Max - Lab	Athabasca River[c] Walleye (ug/g) Max - Lab	Athabasca River[c] Rainbow trout (ug/g) Max - Lab	
PAHS AND SUBSTITUTED PAHS								
Naphthalene group[d]	0.09	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	EXCEEDS
INORGANICS								
Aluminum	11	3	2	12	7.5	14	18	Does not exceed
Arsenic	<0.5	<0.5	<0.5	1.1	0.4	2.3	<0.1	Does not exceed
Barium	<0.5	<0.5	<0.5	0.9	0.18	0.9	<0.5	Does not exceed
Calcium	880	662	627	7660	404	7090	2260	EXCEEDS[f]
Chromium	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	EXCEEDS
Copper	<1	1	2	<1	1.06	<1	<1	EXCEEDS
Iron	16	12	12	<1	15	8	23	Does not exceed
Lead	<2	<2	<2	<5	0.22	<5	<5	EXCEEDS
Magnesium	661	321	377	371	312	457	380	EXCEEDS[f]
Manganese	0.9	1.2	<0.5	6.1	0.33	5.1	0.9	EXCEEDS
Mercury	[e]	[e]	[e]	0.44	0.03	0.45	0.04	Does not exceed
Nickel	<1	<1	2	<2	0.15	<2	<2	EXCEEDS
Phosphorus	2960	2880	2590	5820	2390	6060	3620	Does not exceed
Potassium	5190	4880	4380	4390	4260	5090	4840	EXCEEDS[f]
Selenium	0.3	<0.5	<0.5	0.4	0.4	0.4	0.3	Does not exceed
Silicon	12	4	7	<50	[e]	<50	<50	EXCEEDS[f]
Silver	<0.2	<0.2	<0.2	<1	1.49	<1	<1	EXCEEDS
Sodium	409	440	360	748	504	635	471	EXCEEDS[f]
Strontium	0.9	0.6	<0.5	8	0.8	8	2	Does not exceed
Tin	<2	<2	<2	<5	1.54	<5	<5	EXCEEDS
Vanadium	<1	<1	<1	<1	0.19	<1	<1	EXCEEDS
Zinc	6	9	6	17.5	18.6	17.2	8.9	EXCEEDS

[a] Data from fish sampled by Golder during 1995 (Golder 1996b).

[b] Data from fish exposed to Tar Island Dyke Water (10%) or Refinery Effluent in laboratory (HydroQual 1996a,b).

[c] Data from fish exposed in laboratory to Athabasca River water taken upstream of Fort McMurray (HydroQual 1996). These are considered to be background samples.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer toTable VI.1-1.

[e] No data

[f] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These chemicals were not detected above detection limits

TABLE VI.1-26

PROJECT IMPACTS: COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Muskeg River[a] Longnose Sucker (ug/g) Max	Athabasca River[a] Walleye (ug/g) Max	Athabasca River[a] Goldeye (ug/g) Max	TID Exposed[b] Walleye (ug/g) Max - Lab	Refinery Effluent[b] Exposed Trout (ug/g) Max-Lab	RBC for[c] River Otter Fish Ingestion (ug/g)	RBC for[c] Great Blue Heron Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS								
Naphthalene group[d]	0.09	<0.02	<0.02	<0.02	<0.02	7	[e]	Does not exceed
INORGANICS								
Copper	<1	1	2	<1	1.06	14.7	106.2	Does not exceed
Chromium	<0.5	<0.5	<0.5	<0.5	0.7	2645	2.3	Does not exceed
Lead	<2	<2	<2	<5	0.22	7.7	8.7	Does not exceed
Manganese	0.9	1.2	<0.5	6.1	0.33	85	2206.9	Does not exceed
Nickel	<1	<1	2	<2	0.15	38.7	174.2	Does not exceed
Silver	<0.2	<0.2	<0.2	<1	1.49	100	100	Does not exceed
Tin	<2	<2	<2	<5	1.54	5	5	Does not exceed
Vanadium	<1	<1	<1	<1	0.19	0.2	26	Does not exceed
Zinc	6	9	6	17.5	18.6	154.6	32.8	Does not exceed

[a] Data from fish sampled by Golder during 1995 (Golder 1996b).

[b] Data from fish exposed to Tar Island Dyke Water (10%) or Refinery Effluent in laboratory (HydroQual 1996a,b).

[c] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] No data.

< These chemicals were not detected above detection limits

TABLE VI.1-27

RECLAMATION: COMPARISON OF ESTIMATED CHEMICAL CONCENTRATIONS IN PLANTS GROWING ON RECLAMATION SOILS TO RISK-BASED CONCENTRATIONS (RBCs) FOR WILDLIFE HEALTH

Chemicals	Estimated Plant Concentrations [a] (mg/kg plant)	RBC for Moose (mg/kg plant)	RBC for Hare (mg/kg plant)	RBC for Beaver (mg/kg plant)	RBC for Mouse (mg/kg plant)	RBC for Grouse (mg/kg plant)	Comments
ORGANICS							
Benzo(a)anthracene group[c]	0	5.4	4.9	50.5	11.2	0.2	Does not exceed
Benzo(a)pyrene group[c]	0	0.5	0.5	5.1	1.1	0.016	Does not exceed
Benzo(b&k)fluoranthene group[c]	0	5.4	4.9	50.5	11.2	0.2	Does not exceed
Fluoranthene group[c]	0	6.9	6	63.1	14	31.3	Does not exceed
Phenanthrene group[c]	0	6.9	6	63.1	14	31.3	Does not exceed
Pyrene	0	4.1	3.6	37.9	8.4	31.3	Does not exceed
INORGANICS							
Aluminum	388.7	1	0.9	9.8	2.2	152.3	EXCEEDS (all species)[e]
Arsenic	0.06	0.1	0.1	0.6	0.1	7.1	Does not exceed
Barium	17.4	5.4	4.7	50.5	11	28.9	EXCEEDS (moose, hare, mouse)
Beryllium	0.02	0.6	0.6	5.1	1.4	$^{-5}$	Does not exceed
Boron	49.8	28.3	263	263	57.9	40	EXCEEDS (moose, grouse)
Cadmium	0.35	1.2	0.9	10.11	2.1	2	Does not exceed
Cobalt	2.3	1.3	1.2	12.4	2.7	1	EXCEEDS (moose, hare, grouse)
Chromium	0.85	2757	25712	25712	5663	1.4	Does not exceed
Copper	3	15.6	13.5	143.9	31.5	65.3	Does not exceed
Lead	0.23	8.1	7.2	75.8	16.5	5.3	Does not exceed
Mercury	0.015	1.2	1.1	12.6	0.007	0.625	EXCEEDS (mouse)
Molybdenum	0.79	0.1	1.3	1.3	0.001	4.9	EXCEEDS (mouse, moose)
Nickel	2.8	40.5	35.5	376.3	0.2	107.5	EXCEEDS (mouse)
Selenium	0.11	0.2	1.8	1.8	0.001	0.7	EXCEEDS (mouse, moose, grouse)
Strontium	37	265	2470	2470	1.4	$^{-5}$	EXCEEDS (mouse)
Vanadium	1.7	0.2	0.2	1.8	0.001	15.8	EXCEEDS (mouse, hare, moose)
Zinc	58.3	161.4	142	1503	0.9	20.1	EXCEEDS (mouse, grouse)

[a] Estimated PAH concentrations in plants based on tailings sand (Suncor Beach; CP5) data as reported by ETL (1993; n=1);
For metals, geometric mean of measured concentrations in plants grown on CT capped with sand and muskeg (Xu 1997).

[b] Risk-based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-5} (carcinogens).

[c] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table H12-32.

[d] No data or criterion available

[e] Although aluminum theoretically exceeds the RBCs for some species, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

[e] Zinc was not evaluated in the risk assessment, since it is required element for human nutrition.

TABLE VI.1-28

RECLAMATION: COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC PLANTS GROWN IN TREATED WETLANDS TO BACKGROUND WETLANDS

Chemicals	TREATMENT					BACKGROUND		Comments
	Dyke Drainage[a] Wetlands (mg/kg plant)	Pond 1A[b] Wetlands (mg/kg plant)	Syncrude[c] Pit 7 (mg/kg plant)	Suncor[d] Pond 5 (mg/kg plant)	Hummock[d] Wetlands (mg/kg plant)	Syncrude[e] Reference Wetlands (mg/kg plant)	Control[f] Wetlands (mg/kg plant)	
ORGANICS								
Acenaphthene group[g]	[h]	[h]	0.013	[h]	[h]	<0.001	[h]	EXCEEDS
Benzo(a)anthracene group[g]	[h]	[h]	0.118	[h]	[h]	<0.001	[h]	EXCEEDS
Benzo(a)pyrene group[g]	[h]	[h]	0.019	[h]	[h]	<0.001	[h]	EXCEEDS
Biphenyl	[h]	[h]	0.002	[h]	[h]	0.001	[h]	EXCEEDS
Dibenzo(a,h)anthracene	[h]	[h]	0.001	[h]	[h]	<0.001	[h]	EXCEEDS
Dibenzothiophene group[g]	[h]	[h]	0.774	[h]	[h]	0.001	[h]	EXCEEDS
Fluoranthene group[g]	[h]	[h]	0.035	[h]	[h]	<0.001	[h]	EXCEEDS
Fluorene group[g]	[h]	[h]	0.141	[h]	[h]	0.018	[h]	EXCEEDS
Naphthalene group[g]	[h]	[h]	0.299	[h]	[h]	0.013	[h]	EXCEEDS
Phenanthrene group[g]	[h]	[h]	1.762	[h]	[h]	<0.001	[h]	EXCEEDS
Pyrene	[h]	[h]	0.001	[h]	[h]	<0.001	[h]	EXCEEDS
INORGANICS								
Aluminum	367	701.86	1610	132	384	1440	358.67	EXCEEDS
Arsenic	[h]	[h]	1.6	1	0.7	2.5	[h]	Does not exceed
Barium	[h]	[h]	28.7	11.5	42	21.5	[h]	EXCEEDS
Beryllium	[h]	[h]	0.14	<0.2	<0.2	0.15	[h]	Does not exceed
Boron	[h]	[h]	44	39	48	15	[h]	EXCEEDS
Cadmium	0.06	0.07	0.29	<0.08	<0.08	0.34	0.07	Does not exceed
Calcium	[h]	[h]	6150	6340	11100	8490	[h]	EXCEEDS*
Copper	2.29	2.82	6.2	4.71	4.63	9.74	3.66	Does not exceed
Lead	[h]	[h]	0.6	2.01	1.89	1.2	[h]	EXCEEDS
Lithium	[h]	[h]	5	[h]	[h]	<4	[h]	EXCEEDS
Iron	642.67	363.43	2300	1120	5910	4400	936.78	EXCEEDS*
Magnesium	[h]	[i]	2130	1860	2540	2600	[h]	Does not exceed
Manganese	266.88	303	217	174	385	828	741.5	Does not exceed
Mercury	0.07	0.11	[h]	[h]	[h]	[h]	0.02	EXCEEDS
Nickel	2.22	2.27	3.5	9.76	0.77	2.7	2.66	EXCEEDS
Phosphorus	[h]	[h]	1350	1710	2000	1060	[h]	EXCEEDS*
Potassium	[h]	[h]	6730	17100	16000	12200	[h]	EXCEEDS*
Silicon	[h]	[h]	283	1	1.2	302	[h]	Does not exceed
Sodium	[h]	[j]	11100	14200	14900	3750	[h]	EXCEEDS*
Strontium	[h]	[h]	60.3	63.7	93.4	34.1	[h]	EXCEEDS
Titanium	[h]	[h]	9.48	[h]	[h]	16.3	[h]	Does not exceed
Vanadium	[h]	[h]	4.7	16.7	0.69	5.1	[h]	EXCEEDS
Zinc	33.75	20.78	22.1	20.5	23.8	34.1	41.35	Does not exceed
Zirconium	[h]	[h]	2	[h]	[h]	1.5	41.35	Does not exceed

[a] Data from dyke drainage water constructed wetland (Nix et al. 1995).

[b] Data from Pond 1A constructed wetland (Nix et al. 1995).

[c] Data from Syncrude, Pit 7 (unpublished data). Plants grown in fine tails.

[d] Data from Suncor Hummock Wetlands and Pond 5 (Golder 1997g).

[e] Data from Syncrude reference wetlands (unpublished data). This sample was considered to be representative of background values.

[f] Data from control constructed wetlands (Nix et al. 1995). This sample was considered to be representative of background values.

[g] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[h] Not analyzed or no data available.

[i] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE VI.1-29

RECLAMATION: COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC PLANTS GROWN IN TREATED WETLANDS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Page 1 of 1

Chemicals	Dyke Drainage[a] Wetlands (mg/kg plant)	Pond 1A [b] Wetlands (mg/kg plant)	Syncrude [c] (mg/kg plant)	Suncor[d] Pond 5 (mg/kg plant)	Hummock[d] Wetlands (mg/kg plant)	RBC for[e] Mallard (mg/kg plant)	RBC for[e] Beaver (mg/kg plant)	RBC for[e] Moose (mg/kg plant)	Comments
PAHS AND SUBSTITUTED PAHS									
Acenaphthene group[g]	[f]	[f]	0.013	[f]	[f]	158.6	88.4	9.3	Does not exceed
Benzo(a)anthracene group[g]	[f]	[f]	0.118	[f]	[f]	0.8	50.5	5.4	Does not exceed
Benzo(a)pyrene group[g]	[f]	[f]	0.019	[f]	[f]	0.1	5.1	0.5	Does not exceed
Biphenyl	[f]	[f]	0.002	[f]	[f]	[f]	469.7	50.3	Does not exceed
Dibenzo(a,h)anthracene	[f]	[f]	0.001	[f]	[f]	[f]	1	0.1	Does not exceed
Dibenzothiophene group[g]	[f]	[f]	0.774	[f]	[f]	158.6	37.9	4.1	Does not exceed
Fluoranthene group[g]	[f]	[f]	0.035	[f]	[f]	158.6	63.1	6.9	Does not exceed
Fluorene group[g]	[f]	[f]	0.141	[f]	[f]	158.6	63.1	6.9	Does not exceed
Naphthalene group[g]	[f]	[f]	0.299	[f]	[f]	158.6	68.2	7.5	Does not exceed
Phenanthrene group[g]	[f]	[f]	1.47	[f]	[f]	158.6	20.5	2.2	Does not exceed
Pyrene	[f]	[f]	0.001	[f]	[f]				Does not exceed
INORGANICS									
Aluminum	367	701.86	1610	132	384	771.5	9.8	1	EXCEEDS (mallard; beaver; moose)[h]
Barium	[f]	[f]	28.70	11.5	42	146.5	50.5	5.4	EXCEEDS (moose)
Boron	[f]	[f]	36.5	39	48	202.6	262.6	28.3	EXCEEDS (moose)
Lead	[h]	[h]	0.6	2.01	1.89	27.1	75.8	8.1	Does not exceed
Lithium	[f]	[f]	5	[f]	[f]	[f]	113.6	12.1	Does not exceed
Mercury	0.07	0.07	[f]	[f]	[f]	3.16	12.6	1.2	Does not exceed
Nickel	2.22	[f]	3.5	9.76	0.77	544.4	376.3	40.5	Does not exceed
Strontium	[f]	[f]	60.3	63.7	93.4	[f]	2470	265	Does not exceed
Vanadium	[h]	[h]	4.7	16.7	0.69	80	1.8	0.2	EXCEEDS (beaver, moose)

[a] Data from dyke drainage water constructed wetland (Nix et al. 1995).

[b] Data from Pond 1A constructed wetland (Nix et al. 1995).

[c] Data from Syncrude, Pit 7 (unpublished data). Plants grown in fine tails.

[d] Data from Suncor Hummock Wetlands and Pond 5 (Golder 1997g).

[e] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set to 1.0.

[f] Not analyzed or no data available.

[g] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[h] Although aluminum theoretically exceeds the RBCs for some species, aluminum is less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

TABLE VI.1-30

RECLAMATION: COMPARISON OF ON-SITE WATER SEEPAGE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	On-Site Seepage Water Concentrations[a]	RBC for[b] Moose	RBC for[b] Beaver	RBC for[b] Mouse	RBC for[b] Grouse	RBC for[b] Snowshoe Hare	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs							
Benzo(a)anthracene group[d]	0.0011	1.7	27	7.7	0.1	4	Does not exceed.
Fluorene group[d]	0.00003	2.2	33.8	9.6	15.7	4.9	Does not exceed.
Naphthalene group[d]	0.00005	2.4	36.5	10.2	[c]	5.3	Does not exceed.
Pyrene	0.00004	1.3	20.3	5.7	15.7	2.9	Does not exceed.
INORGANICS							
Aluminum	1.27	0.3	5.3	1.5	76.6	0.8	EXCEEDS (moose, hare)[e]
Arsenic	0.0036	0.02	0.3	0.1	3.6	0.05	Does not exceed.
Barium	0.11	1.7	27	7.5	14.5	3.9	Does not exceed.
Beryllium	0.0026	0.2	2.7	0.9	[c]	0.5	Does not exceed.
Boron	2.2	9	140.5	39	20	20.4	Does not exceed.
Cadmium	0.004	1.2	5.4	1.4	1	0.9	EXCEEDS (grouse, hare)
Chromium	0.005	1	16.2	4.6	0.7	2.4	Does not exceed.
Copper	0.0084	4.9	77	21.5	33	11.2	Does not exceed.
Lead	0.02	2.6	40.5	11.2	2.7	5.9	Does not exceed.
Manganese	0.19	28	442	124	682	64.3	Does not exceed.
Mercury	0.00005	0.4	6.8	1.8	0.3	0.9	Does not exceed.
Molybdenum	0.23	0.04	0.7	0.2	2.4	0.1	EXCEEDS (moose, hare)
Nickel	0.03	12.8	201	56.4	54	29.3	Does not exceed.
Selenium	0.0007	0.1	0.9	0.3	0.3	0.1	Does not exceed.
Strontium	0.55	83.8	1321	371	[c]	192.2	Does not exceed.
Vanadium	0.034	0.1	0.9	0.3	7.9	0.1	Does not exceed.
Zinc	0.06	51	804	226	10	116.9	Does not exceed.

[a] Maximum measured concentration in groundwater within study area; used to represent hypothetical concentrations in mineral licks used by wildlife (1995); maximum used where limited data

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] Although aluminum theoretically exceeds the RBCs for some species, aluminum is less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

TABLE VI.1-31

RECLAMATION: COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC INVERTEBRATE TISSUE TO BACKGROUND CONCENTRATIONS

Page 1 of 1

Chemical	Dyke Drainage[1] (ug/g)	Split Dyke[1] Drainage (ug/g)	Control[2] (ug/g)	Comments
Benthic Invertebrates				
Aluminum	450	1800	220	Does not exceed
Barium	71.5	29	52.6	Does not exceed
Cadmium	<[3]	<[3]	<[3]	Does not exceed
Copper	40	20	20	EXCEEDS
Iron	2650	2970	2100	Does not exceed
Lead	<[3]	<[3]	<[3]	Does not exceed
Manganese	77	110	46	Does not exceed
Mercury	<[3]	<[3]	<[3]	Does not exceed
Titanium	20	30	9	Does not exceed
Total Extractable Hydrocarbons	74.1	66.8	99.8	Does not exceed
Zinc	110	94	94	EXCEEDS
Emergent Insects				
Aluminum	70	-[4]	40	Does not exceed
Barium	84.4	-[4]	41	EXCEEDS
Cadmium	<[3]	-[4]	<[3]	Does not exceed
Copper	70	-[4]	70	Does not exceed
Iron	650	-[4]	1800	Does not exceed
Lead	<[3]	-[4]	<[3]	Does not exceed
Manganese	190	-[4]	80	Does not exceed
Mercury	<[3]	-[4]	<[3]	Does not exceed
Titanium	10	-[4]	<30	EXCEEDS
Zinc	220	-[4]	200	Does not exceed
Chironomid Larvae				
Aluminum	18.38	-[4]	71	Do not exceed
Cadmium	0.57	-[4]	0.34	EXCEEDS
Iron	6590.6	-[4]	3394	EXCEEDS
Lead	5.73	-[4]	2.4	EXCEEDS
Mercury	5.39	-[4]	8.5	Do not exceed
Zinc	145.11	-[4]	234.07	Do not exceed

[1] Data from dyke drainage water constructed wetland (Nix et al. 1995).

[2] Data from control constructed wetlands (Nix et al. 1995) considered to be representative of background values.

[3] Not detected. Detection limit not specified.

[4] Not analyzed.

[5] Iron was not evaluated in the risk assessment since it is a required nutrient.

TABLE VI.1-32

RECLAMATION: COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC INVERTEBRATE TISSUE TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Dyke Drainage[1] (mg/kg)	Dyke Drainage[1] (split trench) (mg/kg)	RBC for[2] Mallard (mg/kg prey)	Comments
Benthic Invertebrates				
Copper	40	20	112	Does not exceed
Zinc	110	94	34.6	EXCEEDS
Emergent Insects				
Barium	84.4	-[3]	50	EXCEEDS
Titanium	10	-[3]	-[3]	No RBC
Chironomid Larvae				
Cadmium	0.57	-[3]	3.5	Does not exceed
Lead	5.73	-[3]	9.2	Does not exceed

[1] Data from dyke drainage water constructed wetland (Nix et al. 1995).

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set to 1.0.

[3] Not analyzed, or no data available.

TABLE VI.1-33

CEA: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2044[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Background Athabasca River[c]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS						
Benzo(a)anthracene group[e]	[g]	0.0000066	0.0000057	[d]	<0.00004	No criterion; Exceeds background
Benzo(a)pyrene group[e]	[g]	0.00000089	0.00000068	[d]	<0.00004	No criterion; Exceeds background
INORGANICS						
Antimony	[g]	0.00002	[g]	[d]	0.0002	No criterion; Does not exceed background
Arsenic	[g]	0.0015	[g]	0.5	0.007	Does not exceed
Boron	[g]	0.09	[g]	5	0.09	Does not exceed.
Calcium	[g]	33.2	[g]	1000	74	Does not exceed.
Lead	0.000092	0.00026	0.000084	0.1	[d]	Does not exceed
Magnesium	[g]	8.2	[g]	[d]	21	No criterion; Does not exceed background
Molybdenum	[g]	0.013	[g]	0.05	0.01	Does not exceed.
Selenium	[g]	0.0003	[g]	0.05	0.0004	Does not exceed.
Silver	[g]	0.000021	[g]	[d]	0.0003	No criterion; Does not exceed background
Sodium	[g]	18.1	12.7	[d]	24.6	No criterion; Does not exceed background
Sulphate	[g]	27.1	[g]	1000	58	Does not exceed.
Zinc	[g]	0.014	[g]	50	0.085	Does not exceed.

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing, approved and planned developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 fo

[b] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[c] Measured concentrations in the Athabasca River upstream of Lease 19 sampled by Golder in 1995 and NAQUADAT 1985-1995.

[d] No data or criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[f] Data not included because values are less than predicted concentrations from Project Millennium plus existing and approved developments (See Table VI.1-19); chemicals not included in this table for the same reason.

< These chemicals were not detected above detection limits

TABLE VI.1-34

CEA: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2044[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Shrew (mg/L)	RBC for[b] River Otter (mg/L)	RBC for[b] Killdeer (mg/L)	RBC for[b] Great Blue Heron (mg/L)	RBC for [b] Deer Mouse (mg/L)	RBC for [b] Beaver (mg/L)	RBC for[b] Moose (mg/L)	RBC for[b] Snowshoe Hare (mg/L)	RBC for[b] Black Bear (mg/L)	Comments
ORGANICS													
Benzo(a)anthracene group[d]	[g]	0.0000066	0.0000057	8	3.1	10.2	22.4	7.7	27	1.7	4	2	Does not exceed.
Benzo(a)pyrene group[d]	[g]	0.00000089	0.00000068	0.8	0.3	0.05	0.1	0.7	2.7	0.2	0.4	0.2	Does not exceed.
INORGANICS													
Arsenic	[g]	0.0015	[g]	0.1	0.04	10.2	22.4	0.1	0.3	0.02	0.05	0.03	Does not exceed.
Molybdenum	[g]	0.013	[g]	0.2	0.1	1.6	968.6	0.2	0.7	0.04	0.1	0.05	Does not exceed.

[a] Predicted concentrations in the Athabasca River for Project Millennium plus existing, approved and planned developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] Data not included because values are less than predicted concentrations from Project Millennium plus existing and approved developments (See Table VI.1-19).

TABLE VI.1-35

PROJECT IMPACTS: LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR WILDLIFE

Chemical	Water Shrew	Killdeer	River Otter	Moose	Snowshoe Hare	Black Bear	Ruffed Grouse	Beaver	Mallard	Deer Mouse
W-2: Exposure to Water and/or Aquatic Invertebrates (Operations)										
Barium	x	x								
Chromium		x								
Cobalt	x	x								
Copper	x	x								
Manganese	x									
Molybdenum	x		x	x	x	x	x		x	x
Zinc	x	x								
W-2 Exposure to Plants (Operations)										
Antimony										
Barium										
Boron										
Cadmium										
Cobalt										
Copper										
Manganese										
Molybdenum										
Selenium										
Vanadium										
W-2 Multi-Media Exposure (Operations)										
Antimony										
Barium	x	x								
Boron										
Cadmium										
Chromium		x								
Cobalt	x	x								
Copper	x	x								
Manganese	x									
Molybdenum	x		x	x	x	x	x		x	x
Selenium										
Vanadium										
Zinc	x	x								
W-3 Reclaimed Landscape Exposure (Closure)										
Barium				x	x					x
Boron				x			x			
Cadmium					x		x			
Cobalt				x	x		x			
Mercury										x
Molybdenum				x						x
Nickel										x
Selenium				x			x			x
Strontium										x
Vanadium				x	x			x		x
Zinc							x			x

VI.1.3 Chemical Screening for Human Health

A similar methodical step-wise screening process was applied to identify chemicals of potential concern that might affect human health.

Steps 1 and 2: Compile Validated Site and Background Chemical Concentration Data

HH-1: Water-Mediated Exposure (Operation)

Water - Since operational release waters from Project Millennium were not available, water chemistry data from existing oil sands operations (i.e., Suncor and Syncrude) were used for water quality modelling. Predicted concentrations in the Athabasca River and Shipyard Lake during the operational phase were used for chemical screening. For more details on water quality, refer to Section C3. Maximum measured or reasonable worst-case predicted concentrations were used for screening purposes. Background water quality data included water samples that were collected in the Athabasca River upstream of existing oil sands operations.

Fish - Refer to wildlife health screening section for details (Section VI.1.2).

HH-2: Air-Mediated Exposure (Operation)

Air - Air quality data were modelled based on predicted emissions from extraction and utilities, diesel exhaust emissions and off-gasing from tailings ponds and mine surfaces, as summarized in Section B. This data was used in the chemical screening for key question HH-2.

HH-3: Plant- and Game-Mediated Exposure (Operation)

Plants - Refer to wildlife health screening section for details (Section VI.1.2).

Meat - Data from recent animal tissue sampling programs, involving rodents, were used in chemical screening (Pauls and Arner 1989; Conor Pacific Environmental Technologies Ltd. 1998a). In addition, meat and liver concentrations in a bison that had been pastured near the Syncrude facility were screened (Pauls et al. 1995).

HH-5: Multi-Media Exposure (Closure)

Water - Predicted water concentrations in the Athabasca River, Shipyard Lake and the end pit lake at closure and in the far future were used for chemical screening. For more details on water quality, refer to Section C3.

Reasonable worst-case predicted concentrations were used for screening purposes.

Plants - Refer to wildlife health screening section for details (Section VI.1.2).

Meat - Game meat data were obtained from two sources for chemical screening: (i) duckling liver concentrations, following exposure to release water effluent in artificial wetlands (EVS 1996); (ii) bison liver concentrations, following exposure on a reclaimed tailings sand pasture (Pauls et al. 1995).

Step 3: Compile Relevant Environmental Criteria and Select Screening Level Criteria

Human health criteria were compiled from various published sources and used to identify Screening Level Criteria (SLC). Each chemical identified in Step 1 and measured at concentrations above the analytical detection limit was compared to the SLC as outlined below.

Water - Drinking water criteria included:

- Health Canada (HC) Guidelines for Canadian Drinking Water Quality. Maximum Acceptable Concentration (Health Canada 1996);
- U.S. EPA's (U.S. Environmental Protection Agency) Drinking Water Regulations and Health Advisories. Maximum Contaminant Level for Drinking Water. (U.S. EPA 1996); and
- BC Environment (BCE) Contaminated Sites Regulation. Schedule 6. Generic Numerical Water Standards. Drinking Water (BCE 1997).

The lowest value of the three above criteria was used as the SLC for chemicals in drinking water for people (Table VI.1-36).

Air - The following criteria were used for screening chemicals in air:

- Odorous compounds: odour thresholds reported by Ruth (1986) and Amoore and Hautala (1983);
- Alberta Ambient Air Quality Guidelines;
- BC Environment Air Quality Standards;
- Canadian National Ambient Air Quality Objectives;
- US EPA National Ambient Air Quality Standards; and
- National Ambient Air Quality Objectives for Particulate Matter (WGAQOG 1997).

Fish, Meat and Plants - Regulatory SLC were not available for screening of fish, meat and plants.

Step 4: Comparison of Maximum Observed or Predicted Concentrations to SLC

Site concentrations were compared to SLC. If chemical concentrations were greater than or equal to the SLC, the chemicals were carried forward to Step 5. If chemical concentrations were much less than the SLC, they were eliminated from further consideration in the risk assessment. However, if chemical concentrations were marginally less than the SLC, these chemicals were conservatively carried forward to Step 5. If no SLC were available, chemicals were carried forward to Step 5.

Step 5: Comparison of Maximum Observed or Predicted Concentrations to Background Concentrations

Site concentrations were compared to background chemical concentrations. If chemical concentrations were less than or equal to background concentrations, they were eliminated from further consideration in the risk assessment, since these chemical concentrations were assumed to be natural in origin and not Project-related. If chemical concentrations exceeded background concentrations or if no background data were available, they were carried forward to Step 6.

Step 6: Identification of Risk-Based Concentrations (RBCs) for Remaining Chemicals

At this stage, risk-based concentrations (RBCs) were identified for all chemicals for which site concentrations exceeded both SLC and background concentrations. RBCs for the ingestion of drinking water, fish and inhalation of air are available from the U.S. EPA's Region III Risk-Based Concentration Table (Smith 1997), based on adult exposure and a target hazard quotient of 1.0. These RBCs were conservatively recalculated for non-carcinogenic chemicals to account for child exposure and a target hazard quotient of 0.1, assuming that a person could only receive one-tenth of his/her daily exposure from each media. The resulting RBCs for non-carcinogenic chemicals were approximately 27-fold lower than those reported in Smith (1997). RBCs were not recalculated from Smith (1997) for carcinogenic chemicals, since these RBCs were based on child and adult exposure during the first 30 years of life and an acceptable risk level of one-in-one million, rather than the acceptable risk level of one-in-one-hundred-thousand endorsed by Health Canada, and therefore were already conservatively calculated. RBCs for plants and game meat were calculated using the equations outlined in Smith (1997) and the conservative assumptions described previously for water, fish and meat.

If RBCs were not available and could not be derived, chemicals were retained and evaluated for nutrient and/or non-toxic status under Step 7. If RBCs were available, chemicals were retained and evaluated for exceedance of RBCs in Step 8.

Step 7: Evaluation of Nutritional or Non-Toxic Status

Chemicals, for which RBCs could not be identified, were retained for further evaluation in Step 7. Certain compounds may be eliminated from further consideration based on their importance as a dietary component, status as an essential nutrient, or general lack of toxic effects at the measured concentrations. Calcium, magnesium, potassium, iron and sodium can generally be eliminated from further evaluation at the screening stage based on dietary and nutritional status (U.S. EPA 1989). Other chemicals may be considered non-toxic under certain conditions of exposure. These are described below.

Aluminum

Aluminum is the third most abundant element in the earth's crust and is present in all rock types and most geologic materials, especially clays (CCREM 1987). Total aluminum measurements in soil reflect the natural abundance of aluminum silicate in soils, which are less than 1% bioavailable by the oral route. The daily intake of aluminum, estimated at 88 mg per day by WHO, is largely from food. For these reasons, the elevated aluminum concentrations in reclamation soils were not evaluated further in the risk assessment.

Ammonia

Although considered an odour nuisance at low concentrations in water, ammonia was not considered a human health concern via the ingestion pathway. The RBC for ammonia is based on a threshold for inhalation; drinking water thresholds (HEAST 1995) are based on aesthetic effects, rather than adverse health effects.

Chloride

Chloride is an essential nutrient for people, which functions to ensure the proper fluid-electrolyte balance. Water is a relatively minor contributor of chloride compared to intake from other sources such as food (CCREM 1987). Therefore, health implications with respect to chloride are not considered to be significant. The main consideration regarding chloride is prevention of undesirable taste in water and water-based beverages. Given that chloride is essential for human health, chloride was eliminated from further consideration.

Manganese

Manganese is an essential nutrient and concentrations related to possible health concerns are much greater than those related to aesthetic considerations (CCREM 1987). Manganese will stain plumbing and laundry, produce an undesirable taste and cause encrustation problems in piping. The water quality guideline for drinking water is based on an aesthetic objective rather human health considerations (Health Canada 1996). In addition, the body normally controls the amount of manganese that is taken up and retained (ATSDR 1991). For example, if large amounts are ingested, the amount that is taken up in the body becomes smaller. If too much does enter the body, the excess is usually removed in the feces. Therefore, the total amount of manganese in the body usually tends to stay about the same, even when exposure rates are higher or lower than usual. Therefore, given that there is no anthropogenic source for manganese, that absorption of manganese into the body is low and that manganese is an essential nutrient, this chemical was eliminated from further consideration.

Silicon

Silicon is insufficiently bioavailable to be absorbed following intake and is also considered biologically inert (HSDB 1995), therefore, it was considered non-hazardous for the purpose of this assessment and eliminated from further evaluation.

Sulphate

Soluble sulphate salts of sodium, magnesium, potassium, lithium, etc. are rather slowly absorbed from the alimentary tract. The amount of sulphate anion usually absorbed has no toxicological significance (Gosselin et al. 1984); therefore, it was considered non-hazardous for the purpose of this assessment.

Zinc

Zinc is a natural element present in the earth's crust and an essential dietary element for people and wildlife. The available Health Canada toxicity reference value for zinc is based on the recommended daily intake for this essential nutrient, rather than a level associated with toxicity. Zinc was identified in the chemical screening of plant tissue concenrations. This is not unexpected since zinc is a common constituent of food. Therefore, due to its nutrient status, zinc was not evaluated further in the risk assessment.

Step 8: Comparison of Maximum Observed or Predicted Concentrations to Risk-Based Concentrations

In this step, the maximum chemical concentrations measured or predicted in water, fish, plants and game animals were compared to the RBCs. If the maximum concentration of a chemical was equal to or greater than the RBC, the chemical was retained for further evaluation in the risk assesssment. If the concentration was less than the RBC, the chemical was eliminated from further consideration.

Screening tables for the baseline assessment are presented in Tables VI.1-37 to VI.1-40, with a summary list in Table VI.1-41. Screening tables for project impacts and the CEA are presented in Tables VI.1-42 to VI.1-51, with a summary list in Table VI.1-52. For key questions HH-4 and HH-5, all chemicals that were identified in one or more media were evaluated in all media. This was done to determine the combined exposure to these chemicals from all potentially affected media (i.e., water, air, plants, game meat, fish) during operation (HH-4) and following closure (HH-5).

Chemicals of Concern in Background Media

It should be noted that a few chemicals have been identified at elevated concentrations in background media. These include:

- mercury (water and fish)
- arsenic (water)
- beryllium (water)

Levels of mercury in fish tissues are relatively high and may pose a health risk to people eating fish from this region of the river. Relatively high levels of mercury in fish tissues have also been noted by NRBS, and the high levels of mercury have been attributed to natural sources (NRBS 1996). Arsenic and beryllium concentrations in the Athabasca River are also naturally elevated. The Project site is not expected to contribute to increased levels of mercury, arsenic or beryllium in water or fish tissue. However, due to interest articulated by regulators, arsenic and beryllium were evaluated in the risk assessment. With respect to mercury, further analysis of water and fish tissue is required to address elevated background concentrations of this element and potential food chain effects.

TABLE VI.1-36

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
PAHS AND SUBSTITUTED PAHS				
Acenaphthylene	(e)	(e)	(e)	(e)
Acenaphthene group[f]	(e)	(e)	(e)	(e)
Benzo(a)anthracene group[f]	(e)	0.0001	(e)	0.0001
Benzo(a)pyrene group[f]	0.00001	0.0002	0.00001	0.00001
Benzo(ghi)perylene	(e)	(e)	(e)	(e)
Biphenyl	(e)	(e)	(e)	(e)
Dibenzothiophene group[f]	(e)	(e)	(e)	(e)
Fluorene group[f]	(e)	(e)	(e)	(e)
Fluoranthene group[f]	(e)	(e)	(e)	(e)
Naphthalene group[f]	(e)	(e)	(e)	(e)
Phenanthrene group[f]	(e)	(e)	(e)	(e)
Pyrene	(e)	(e)	(e)	(e)
VOLATILES				
Carbon tetrachloride	0.005	0.005	0.005	0.005
Chloroform	0.1	0.1	0.1	0.1
Ethylbenzene	0.0024[g]	0.7	0.0024	0.0024[g]
Methylene chloride	0.05	0.005	0.05	0.005
Toluene	0.024[g]	1	-[5]	0.024[g]
m-+p-xylenes	0.3[g]	10	0.3	0.3[g]
o-xylene	0.3[g]	10	0.3	0.3[g]
PHENOLIC COMPOUNDS				
Phenol	(e)	(e)	(e)	(e)
2,4-Dimethylphenol	(e)	(e)	(e)	(e)
m-cresol	(e)	(e)	(e)	(e)
NAPHTHENIC ACIDS				
Naphthenic acids	(e)	(e)	(e)	(e)
INORGANICS				
Aluminum	(e)	0.2[g]	0.2	0.2[g]

TABLE VI.1-36

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
Ammonia	(e)	(e)	(e)	(e)
Antimony	(e)	0.006	(e)	0.006
Arsenic	0.025	0.05	0.025	0.025
Barium	1	2	1	1
Beryllium	(e)	0.004	(e)	0.004
Boron	5	(e)	5	5
Cadmium	0.005	0.005	0.005	0.005
Calcium	(e)	(e)	(e)	(e)
Chloride	250[g]	250[g]	250[g]	250[g]
Chromium	0.05	0.1	0.05	0.05
Cobalt	(e)	(e)	(e)	(e)
Copper	1	1.3	1	1
Cyanide	0.2	0.2	0.2	0.2
Iron	0.3[g]	0.3[g]	0.3[g]	0.3[g]
Lead	0.01	0.015	0.01	0.01
Lithium	(e)	(e)	(e)	(e)
Magnesium	(e)	(e)	(e)	(e)
Manganese	0.05[g]	0.05[g]	0.05[g]	0.05[g]
Mercury	0.001	0.002	0.001	0.001
Molybdenum	(e)	(e)	0.25	0.25
Nickel	(e)	0.14	0.2	0.14
Phosphorus	(e)	(e)	(e)	(e)
Potassium	(e)	(e)	(e)	(e)
Selenium	0.01	0.05	0.01	0.01
Silicon	(e)	(e)	(e)	(e)
Silver	(e)	0.1[g]	-[5]	0.1[g]
Sodium	200[g]	(e)	200[g]	200[g]
Strontium	(e)	(e)	(e)	(e)
Sulphate	500[g]	500[g]	500[g]	500[g]

TABLE VI.1-36

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
Tin	(e)	(e)	(e)	(e)
Titanium	(e)	(e)	(e)	(e)
Uranium	(e)	0.02	(e)	0.02
Vanadium	(e)	(e)	(e)	(e)
Zinc	5[g]	5[g]	5[g]	5[g]
Zirconium	(e)	(e)	(e)	(e)

[a] Health Canada Maximum Acceptable Concentrations (MAC) (HC 1996)

[b] U.S. Environmental Protection Agency Maximum Contaminants Level for drinking water for human health (U.S. EPA 1996).

[c] British Columbia Ministry of the Environment water standards for drinking water (B.C. Contaminated Sites Regulation, 1997).

[d] Screening Level Criteria were based the lowest available criteria.

[e] No criterion.

[f] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[g] Based on an aesthetic objective for drinking water.

TABLE VI.1-37

BASELINE: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Predicted Baseline Concentrations 1997-2004[a]	RBC for [b] Water Ingestion (RBC)	Comments
	(mg/L)	(mg/L)	
ORGANICS			
Naphthenic Acids	0.5	[c]	Does not exceed.
Total Phenolics (evaluated as phenol)	0.002	0.8	Does not exceed.
INORGANICS			
Aluminum	0.58	1.37	Does not exceed.
Antimony	<0.0004	0.0006	Does not exceed.
Arsenic	0.001	0.000045	EXCEEDS
Barium	0.07	0.096	Does not exceed.
Beryllium	0.0008	0.000016	EXCEEDS
Boron	0.19	0.12	EXCEEDS
Cadmium	0.001	0.0007	Does not exceed.
Chromium	0.003	1.37	Does not exceed.
Copper	0.003	0.056	Does not exceed.
Lead	0.00005	0.0006	Does not exceed.
Manganese	0.33	0.03	EXCEEDS[d]
Mercury	<0.0002	0.004	Does not exceed.
Molybdenum	0.000005	0.01	Does not exceed.
Nickel	0.001	0.03	Does not exceed.
Selenium	0.0002	0.007	Does not exceed.
Silver	0.000006	0.19	Does not exceed.
Strontium	0.2	0.81	Does not exceed.
Vanadium	0.003	0.004	Does not exceed.
Zinc	0.03	0.41	Does not exceed.

[a] Modelled water concentrations in Shipyard Lake for 1997-2004, based on inputs from existing and approved developments (refer to Section C3 for details).

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

[c] No data or criterion.

[d] Manganese was not evaluated since it is an essential nutrient and RBC is based on aesthetic considerations

TABLE VI.1-38

BASELINE: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Baseline[a] 1997	Baseline[a] 2000-2025	Baseline[a] 2030	Baseline[a] Far Future	RBC for[b] Water Ingestion	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS						
Benzo[a]anthracene group[f]	0.0000015	0.0000044	0.0000048	0.0000048	0.00001	Does not exceed.[c]
Benzo[a]pyrene group[f]	0.00000072	0.0000014	0.0000013	0.0000006	0.000001	EXCEEDS (2000-2025, 2030)
Naphthenic Acids	0.02	0.49	0.55	0.55	[e]	No RBC
Total Phenolics (phenol)	0.002	0.002	0.002	0.002	0.8	Does not exceed.
INORGANICS						
Aluminum	0.68	0.68	0.68	0.68	1.37	Does not exceed.
Antimony	0.00001	0.00001	0.0000077	0.0000019	0.0006	Does not exceed.
Arsenic	0.0012	0.0017	0.0014	0.0013	0.000045	EXCEEDS (all)
Barium	0.07	0.07	0.07	0.07	0.096	Does not exceed.
Beryllium	0.001	0.001	0.001	0.001	0.000016	EXCEEDS (all)
Boron	0.05	0.05	0.06	0.06	0.12	Does not exceed.
Cadmium	0.001	0.001	0.001	0.001	0.0007	EXCEEDS (all)
Chromium	0.004	0.004	0.004	0.004	1.37	Does not exceed.
Copper	0.004	0.004	0.004	0.004	0.056	Does not exceed.
Lead	0.000077	0.00009	0.000073	0.000073	0.0006	Does not exceed.
Manganese	0.4	0.4	0.4	0.4	0.03	EXCEEDS (all)[d]
Mercury	0.0001	0.0001	0.0001	0.0001	0.004	Does not exceed.
Molybdenum	0.0028	0.0049	0.0049	0.0015	0.01	Does not exceed.
Nickel	0.00081	0.00055	0.00055	0.00017	0.03	Does not exceed.
Selenium	0.0002	0.0004	0.0002	0.0002	0.007	Does not exceed.
Silver	0.00001	0.00001	0.00001	0.0000046	0.19	Does not exceed.
Strontium	0.22	0.22	0.22	0.22	0.81	Does not exceed
Vanadium	0.01	0.007	0.007	0.004	0.004	EXCEEDS (2000-2025,2030)
Zinc	0.012	0.016	0.013	0.012	0.41	Does not exceed.

[a] Maximum predicted concentrations in the Athabasca River for existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10-6 (carcinogens)

[c] Although benzo(a)anthracene concentrations did not exceed the RBC for water ingestion, this group of chemicals was evaluated in the risk assessment to account for total carcinogenic risk.

[d] Manganese was not evaluated in the risk assessment, since it is an essential nutrient and the RBC is based on aesthetic considerations

[e] No data or criterion

[f] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

TABLE VI.1-39

BASELINE: COMPARISON OF CHEMICAL CONCENTRATIONS IN PLANT TISSUE TO RISK-BASED CONCENTRATIONS FOR HUMANS

Chemical	Muskeg River Mine Project Site[a] (ug/g) Max	Suncor Lease 25[b] (ug/g) Max	RBC for Plant Ingestion[c] (ug/g)	Comments
Blueberries				
Boron	7	6	6.1	EXCEEDS
Cadmium	0.09	<0.08	0.03	EXCEEDS
Copper	4.15	3.14	2.5	EXCEEDS
Lead	<0.4	0.3	0.24	EXCEEDS
Manganese	194	315	0.34	EXCEEDS[d]
Nickel	0.99	0.66	1.4	Does not exceed
Strontium	1.48	1.3	40.7	Does not exceed
Zinc	1	11	20.3	Does not exceed
Labrador Tea				
Naphthalene group	0.2	0.25	12	Does not exceed
Antimony	<0.04	0.68	0.12	EXCEEDS
Barium	120	112	21	EXCEEDS
Boron	21	25	27	Does not exceed
Cadmium	0.08	0.09	0.15	Does not exceed
Chromium	<0.5	0.4	298	Does not exceed
Cobalt	0.31	0.13	18	Does not exceed
Copper	74	23.2	11	EXCEEDS
Lead	2.9	0.8	1.1	EXCEEDS
Manganese	1070	1010	1.5	EXCEEDS[d]
Mercury	0.03	0.05	0.09	Does not exceed
Nickel	6.92	4.67	6	EXCEEDS
Strontium	8.58	19.9	179	Does not exceed
Vanadium	<0.08	0.15	2.1	Does not exceed
Zinc	54.5	34	89	Does not exceed
Cattail Root				
Aluminum	693	611	298	EXCEEDS[e]
Barium	46.9	47.3	21	EXCEEDS
Boron	29	13	27	EXCEEDS
Cadmium	0.17	0.09	0.15	Does not exceed
Chromium	1	1.2	298	Does not exceed
Cobalt	5.24	1.37	18	Does not exceed
Copper	3.36	14.4	11	EXCEEDS
Lead	1.4	2.5	1.1	EXCEEDS
Mercury	0.04	0.07	12	Does not exceed
Molybdenum	<0.4	1.7	1.5	EXCEEDS
Nickel	6.43	3.98	6	EXCEEDS
Selenium	0.2	0.7	1.5	Does not exceed
Strontium	36.4	38.5	179	Does not exceed
Vanadium	7.16	6.07	2.1	EXCEEDS
Zinc	59.2	26	89	Does not exceed

[a] Samples collected on Shell Lease 13 by Golder during 1997.

[b] Samples collected on Suncor Lease 25 within zone of potential influence from air emissions by Golder during 1997.

[c] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10-6 (carcinogens).

[d] Manganese was not evaluated in the risk assessment since it is a required nutrient.

[e] Although aluminum theoretically exceeds the RBC for plant ingestion, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

< These compounds were not detected above detection limits.

Note: Comparison of site concentrations to background concentrations was previously presented in Tables X-11 to X-13.

TABLE VI.1-40
BASELINE: COMPARISON OF GAME MEAT CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Maximum Animal Tissue Concentrations						Comments
	Vole	Mouse	Mouse	Bison	Bison	RBC [b]	
	Whole Body	Whole Body	Whole Body	Muscle	Liver		
	1987	1987	1994	1995	1995		
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
INORGANICS							
Aluminum	355.5	364.5	366	8.5	43	20.2	EXCEEDS(vole, mouse, bison liver)
Barium	22.2	24.7	17.8	0.4	2.8	1.4	EXCEEDS(vole, mouse, bison liver)
Cadmium	1.2	0.5	1.2	0.03	0.27	0.01	EXCEEDS(vole, mouse,bison)
Chromium	18	31	2.4	0.3	0.4	20.2	EXCEEDS(mouse)
Cobalt	[a]	[a]	[a]	<0.08	0.2	1.2	Does not exceed
Copper	12.5	10.5	15.1	5.4	52.4	0.81	EXCEEDS(vole, mouse, bison)
Manganese	42	22.5	16.1	0.98	12.4	0.47	EXCEEDS(vole, mouse,bison)
Nickel	[a]	[a]	2.1	0.4	1	0.40	EXCEEDS(mouse, bison liver)
Lead	3	3	5.4	<0.8	<0.8	0.07	EXCEEDS(vole, mouse)
Selenium	[a]	[a]	[a]	0.2	1	0.10	EXCEEDS(bison)
Strontium	[a]	[a]	[a]	1.6	2.3	12.1	Does not exceed
Titanium	20	8.6	6.6	0.4	1.89	[a]	Does not exceed
Vanadium	6	[a]	0.9	<0.2	<0.2	0.14	EXCEEDS(vole, mouse)
Zinc	166.5	142	118	138	121	6.1	EXCEEDS(vole , mouse, bison)

[a] No data or criterion.

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

TABLE VI.1-41

BASELINE: LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR HUMAN HEALTH

Chemical	Baseline Water Exposure	Baseline Air Exposure	Baseline Plant Exposure	Baseline Game Meat Exposure
INORGANIC CHEMICALS				
Antimony			x	
Arsenic	x			
Barium			x	x
Beryllium	x			
Boron	x			
Cadmium	x			x
Chromium				x
Copper			x	x
Lead			x	x
Molybdenum			x	
Nickel				x
Selenium				x
Vanadium	x		x	x
ORGANIC CHEMICALS				
Benzo(a)anthracene	x			
Benzo(a)pyrene	x			
Naphthenic Acids				
Aldehydes				
Ketones				
Aliphatics				
Aromatics				
Non-carcinogenic PAHs				
Formaldehyde				
Acetaldehyde				
Benzene				
Chrysene				
Benzo(b)fluoranthene				
Benzo(k)fluoranthene				
Indeno(1,2,3)pyrene				
Dibenz(a)anthracene				

TABLE VI 1-42

PROJECT IMPACTS: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2045[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Naphthenic acids	1.05	0.74	0.47	[c]	No criterion
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	[c]	No criterion
INORGANICS					
Aluminum	0.64	0.61	0.58	0.2	EXCEEDS
Ammonia	0.02	0.02	0.02	[e]	No criterion [e]
Arsenic	0.001	0.001	0.001	0.025	Does not exceed
Barium	0.08	0.07	0.06	1	Does not exceed
Beryllium	0.0009	0.0009	0.0008	0.004	Does not exceed
Boron	0.27	0.25	0.19	5	Does not exceed
Cadmium	0.001	0.001	0.001	0.005	Does not exceed
Calcium	52	51.2	50.7	[c]	No criteria [e]
Chloride	219	168.5	106	250[f]	Does not exceed
Chromium	0.004	0.003	0.003	0.05	Does not exceed
Copper	0.003	0.003	0.003	1	Does not exceed
Iron	2.8	2.6	2.5	0.3[f]	EXCEEDS [e]
Lead	0.000029	2.90E-19	5.60E-32	0.01	Does not exceed
Magnesium	15	16	15	[c]	No criterion [e]
Manganese	0.37	0.35	0.32	0.05	EXCEEDS
Mercury	0.000092	0.000085	0.000078	0.001	Does not exceed
Molybdenum	0.00045	4.50E-18	8.90E-31	0.25	Does not exceed
Nickel	0.001	0.001	0.001	0.14	Does not exceed
Selenium	0.0002	0.0002	0.0002	0.01	Does not exceed
Silver	0.00012	0.0000079	0.0000048	0.1	Does not exceed
Sodium	177	140	91	200[f]	Does not exceed
Strontium	0.4	0.3	0.2	[c]	No criterion
Sulphate	19	18	17	500[f]	Does not exceed
Vanadium	0.004	0.003	0.003	[c]	No criterion
Zinc	0.03	0.03	0.03	5	Does not exceed

[a] Modelled concentrations in Shipyard Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for human health.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI 1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

[f] Based on an aesthetic objective for drinking water.

TABLE VI.1-43

PROJECT IMPACTS: COMPARISON OF SHIPYARD LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2045[a]	Predicted Concentrations Far Future[a]	RBC for [b] Water Ingestion (RBC)	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Naphthenic Acids	1.16	0.53	0.64	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.002	0.002	0.002	0.8	Does not exceed
INORGANICS					
Aluminum	0.64	0.61	0.58	1.37	Does not exceed
Arsenic	0.001	0.001	0.001	0.000045	EXCEEDS(2005-2025,2030-2045, far future)
Barium	0.08	0.07	0.06	0.096	Does not exceed
Beryllium	0.0009	0.0009	0.0008	0.000016	EXCEEDS(2005-2025,2030-2045, far future)
Boron	0.27	0.25	0.19	0.12	EXCEEDS(2005-2025,2030-2045, far future)
Copper	0.003	0.003	0.003	0.056	Does not exceed
Lead	0.000029	2.90E-19	5.60E-32	0.0006	Does not exceed
Manganese	0.37	0.35	0.32	0.03	EXCEEDS(2005-2025,2030-2045, far future) [e]
Molybdenum	0.00045	4.50E-18	8.90E-31	0.01	Does not exceed
Nickel	0.001	0.001	0.001	0.03	Does not exceed
Selenium	0.0002	0.0002	0.0002	0.007	Does not exceed
Strontium	0.4	0.3	0.2	0.81	Does not exceed
Vanadium	0.004	0.003	0.003	0.004	EXCEEDS(2005-2025)
Zinc	0.03	0.02	0.03	0.41	Does not exceed

[a] Modelled concentrations in Shipyard Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] Manganese was not evaluated in the risk assessment, since it is an essential nutrient and the RBC is based on aesthetic considerations

TABLE 1-44

PROJECT IMPACTS: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2044[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Background Athabasca River[c]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS						
Benzo(a)anthracene group[e]	[h]	0.0000057	[h]	0.0001	<0.00004	Does not exceed
Naphthenic acids	[h]	0.57	[h]	[d]	<1	No criterion; EXCEEDS BACKGROUND
INORGANICS						
Antimony	[h]	[h]	0.0000023	0.006	0.0002	Does not exceed
Boron	[h]	0.07	[h]	5	0.09	Does not exceed.
Chloride	5.2	5.3	[h]	250[g]	14.8	Does not exceed
Lead	[h]	0.00014	0.000077	0.01	[d]	Does not exceed
Molybdenum	[h]	0.0063	0.002	0.25	0.01	Does not exceed
Nickel	[h]	[h]	0.00018	0.14	0.01	Does not exceed.
Strontium	[h]	0.23	[h]	[d]	0.36	No criterion; Does not exceed background
Sulphate	[h]	24.5	[h]	500[g]	58	Does not exceed

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for human health.

[c] Measured concentrations in the Athabasca River upstream of Lease 19 sampled by Golder in 1995 and NAQUADAT 1985-1995.

[d] No data or criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[f] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

[g] Based on an aesthetic objective for drinking water.

[h] Data not included because predicted concentrations for Project Millennium are not greater than baseline Athabasca River concentrations; chemicals not listed are not included for the same reason

< These chemicals were not detected above detection limits

TABLE VI.1-45

PROJECT IMPACTS: COMPARISON OF PREDICTED ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2044[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Ingestion (mg/L)	Comments
ORGANICS					
Benzo[a]anthracene group[f]	[h]	0.0000057	[h]	0.00001	Does not exceed[c]
Naphthenic Acids	[h]	0.57	[h]	[e]	No RBC
INORGANICS					
Antimony	[h]	[h]	0.0000023	0.0006	Does not exceed
Boron	[h]	0.07	[h]	0.12	Does not exceed
Lead	[h]	0.00014	0.000077	0.0006	Does not exceed
Molybdenum	[h]	0.0063	0.002	0.01	Does not exceed

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing and approved developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details)

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

[c] Although benzo(a)anthracene concentrations did not exceed the RBC for water ingestion, this group of chemicals was evaluated in the risk assessment to account for total carcinogenic risk.

[d] Manganese was not evaluated in the risk assessment, since it is an essential nutrient and the RBC is based on aesthetic considerations

[e] No data or criterion

[f] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[g] Data not included because predicted concentrations for Project Millennium are not greater than baseline Athabasca River concentrations; chemicals not listed are not included for the same reason

TABLE 46

PROJECT IMPACTS: COMPARISON OF END PIT LAKE CONCENTRATIONS TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2045[a]	Predicted Concentrations 2052[a]	Predicted Concentrations Far Future[a] 2130	Screening Level Criteria[b]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Benzo(a)anthracene group[d]	0.00016	0.000099	4.00E-18	0.0001	EXCEEDS
Benzo(a)pyrene group[d]	0.000035	0.000024	1.84E-22	0.00001	EXCEEDS
Naphthenic acids	2.6	2.5	0.07	[c]	No criterion
Total Phenolics (evaluated as phenol)	0.0091	0.0087	0.0027	[c]	No criterion
INORGANICS					
Aluminum	1.3	1.2	0.4	0.2	EXCEEDS
Ammonia	0.14	0.14	0.0073	[c]	No criterion [e]
Antimony	0.0009	0.0009	0.0001	0.006	Does not exceed
Arsenic	0.0044	0.0041	0.001	0.025	Does not exceed
Barium	0.115	0.109	0.05	1	Does not exceed
Beryllium	0.0035	0.0033	0.00052	0.004	Does not exceed
Boron	2.34	2.17	0.45	5	Does not exceed
Cadmium	0.0042	0.0039	0.0007	0.005	Does not exceed
Calcium	105	103	60	[c]	No criterion [e]
Chloride	41	39	13.7	250[f]	Does not exceed
Chromium	0.012	0.012	0.0016	0.05	Does not exceed
Copper	0.013	0.013	0.0038	1	Does not exceed
Iron	1.22	1.15	0.94	0.3[f]	EXCEEDS [e]
Lead	0.01	0.01	0.0013	0.01	Does not exceed
Magnesium	21.1	20.9	15	[c]	No criterion [e]
Manganese	0.079	0.074	0.064	0.05	EXCEEDS
Mercury	0.000026	0.000025	0.0000033	0.001	Does not exceed
Molybdenum	0.74	0.71	0.095	0.25	EXCEEDS
Nickel	0.015	0.015	0.002	0.14	Does not exceed
Selenium	0.0019	0.0018	0.0003	0.01	Does not exceed
Silver	0.001	0.001	0.00013	0.1	Does not exceed
Sodium	332	307	67.5	200[f]	EXCEEDS [e]
Strontium	1.19	1.14	0.3	[c]	No criterion
Sulphate	670	641	94	500[f]	EXCEEDS [e]
Vanadium	0.09	0.086	0.012	[c]	No criterion
Zinc	0.05	0.05	0.04	5	Does not exceed

[a] Modelled concentrations in End Pit Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for human health.

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

[f] Based on an aesthetic objective for drinking water.

TABLE VI.1-47
PROJECT IMPACTS: COMPARISON OF END PIT LAKE CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Page 1 of 1

Chemical	Predicted Concentrations 2045[a]	Predicted Concentrations 2052[a]	Predicted Concentrations Far Future[a]	RBC for[b] Water Ingestion (RBC)	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS					
Benzo[a]anthracene group[d]	0.00016	0.000099	4.00E-18	0.00001	EXCEEDS(2045, 2052)
Benzo[a]pyrene group[d]	0.000035	0.000024	1.84E-22	0.000001	EXCEEDS(2045, 2052)
Naphthenic Acids	2.6	2.5	0.07	[c]	No RBC
Total Phenolics (evaluated as phenol)	0.0091	0.0087	0.0027	0.8	Does not exceed
INORGANICS					
Aluminum	1.3	1.2	0.4	1.37	Does not exceed
Antimony	0.0009	0.0009	0.0001	0.0006	EXCEEDS(2045, 2052)
Arsenic	0.0044	0.0041	0.001	0.000045	EXCEEDS(2045, 2052, far future)
Barium	0.115	0.109	0.05	0.096	EXCEEDS(2045, 2052)
Beryllium	0.0035	0.0033	0.00052	0.000016	EXCEEDS(2045, 2052, far future)
Boron	2.34	2.17	0.45	0.12	EXCEEDS(2045, 2052, far future)
Copper	0.013	0.013	0.0038	0.056	Does not exceed
Lead	0.01	0.01	0.0013	0.0006	EXCEEDS(2045, 2052, far future)
Manganese	0.079	0.074	0.064	0.03	EXCEEDS(2045, 2052, far future)
Molybdenum	0.74	0.71	0.095	0.01	EXCEEDS(2045, 2052, far future)
Nickel	0.015	0.015	0.002	0.03	Does not exceed
Selenium	0.0019	0.0018	0.0003	0.007	Does not exceed
Strontium	1.19345	1.14324	0.29730	0.81	EXCEEDS(2045, 2052)
Vanadium	0.09	0.086	0.012	0.004	EXCEEDS(2045, 2052, far future)
Zinc	0.05	0.05	0.04	0.41	Does not exceed

[a] Modelled concentrations in End Pit Lake based on inputs from Project Millennium plus existing and approved developments (refer to Section C3 for details).

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[e] Manganese was not evaluated in the risk assessment, since it is an essential nutrient and the RBC is based on aesthetic considerations

TABLE VI.1-48
PROJECT IMPACTS: COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Muskeg River[a] Longnose Sucker (ug/g) Max	Athabasca River[a] Walleye (ug/g) Max	Athabasca River[a] Goldeye (ug/g) Max	TID Exposed[b] Walleye (ug/g) Max - Lab	Refinery Effluent[b] Exposed Trout (ug/g) Max-Lab	RBC for[c] Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS							
Naphthalene group[d]	0.09	<0.02	<0.02	<0.02	<0.02	2	Does not exceed
INORGANICS							
Copper	<1	1	2	<1	1.06	2	Does not exceed
Chromium	<0.5	<0.5	<0.5	<0.5	0.7	52	Does not exceed
Lead	<2	<2	<2	<5	0.22	1.2	Does not exceed
Manganese	0.9	1.2	<0.5	6.1	0.33	1	EXCEEDS[f]
Nickel	<1	<1	2	<2	0.15	1	EXCEEDS[f]
Silver	<0.2	<0.2	<0.2	<1	1.49	1.7	Does not exceed
Tin	<2	<2	<2	<5	1.54	30	Does not exceed
Vanadium	<1	<1	<1	<1	0.19	0.35	Does not exceed
Zinc	6	9	6	17.5	18.6	15	EXCEEDS[e]

[a] Data from fish sampled by Golder during 1995 (Golder 1996b).

[b] Data from fish exposed to Tar Island Dyke Water (10%) or Refinery Effluent in laboratory (HydroQual 1996a,b).

[c] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens).

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VIII-1.

[e] These compounds were not evaluated in the risk assessment since they are required nutrients and do not exceed the RBC by more than 10-fold.

[f] Nickel was not evaluated in the risk assessment for HH-1 since it was only detected in one fish sample at a concentration exceeding marginally exceeding the RBC; it was evaluated in HH-4 (combined exposure scenario).

< These chemicals were not detected above detection limits.

Note: Comparison of site concentrations to background concentrations was previously presented in Table VI.1-24.

TABLE VI.1-49

RECLAMATION: COMPARISON OF ESTIMATED CHEMICAL CONCENTRATIONS IN PLANTS GROWING ON RECLAMATION SOILS TO RISK-BASED CONCENTRATIONS (RBCs) FOR HUMAN HEALTH

Chemicals	Estimated Plant Concentrations [a] (mg/kg plant)	RBC for Plant Ingestion[b] (mg/kg plant)	Comments
ORGANICS			
Benzo(a)anthracene group[c]	0	0.0005	EXCEEDS
Benzo(a)pyrene group[c]	0	0.00005	EXCEEDS
Benzo(b&k)fluoranthene group[c]	0	0.0005	Does not exceed
Fluoranthene group[c]	0	0.19	Does not exceed
Phenanthrene group[c]	0	0.14	Does not exceed
Pyrene	0	0.14	Does not exceed
INORGANICS			
Aluminum	388.7	169.46	EXCEEDS[e]
Arsenic	0.06	0.01	EXCEEDS
Barium	17.4	11.86	EXCEEDS
Beryllium	0.02	0.0036	EXCEEDS
Boron	49.8	15.25	EXCEEDS
Cadmium	0.35	0.08	EXCEEDS
Cobalt	2.3	10.17	Does not exceed
Chromium	0.85	169.46	Does not exceed
Copper	3	6.29	Does not exceed
Lead	0.23	0.6	Does not exceed
Mercury	0.015	0.05	Does not exceed
Molybdenum	0.79	0.85	Does not exceed
Nickel	2.8	3.39	Does not exceed
Selenium	0.11	0.85	Does not exceed
Strontium	37	101.68	Does not exceed
Vanadium	1.7	1.19	EXCEEDS
Zinc	58.3	50.84	EXCEEDS[f]

[a] Estimated PAH concentrations in plants based on tailings sand (Suncor Beach; CP5) data as reported by ETL (1993, n=1);
For metals, geometric mean of measured concentrations in plants grown on CT capped with sand and muskeg (Xu 1997).

[b] Risk-based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens).

[c] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table H12-32.

[d] No data or criterion available

[e] Although aluminum theoretically exceeds the RBCs for some species, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore

[f] Zinc was not evaluated in the risk assessment, since it is required element for human nutrition.

TABLE VI.1-50

CEA: COMPARISON OF ATHABASCA RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Chemical	Predicted Concentrations 2005-2025[a]	Predicted Concentrations 2030-2044[a]	Predicted Concentrations Far Future[a]	Screening Level Criteria[b]	Background Athabasca River[c]	Comments
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
ORGANICS						
Benzo(a)anthracene group[e]	(g)	0.0000066	0.0000057	0.0001	<0.00004	Does not exceed
Benzo(a)pyrene group[e]	(g)	0.00000089	0.00000068	0.00001	<0.00004	Does not exceed
INORGANICS						
Antimony	(g)	0.00002	(g)	0.006	0.0002	Does not exceed
Arsenic	(g)	0.0015	(g)	0.025	0.007	Does not exceed.
Boron	(g)	0.09	(g)	5	0.09	Does not exceed.
Calcium	(g)	33.2	(g)	(e)	74	No criterion; Does not exceed background
Lead	0.000092	0.00026	0.000084	0.01	(d)	Does not exceed
Magnesium	(g)	8.2	(g)	(e)	21	No criterion; Does not exceed background
Molybdenum	(g)	0.013	(g)	0.25	0.01	Does not exceed
Selenium	(g)	0.0003	(g)	0.01	0.0004	Does not exceed.
Silver	(g)	0.000021	(g)	0.1	0.0003	Does not exceed
Sodium	(g)	18.1	12.7	200[f]	24.6	Does not exceed
Sulphate	(g)	27.1	(g)	500[f]	58	Does not exceed.
Zinc	(g)	0.014	(g)	5	0.085	Does not exceed.

[a] Predicted concentrations in the Athabasca River based on inputs from Project Millennium plus existing, approved and planned developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details).

[b] Screening level criteria were based on the lowest water quality criteria for human health.

[c] Measured concentrations in the Athabasca River upstream of Lease 19 sampled by Golder in 1995 and NAQUADAT 1985-1995.

[d] No data or criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[f] Based on an aesthetic objective for drinking water.

[g] Data not included because values are not greater than predicted concentrations from Project Millennium plus existing and approved developments

< These chemicals were not detected above detection limits

TABLE VI.1-51

CEA: COMPARISON OF PREDICTED ATHABASCA RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Predicted Concentrations 2005-2025[a] (mg/L)	Predicted Concentrations 2030-2044[a] (mg/L)	Predicted Concentrations Far Future[a] (mg/L)	RBC for[b] Water Ingestion (mg/L)	Comments
ORGANICS					
Benzo[a]anthracene group[c]	[d]	0.0000066	0.0000057	0.00001	Does not exceed
Benzo[a]pyrene group[c]	[d]	0.00000089	0.00000068	0.000001	Does not exceed
INORGANICS					
Antimony	[d]	0.00002	[d]	0.0006	Does not exceed
Arsenic	[d]	0.0015	[d]	0.000045	EXCEEDS(2030-2044)
Boron	[d]	0.09	[d]	0.12	Does not exceed
Lead	0.000092	0.00026	0.000084	0.0006	Does not exceed
Molybdenum	[d]	0.013	[d]	0.01	EXCEEDS(2030-2044)
Selenium	[d]	0.0003	[d]	0.007	Does not exceed
Zinc	[d]	0.014	[d]	0.41	Does not exceed

[a] Predicted concentrations in the Athabasca River for Project Millennium plus existing, approved and planned developments; mean open water flow conditions at 10% mixing zone boundaries (refer to Section C3 for details)

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens)

[c] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table VI.1-1.

[d] Data not included because values are less than predicted concentrations from Project Millennium plus existing and approved developments

TABLE VI.1-52

PROJECT IMPACTS AND CEA: LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR HUMAN HEALTH

Chemical	HH-1 Water Exposure (Operation)	HH-2 Air Exposure (Operation)	HH-3 Plant/Meat Exposure (Operation)	HH-4 Combined Exposure (Operation)	HH-5 Reclaimed Landscape Exposure (Part A)	HH-5 Reclaimed Landscape Exposure (Part B)	CEA Water Exposure (Operation and Closure)
INORGANIC CHEMICALS							
Arsenic	x			x	x	x	x
Barium				x	x	x	
Beryllium	x			x	x	x	
Boron	x			x	x	x	
Cadmium						x	
Chromium						x	
Copper						x	
Lead				x	x	x	
Molybdenum				x	x	x	x
Selenium						x	
Strontium				x	x	x	
Vanadium	x			x	x	x	
ORGANIC CHEMICALS							
Benzo(a)anthracene	x			x	x	x	
Benzo(a)pyrene	x			x	x	x	
Naphthenic Acids							
Aldehydes							
Ketones							
Aliphatics							
Aromatics							
Non-carcinogenic PAHs							
Formaldehyde							
Acetaldehyde							
Benzene							
Chrysene							
Benzo(b)fluoranthene							
Benzo(k)fluoranthene							
Indeno(1,2,3)pyrene							
Dibenz(a)anthracene							

VI.2 RECEPTOR SCREENING

VI.2 RECEPTOR SCREENING

Details of the receptor screening process are described below for each key question.

VI.2.1 Receptor Screening for Wildlife Health

The reclaimed site must, according to government regulations (AEP 1995b), develop into a normal, healthy ecosystem. In addition, exposure to chemicals associated with the site must not lead to unacceptable impacts in organisms supported by the ecosystem. It is, therefore, necessary to assess potential impacts for all major trophic levels. It is of course, impossible, and not necessary, to examine potential effects on every organism that might be exposed to chemicals associated with the site. Instead, representative species (or receptors) were selected as the basis for evaluating potential impacts.

The objective of wildlife receptor screening was to: i) identify wildlife that might currently use the local water bodies; ii) identify herbivores that might forage near the Project Millennium site during operation; iii) identify wildlife that might inhabit the reclaimed landscape; and iv) to focus the assessment on a manageable number of key receptors. Receptors were selected based on a wildlife inventory of the area, discussions with wildlife biologists conducting baseline studies, and guidance from the literature (Algeo et al. 1994; Suter 1993). The overall emphasis of the ecological receptor screening was the selection of representative receptors that would be at greatest risk, that play a key role in the food web, and that have sufficient characterization data to facilitate calculations of exposure and health risks. Receptors were also selected to include animals that have societal relevance and that are a food source for people. Wildlife species determined to be KIRs for the Project Millennium EIA were also given extra weight in the evaluation. To be consistent, the wildlife receptors chosen in this assessment are the same as those evaluated in previous environmental impact assessments for the Aurora Mine (BOVAR 1996e), Steepbank Mine (Golder 1996d,r) and the Muskeg River Mine Project (Shell Canada Ltd. 1998).

A different set of wildlife receptors were selected for evaluation of each key question, based on maximum likely exposure to the media being evaluated.

W-2: Operational Exposure

For key question W-2, aquatic wildlife (i.e., water shrew, killdeer, river otter, great blue heron) were chosen to represent various trophic levels of receptors likely to use the Athabasca River, McLean Creek and/or Shipyard Lake as a source of drinking water and food (i.e., invertebrates and fish). Insectivores were considered important as PAHs may accumulate

in some invertebrate prey. Fish-eating predators also were included to assess the potential for food chain effects.

Herbivorous or omnivorous wildlife species were also selected, since these species would incur the maximum exposures through consumption of plants. The selected receptors included moose, snowshoe hare, black bear, ruffed grouse and mallards. Snowshoe hare, black bear and ruffed grouse would be exposed to terrestrial plants, mallards would be exposed to aquatic plants, and moose would be exposed to both terrestrial and aquatic plants. All of these animals would also consume drinking water from local sources.

Finally, the red-tailed hawk was selected as a predator species for evaluation of consumption of voles and deer mice.

W-3: Reclaimed Landscape Exposure

For key question W-3, birds and mammals which may inhabit the reclaimed landscape were selected. Herbivores were selected as important receptors since metals can potentially accumulate in some plant tissues, and insectivores were considered important since PAHs may accumulate in some invertebrate prey. Some of these species (i.e., moose, snowshoe hare, ruffed grouse) are also important game animals. Predators also were considered to assess the potential for food chain effects. However, most of the chemicals identified in the screening process do not have the potential to significantly biomagnify through food chains. Furthermore, exposures on the reclaimed landscape are not expected to be significantly different than exposures in areas near the oil sands facilities during operation, and risk assessment predictions for red-tailed hawks from consumption of mice and voles (collected from areas near operating oil sands facilities) indicated no unacceptable risks. For these reasons, predator wildlife species were not selected as receptors for the reclaimed landscape scenario. Wildlife receptors evaluated in the reclamation scenario included:

Mammalian Receptors

- beaver (semi-aquatic herbivore)
- moose (large herbivore)
- snowshoe hare (small terrestrial herbivore)
- deer mouse (small terrestrial omnivore)

Avian Receptors

- mallard (semi-aquatic omnivore)
- ruffed grouse (terrestrial herbivore)

VI.2.2 Receptor Screening for Human Health

HH-1: Water-Mediated Exposure (Operation)

During operation of Project Millennium, human use of the land will be restricted to workers. However, it is reasonable to assume that the Athabasca River and Shipyard Lake could be used by members of the Fort McKay First Nations community and others for activities such as swimming, hiking, fishing and boating. Hence, the assessment of potential impacts on human health focused on: i) swimming and ii) recreational use. The swimming scenario addresses chemical intake via dermal exposure and incidental ingestion that would occur while swimming (or using the water for washing and/or bathing). The recreational scenario addresses occasional use of river water as a drinking water source, such as might occur during recreational activities. Both children and adults may take part in these activities.

HH-2: Air-Mediated Exposure (Operation)

Adults and children may be exposed to air emissions from the Project that may be dispersed by winds to nearby residential communities, such as Fort McKay, Fort McMurray and Fort Chipewyan. In addition, an adult worker-resident receptor was evaluated, who was assumed to work on the Project site for 8 hours per day and to reside in the closest residential community.

HH-3: Plant- and Game-Mediated Exposure (Operation)

First Nations communities harvest many local nutritional (e.g., berries, Labrador tea, cattail root) and medicinal plants (e.g., ratroot), and hunt many types of game animals (including moose, hare, grouse, ducks). Both children and adults may consume these plants and animals and therefore both of these lifestages were evaluated for this key question.

HH-4: Water-, Air-, Plant- and Game-Mediated Exposure(Operation)

Child, adult and composite receptors were evaluated for this key question to determine the potential risks from combined exposure to various potentially affected media.

HH-5: Multi-Media Exposure on Reclaimed Landscape (Closure)

Due to the close proximity of the Project to Fort McKay, it is reasonable to assume that following reclamation, the site might be used by members of the Fort McKay First Nations for traditional activities, including hunting, trapping and gathering. Although all ages of people might utilize these lands, the most extensive uses would be from adults

who might live on the land for extended periods of time while hunting and trapping. Therefore, the human receptors evaluated in this assessment were assumed to be adult hunters and trappers, who might reside on-site throughout the year. In addition, a child receptor was evaluated, since it was assumed the hunter/trapper would bring plants and game meat back to feed his family. Children and adults were also identified for recreational exposures at closure and in the far future.

Lifestages Evaluated

Potential health impacts on children and adults were evaluated. Health Canada (1994) defines five distinct life stages for the purpose of risk assessment. In conformance with this guidance, adults are defined as 20 years of age and older (up to a lifespan of 70 years). For all exposures, except air inhalation, children were defined as between the ages of 7 months and 4 years (i.e., "pre-school children" as defined in guidance), since the exposure parameters for this lifestage maximize exposures due to ingestion of food and water (i.e., maximum ingestion rate to body weight ratio). For air inhalation, children were defined as between the ages of 5 and 11 years, since the ratio of inhalation rate to body weight is maximized for this lifestage. For these reasons, the predicted exposures for children were conservatively maximized in the risk assessment.

Senior citizens were also considered as potential receptors for the risk assessment due to concerns expressed at the Human and Ecological Health Component Focus Workshop (October 30, 1997). For the reasons outlined in Section F1.1.4.3 of the main text, it was concluded that results for the adult receptor (age 20+) would also apply to seniors (age 60+) and therefore a separate senior receptor was not evaluated.

Since development of cancer may be a long-term process, it is best to evaluate carcinogenic effects which may over the total lifespan of a receptor, rather than considering effects only for a certain phase of life (e.g., childhood). Thus, for carcinogenic chemicals, a so-called "composite receptor" was evaluated from birth until 70 years of age to address the residual risk from non-threshold substances after cessation of exposure.

Gender Issues

Receptor parameters used in this assessment were obtained from Health Canada (1994) and are representative of average Canadians, regardless of gender. In risk assessment, it is generally thought that female receptors may be more sensitive to chemical exposures due to their higher chemical intake on a body weight basis, in comparison to male receptors of the same age group. In a recent review of Canadian human exposure parameters, no gender-specific differences in body weights were evident in children, but body weights of female adults were on average lower than males. In addition, closer scrutiny of the exposure parameters for female child and

adult receptors, as reported in Richardson (1997), revealed that intake rates for females were significantly lower than those recommended by Health Canada (1994), which would result in overall lower exposure estimates for females if these receptor parameters were used. Therefore, the Health Canada (1994) receptor parameters were chosen as the most conservative exposure parameters to use in this assessment.

VI.3 EXPOSURE PATHWAY SCREENING

VI.3 EXPOSURE PATHWAY SCREENING

The objective of screening exposure pathways is to: i) identify potential routes through which people and wildlife could be exposed to chemicals and, ii) determine the relative significance or importance of operable exposure pathways. A chemical represents a potential health risk only if it can reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a chemical to reach a receptor, there can be no risk, regardless of the source concentration. The goal of this task is to identify all possible exposure pathways and then to evaluate which pathways are likely to be realistic and applicable to the site under investigation.

VI.3.1 Exposure Pathway Screening for Wildlife Health

W-2: Operational Exposure

Ingestion of surface water - Wildlife may be exposed to water releases from the Project by ingesting surface water as a drinking water source. Thus, this exposure pathway was retained for further evaluation in the risk assessment for key question W-2.

Ingestion of fish and/or aquatic invertebrates - Water releases from the Project may contribute to increased concentrations of metals and organic chemicals in the tissues of fish and aquatic invertebrates. Since a large part of the diet of aquatic wildlife (e.g., water shrew, river otter, great blue heron) consists of fish and/or aquatic invertebrates, this exposure was retained for further evaluation in the risk assessment for key question W-2.

Direct contact with surface water - Although wildlife may be exposed by directly contacting surface water, birds and fur-bearing mammals likely receive insignificant doses through this route relative to other routes, such as direct ingestion of water (Environment Canada 1994). Therefore, this pathway was excluded from further consideration.

Inhalation of air - Animals may be exposed to chemicals in air emissions via inhalation. Inhalation of air was considered to be a minor exposure pathway for wildlife in comparison to the exposures incurred from ingestion of plants, fish, invertebrates and/or water. Furthermore, indirect exposure to air emissions via consumption of plants growing in areas within the zone of potential influence of air emissions from existing facilities was considered. The results of an animal tissue sampling program conducted in 1994 also suggest that ingestion is the primary exposure pathway for animals in the oil sands area (Conor Pacific Environmental Technologies 1998a Draft; refer to Section F1.2.5 for further details of the study). Therefore, air inhalation was not retained as an exposure pathway for the risk assessment of key question W-2.

Ingestion of plants - Air emissions from the Project may deposit directly onto plant surfaces and they may deposit onto soils and be taken up by plant roots. Herbivorous wildlife could be exposed by consuming the plants. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-2.

W-3: Reclaimed Landscape Exposure

Inhalation of volatile chemicals - Volatilization of VOCs from surface water and soils into the air can result in direct exposure to wildlife, especially soil dwelling and burrowing insects and mammals, through inhalation of vapours. However, this pathway was not evaluated since it was considered to be a minor exposure pathway for wildlife and concentrations of volatile chemicals are expected to decrease over time.

Inhalation of fugitive dust generated from surface soils - Fugitive dust generated from surface soils can result in exposure to wildlife through inhalation of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because CT deposits will be capped with sand and muskeg so erodible chemical concentrations of soils will be comparable to natural background levels and landscapes will also be covered with vegetation; thereby further reducing potential for dust generation. Therefore, this exposure pathway was excluded from further evaluation.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to wildlife through dermal uptake of chemicals present in air vapours. However, dermal uptake of volatile chemicals is not expected to contribute significantly to exposure of wildlife, and was therefore excluded from further analysis.

Direct contact with soils - Digging and fugitive dust generation can result in exposure to wildlife through dermal contact with soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent direct contact with CT deposits. In addition, dermal exposure of birds and furbearing mammals is generally considered an insignificant exposure pathway, except directly after pesticide spraying (Environment Canada 1994). Therefore, this exposure pathway was excluded from further consideration.

Direct contact with surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Although wildlife could be exposed by directly contacting surface water, birds and fur-bearing mammals likely receive insignificant doses through this route relative to other routes, such as direct ingestion of water (Environment Canada 1994). Therefore, this pathway was excluded from further consideration.

Ingestion of fugitive dust - Fugitive dust generated from surface soils can result in exposure to wildlife through ingestion of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent dust arising from wind-based erosion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Wildlife could be exposed by drinking surface water. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-3.

Ingestion of soils/sediment - Digging and fugitive dust generation can result in exposure to wildlife through incidental ingestion of soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent ingestion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of plants - Plants that are growing on reclaimed surfaces may accumulate metals and organic compounds in their tissue. Herbivorous wildlife could be exposed by consuming the plants. Since large areas of reclaimed landscape are to be constructed, ingestion of plants is a potential exposure pathway for wildlife. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-3.

Ingestion of animals - Carnivorous and omnivorous animals have the potential to accumulate some metals and organic compounds in tissue from their prey. Although consumption of prey is a potential exposure pathway for wildlife, none of the chemicals of concern identified during chemical screening are expected to bioaccumulate through the food chain. For this reason, ingestion of animals was not considered further in the risk assessment for key question W-3.

VI.3.2 Exposure Pathway Screening for Human Health

HH-1: Water-Mediated Exposure (Operation)

Ingestion of surface water - As identified during the chemical screening, several chemicals that are of potential concern will be released during operation. People could be exposed by ingesting surface water intentionally or through incidental ingestion while swimming.

Ingestion of fish - The chemical screening showed no evidence that exposure to operational or reclamation waters from the Project results in accumulation of chemicals to levels above background. Thus, this exposure pathway was not considered further in the risk assessment for key question HH-1.

Direct contact with surface water - People can be exposed to chemicals released from the Project through direct contact with surface water while swimming. Although the contribution of dermal exposure to chemicals in surface water is expected to be small relative to ingestion exposure, this pathway was retained for further analysis to confirm this assumption.

HH-2: Air-Mediated Exposure (Operation)

Inhalation of volatile chemicals - Volatilization of volatile organic compounds (VOCs) from tailings ponds, mine surfaces and stack amd fugitive emissions can result in direct exposure to people through inhalation. Depending on the airborne concentrations of these chemicals, exposures may be incurred both on-site (i.e., by a worker) or off-site (i.e., by local residents in nearby communities). Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of diesel emissions - The vehicle fleet for Project Millennium will release a large quantity of diesel exhaust during the construction and operation phases of the Project. People may be exposed to PAHs and VOCs from diesel emissions both on-site (i.e., by a worker) or off-site (i.e., by local residents in nearby communities). Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of particulates - Particulates will be released from stack sources and the vehicle fleet. Workers and off-site residents may directly inhale these particulates. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of acid gases - Project activities are expected to release acid gases (e.g., SO_2, NO_x) into the air. Both workers and off-site residents may

be exposed directly to these gases through inhalation. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to people through dermal uptake of chemicals present in air vapours. However, the contribution by this pathway, in comparison to direct inhalation was assumed to be insignificant and therefore this exposure pathway was not considered further in the risk assessment for key question HH-2.

HH-3: Plant- and Game-Mediated Exposure (Operation)

Ingestion of local plants - Certain local plants (i.e., berries, leaves and cattail/ratroot) are harvested and consumed on a regular basis by members of nearby residential communities. Some of these plants are ingested for their medicinal properties, while others are ingested for nutritional purposes. Air emissions from the Project may deposit directly onto plant surfaces and they may deposit on soils and be taken up by plant roots. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-3.

Ingestion of local game animals - Certain local game animals (i.e., moose, hare, grouse, ducks) are hunted and consumed on a regular basis by members of nearby residential communities. Animals living near the site may be exposed to chemicals via air and water emissions and consumption of plants. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-3.

HH-4: Water-, Air-, Plant- and Game-Mediated Exposure (Operation)

All exposure pathways identified for HH-1, HH-2 and HH-3 were retained for evaluation of key question HH-4. In addition, ingestion of fish was included as an exposure pathway to evaluate the combined contribution from various media.

HH-5: Multi-Media Exposure on Reclaimed Landscape (Closure)

Volatile Chemicals - Volatilization of VOCs from surface water and soils into the air can result in direct exposure to people, particularly to those that might live on the reclaimed site following reclamation, through inhalation of vapours. However, disturbed areas of the site will be capped with a layer of reconstructed soils, reducing the potential for volatile air releases. Currently, there are no data available to estimate the airborne chemical concentrations likely to be present above capped CT deposits. However, these releases will decrease over time as the CT consolidates. Therefore,

this exposure pathway was not considered further in the risk assessment for HH-5.

Fugitive dust generation from surface soils - Fugitive dust generated from surface soils can result in exposure to people through inhalation of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because CT deposits will be capped with sand and muskeg so erodible chemical concentrations of soils will be comparable to natural background levels and landscapes will also be covered with vegetation; thereby further reducing potential for dust generation. Therefore, this exposure pathway was not considered further in the risk assessment for HH-5.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to people through dermal uptake of chemicals present in air vapours. However, dermal uptake of volatile chemicals is not expected to contribute significantly to exposure of people, and was therefore excluded from further analysis.

Direct contact with soils - Digging and fugitive dust generation can result in exposure to people through dermal contact with soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent direct contact with CT deposits.

Direct contact with surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). People could be exposed by directly contacting surface water while swimming or bathing. Although the contribution of dermal exposure to chemicals in surface water is expected to be small relative to ingestion exposure, this pathway was evaluated in the assessment for key question HH-5.

Ingestion of fugitive dust - Fugitive dust generated from surface soils can result in exposure to people through ingestion of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent dust arising from wind-based erosion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Hunters/trappers could be exposed by ingesting surface water intentionally or through incidental ingestion while swimming. Since large volumes of water are associated with CT reclamation units, drinking surface water is a potential exposure

pathway for people. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-5.

Ingestion of soils/sediment - Digging and fugitive dust generation can result in exposure to people through incidental ingestion of soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent ingestion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of plants - Plants that are growing on reclaimed surfaces may accumulate metals and organic compounds in their tissue. Hunters/trappers could be exposed by consuming these plants while they are living on the reclaimed landscape. Children may also be exposed if these plants are harvested and brought back to feed the family. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-5.

Ingestion of game animals - Game animals living and feeding in the reclaimed landscape may accumulate metals and organic compounds in their tissues. Hunters/trappers may be exposed to these compounds through ingestion of game meat. Children may also be exposed if game meat is brought back to feed the family. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-5.

VI.4 EXPOSURE ASSESSMENT EQUATIONS AND PARAMETERS

VI.4 EXPOSURE ASSESSMENT EQUATIONS AND PARAMETERS

Exposure equations used for the wildlife and human health exposure assessments are presented in Table VI.4-1, with the exception of equations used for wildlife health key question W-3 (reclaimed landscape exposure). The specific methodology used for key question W-3 is presented in Section VI.4.1.

Table VI.4-1 Wildlife and Human Exposure Assessment Equations

Pathway	Equation and Equation Parameters
Water Ingestion (W-2; W-3; HH-1; HH-4; HH-5)	$\mathrm{EDI}_{water} = \frac{IR \times BA \times C_{water} \times ET \times EF \times ED}{BW \times AT}$
	EDI_{water} = incidental water consumption while swimming (mg chemical/kg body weight/day) IR = ingestion rate (L/hour) BA = oral bioavailability of compound (chemical-specific, unitless) C_{water} = chemical concentration in water (mg/L) ET = time of exposure (hr/event) EF = frequency of exposure (events/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)
Dermal Exposure (HH-1; HH-4; HH-5)	$\mathrm{EDI}_{dermal} = \frac{SA \times C_{water} \times Kp \times ET \times EF \times ED \times 10^3\ \mathrm{L/m^3}}{BW \times AT}$
	EDI_{dermal} = estimated daily intake from dermal contact while swimming (mg chemical/kg body weight/day) SA = surface area available for contact while swimming (m^2) C_{water} = chemical concentration in water (mg/L) K_p = permeability constant in water (chemical-specific; m/hr) ET = total time of exposure event (hr/event) EF = frequency of exposure events (events/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens,70 years for carcinogens)

Table VI.4-1 Wildlife and Human Exposure Assessment Equations (continued)

Pathway	Equation and Equation Parameters
Air Inhalation (HH-2; HH-4)	$\mathrm{EDI}_{air} = \frac{IR \times BA \times C_{air} \times EF \times ED}{BW \times AT}$
	EDI_{air} = estimated daily intake from air (mg chemical/kg body weight/day) IR = inhalation rate (m^3/hour) BA = inhalation bioavailability of compound (chemical-specific, unitless) C_{air} = chemical concentration in air (mg/m^3) ET = time of exposure (hr/day) EF = frequency of exposure (days/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)
Food Ingestion (i.e., fish, meat, plants, invertebrates) (W-2, W-3, HH-3, HH-4, HH-5)	$\mathrm{EDI}_{food} = \frac{IR \times BA \times C_{food} \times EF \times ED \times SC}{BW \times AT}$
	EDI_{food} = estimated daily intake from food ingestion (mg chemical/kg body weight/day) IR = ingestion rate (kg/day) BA = oral bioavailability of compound (chemical-specific, unitless) C_{food} = chemical concentration in food (mg/kg) EF = frequency of exposure (days/year) ED = duration of exposure (days) SC = site contribution BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)

VI.4.1 Reclaimed Landscape Wildlife Model (W-3)

As discussed previously, the assessment endpoint for the assessment of wildlife health impacts is the protection of wildlife populations. An exposure model was therefore developed to assess the potential for population level effects to terrestrial wildlife exposed to chemicals associated with the reclaimed landscape (W-3). The model incorporates information on the spatial distribution of chemicals within the landscape as well as foraging and movement of the wildlife species. For this model, a wildlife species population was defined as the hypothetical population foraging within the boundaries of the LSA, which includes both reclaimed areas and natural areas. Although the foraging ranges for some wildlife species may extend beyond the LSA boundaries, it was conservatively assumed that all foraging would take place within this area.

Exposure pathways include ingestion of six food and water types that may be present within fifty-seven different ELCs associated with the reclaimed landscape. Each ELC may contain up to three different soil types (6×57×3=1026 possible exposure sources). Depending upon the receptor's, dietary requirements, exposure may occur due to ingestion of water, invertebrates (aquatic or terrestrial) and/or plants (aquatic or terrestrial) growing within the LSA, either on reclaimed areas or natural areas. The amount consumed by a given receptor was determined by ingestion rates and foraging ranges of each species, which were assigned a probabilistic distribution following a literature review (refer to wildlife receptor parameters in the following section). It was assumed that each species would move randomly among the preferred habitat types.

The wildlife exposure model predicted chemical concentrations in food (plants, invertebrates and water) expected for the reclaimed landscape and for natural areas within the LSA. The model then computed a dose by randomly selecting foraging areas for each wildlife species according to foraging preferences and areas for each species. By repeating this exposure calculation many times, an estimate of the dose distribution that might be expected for the regional population was determined.

Daily intake rates were estimated for water, plants and prey (mg chemical per kg-body weight per day) according to (EDI_{water}, EDI_{plant}, and EDI_{prey}, respectively):

$$EDI_{water} = \frac{R_{water} C_{water} f}{BW}$$

$$EDI_{plant} = \frac{R_{plant} C_{plant} f}{BW}$$

$$EDI_{prey} = \frac{R_{prey} C_{prey} f}{BW}$$

where:

R = ingestion rates of soil, water, plants and prey (kg dry weight per day, except water, L per day)

f = fraction of food, water and soil derived from the site (receptor specific; unitless)

C = chemical concentration in water, plants and prey (mg/kg in plants and prey, mg/L in water)

BW = receptor body weight (receptor specific; kg)

Because of the uncertainties associated with wildlife parameter estimates, a probabilistic assessment was used to quantify intake rates. The probabilistic method offers advantages over deterministic (single point) methods. First, all valid data collected from the site and obtained from the scientific literature can be incorporated into the analysis, rather than limiting the analysis to a single data point or study. Second, the approach provides an accurate estimate of the upperbound or maximum plausible risk, since statistically-derived input distributions are used in the models rather than single upperbound values. Third, the results of the probabilistic assessment provide a quantitative estimate of the conservatism of the deterministic point estimate of risk (i.e., the probability of occurrence of the deterministic risk estimate can be identified). Fourth, the probabilistic analysis can be used to identify the variables that are most strongly affecting predicted exposure estimates (i.e., through the use of uncertainty analysis). These features provide valuable additional information for making informed decisions about reclamation options.

Intake rate distributions were estimated by modelling the exposure of a typical individual animal using probabilistic input parameters, then repeating the simulation for 500 iterations using Monte Carlo simulation. Monte Carlo simulation is the process of estimating the intake rate using random deviates for each input in the mathematical equations, then repeating the calculations with new random deviates on each cycle of the simulation, to determine the distribution of possible outcomes. Each iteration consists of a unique set of input values, which are specified by sampling the input parameters from assumed probability distributions. The iterations are repeated many times, such that the full range of the input distributions are adequately sampled in combination with the ranges from other input distributions. The Monte Carlo simulation was conducted using Excel© with Crystal Ball.©

Foraging and movement patterns of wildlife were accounted for by assuming that each species would prefer specific habitat types for foraging, and that ELCs could be used to represent preferred habitats. The landscape of the LSA following closure has been classified using 57 ELC units. Each wildlife species' preference towards specific ELCs was taken into account by specifying the likelihood that a particular species will visit a specific ELC unit on the reclaimed mine site and the surrounding region, based on each species' habitat preferences (Table VI.4-2). The number of ELC areas selected by a specific receptor is dependent on the size of a species' home range and the size of the ELC area. The foraging areas that would be used by each species were selected randomly in the model based on each species' habitat preferences.

The spatial distribution of chemicals in the reclaimed landscape was accounted for in differences of food tissue concentrations, where tissue concentrations were assumed to vary as a function of the types of reclamation materials used on-site. These reclamation materials included overburden and tailings sand. Natural areas of the LSA were assumed to consist of natural soils (i.e., muskeg). A chemical fate model was used to predict chemical concentrations in environmental media and biota when measured concentrations were not available. Predicted concentrations were then used as input concentrations for the wildlife exposure model. In particular, exposure point concentrations were required for surface water, plant and invertebrate tissues.

Water Concentrations

Seepage waters in reclaimed areas of the site in the far future will contain low levels of CT water, since CT flux will have become minimal by this time. The water quality of ponded water sources on the reclaimed landscape will be determined primarily be precipitation, run-off and sand seepage. For this assessment, animals foraging on reclaimed areas of the LSA were assumed to be exposed to on-site seepage water. The water quality of these seepages was assumed to consist of 15% CT seepage water and 85% sand seepage water. While foraging in undisturbed areas of the LSA, wildlife were assumed to be exposed to the maximum water concentrations predicted for the Athabasca River, Shipyard Lake or McLean Creek in the far future.

Table VI.4-2 Wildlife Habitat Preference Specified as Percent Likelihood of Finding the Species in the ELC

ELC Code [a]	Rufed Grouse [b]	Mallard [b]	Moose [b]	Snowshoe Hare [b]	Beaver [b]	Deer Mouse [b]
b1	30-50	0	0-25	10-65	50-100	100
b2	30-50	0	0-25	10-65	50-100	100
b3	30-50	0	0-25	10-65	50-100	100
b4	0-5	0	0-35	0-10	0	0
d1	40-65	0	50-100	25-75	25-50	100
d2	30-50	0	0-25	10-65	50-100	100
d3	0-5	0	0-35	0-10	0	0
e1	40-65	0	50-100	25-75	25-50	100
e2	20-40	0	0-25	0-25	25-50	100
e3	0-5	0	0-35	0-10	0	0
h1	0-20	0-5	0-25	0-10	0-5	100
STNN	0-20	0-5	0-25	0-10	0-5	100
BTNN	0-5	0-5	0-25	0-5	0	100
FTNN	0-5	0-5	0-25	0-5	0-5	100
FFNN	0-5	0-5	0-25	0-5	0-5	100
FONS	0	0-15	50-100	0-20	0	0
FONG	0-5	50-100	25-75	0-5	65-100	0
MONG	0-5	50-100	25-75	0-5	65-100	0
NMC	0	0	0	0	0	100
NWF	0-5	50-100	25-75	0-5	65-100	0
NWL	0-5	50-100	25-75	0-5	65-100	0
NWR	0-5	50-100	25-75	0-5	65-100	0
shrub	0	0	0	0	0	100
WONN	0-20	0-5	0-25	0-10	0.5	100
SFNN	0-20	0-5	0-25	0-10	0-5	100
FFNN	0-5	0-5	0-25	0-5	0-5	100
BFNN	0-5	0-5	0-25	0-5	0	100
MONS	0-5	50-100	25-75	0-5	65-100	0
SONS	0	0-15	50-100	0-20	0	0
NMS	0	0	0	0	0	100
DL	0	0	0	0	0	100
HG/CC	0	0	0	0	0	100
constructed wetlands	0-5	50-100	25-75	0-5	65-100	0

[a] For further details on ELC classifications, refer to Section D4.

[b] Percent likelihood of finding the species indicated in the ELC.

Aquatic Plant and Invertebrate Tissue Concentrations

Aquatic plant tissue concentrations were estimated based on observed concentrations in plants grown in constructed wetlands (Nix 1995). Aquatic invertebrate prey tissue concentrations were estimated based on observed concentrations in organisms collected from experimental wetlands (Nix 1995).

Terrestrial Plant and Invertebrate Tissue Concentrations

The reclaimed areas of the site (i.e., CT deposits) will be covered with a thick layer (i.e., 5-10 metres) of lean CT and sand. This layer will in turn be capped with 20 cm of reconstructed soil (i.e., a mix of muskeg and overburden), which is considered to be equivalent to natural soils in the area in terms of soil chemistry. Measured soil concentrations were available for each of the three soil types: overburden, tailings sand and natural soils (Table VI.4-3). To be conservative, it was assumed that plants growing in reclaimed areas may have roots extending beyond the upper capping layer of muskeg into the tailings sand or overburden layer beneath. Therefore, for areas reclaimed with tailings sand, plant tissue concentrations were based on observed concentrations in plants grown in muskeg capped tailings sand (Golder 1997g). For plants growing on top of CT deposits, data from Xu (1997) for plants growing in CT, capped with 20 cm of tailings sand and 5 cm of muskeg, were used as conservative estimates of the potential concentrations of plants on the Project Millennium reclaimed CT deposits. For natural areas or areas reclaimed with overburden, plant tissue concentrations, C_{tplant}, were estimated based on soil concentrations, C_{soil}, (either natural soil or overburden) and bioconcentration factors for terrestrial plants, BCF_{tplant}, according to the following equation:

$$C_{tplant} = BCF_{tplant} * C_{soil}$$

Terrestrial invertebrate tissue concentrations, $C_{tinvert}$ (mg/kg dry wt), were predicted based on soil concentrations, C_{soil}, specified for the different ELC areas (i.e., tailings sand, overburden or natural soil) and terrestrial invertebrate prey bioconcentration factors, $BCF_{tinvert}$, according to the following equation:

$$C_{tinvert} = BCF_{tinvert} * C_{soil}$$

Table VI.4-3 Soil Concentration Distributions Used for Wildlife Exposure Model [a]

Parameter	Overburden [b] (mg/kg)	Tailings Sand [c] (mg/kg)	Natural (Muskeg) [d] (mg/kg)
Barium	219	4.9	121
Boron	7.2	uniform (0,0.1)	uniform (0,0.1)
Cadmium	uniform (0,0.3)	uniform (0,0.3)	uniform (0,0.3)
Cobalt	12	2	2.8
Mercury	0.07	0.03	0.037
Molybdenum	1.4	uniform (0,2)	1/4
Nickel	30	2	8.4
Selenium	0.74	uniform (0,0.02)	uniform (0,0.02)
Strontium	--	--	--
Vanadium	15.1	2.8	12.3
Zinc	72.7	5.8	25.5

[a] Distribution types: uni (uniform), norm (normal), tri (triangular), -- (no data available).

[b] Overburden soil concentrations from ETL (1993; CP 3; n=1).

[c] Tailings sand chemistry data from ETL (1993; CP 5; n=1).

[d] CT chemistry data from Suncor and Syncrude (1995 unpublished data; n=1).

Summary

In summary, a wildlife exposure model was developed to compute chemical intake for wildlife populations, taking into account spatial differences in chemical concentrations and use of the reclaimed landscape. Intake rates for individuals within the LSA were estimated as follows:

1. Chemical concentration distributions for water, soil, plants and invertebrates within the reclaimed and natural areas of the LSA were predicted;
2. Each species was assumed to forage randomly within the LSA based on preferences for habitat, as defined by ELC type;
3. The movement of an individual within the LSA boundaries was simulated according to its foraging habitat;
4. Chemical intake rates were calculated according to the equations presented above;
5. If the species foraging area requirement was greater than the area of the first selected ELC, steps (3) and (4) were repeated to add more ELC areas to the forage range for the individual until its foraging requirements were met; and
6. Steps (2) to (5) were repeated for many individual animals. On each loop, a new set of input parameters were selected based on random sampling of the input data distributions.

Thus, output from this process represents the intake rate distribution expected for all individuals of a given species foraging within the LSA boundaries following closure of the Project Millennium.

The intake rate estimates presented here are preliminary, since the chemical database on which the calculations are based is rapidly expanding. Also, the wildlife rate estimates presented here assume background exposures are nil, therefore, the intake rates represent incremental doses resulting from exposure to the reclaimed landscape.

VI.4.2 Wildlife Receptor Parameters

Details on the body weight, food ingestion, water ingestion, diet, home range and habitat preferences for each wildlife receptor evaluated in the wildlife health risk assessment are provided in the following sections.

Water Shrew *(Sorex palustris)*

Body Weight:

Mean body mass kg[a]	0.013
standard deviation (SD)	0.00291
coefficient of variation (CV)	0.224
sample size (# studies)	4

Distribution: Normal

(a) Mean body mass for water shrews calculated from data given in Soper (1973), Burt (1976), Wrigley et al. (1979), and van Zyll de Jong (1983).

Food Ingestion Rate:

One 10 g animal consumed a mean of 10.3 g/day (Conoway 1952). Based on a mean O_2 consumption of 7.8 cc/g/hr, shrews require 0.95 g/g/day (Sorensen 1962).

Food ingestion rate[a] (FI rate) (kg/day):	
for shrew with mean mass (0.013 kg)	0.01235
for shrew with minimum mass (0.00718 kg)	0.00682
standard deviation (SD)[b]	0.0028

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[c]

(a) Food ingestion rate calculated as a function of body mass based on data from Conoway (1952).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = cv x FI rate for mean mass shrew).

(c) Assumed to be the same as for body mass.

Diet:

Their diet consists primarily of insects (particularly larvae and nymphs of aquatic insects, e.g. mayfly, caddisfly, and stonefly, Calder 1969). They will also eat other invertebrates (e.g. planaria), small fish (*Notropis, Cottus*) and larval amphibians (Buckner 1970, Lampman 1947, Nussbaum and Maser 1969) but these constitute an insignificant portion of the diet (van

Zyll de Jong 1983). Shrews will also take fish eggs and may also hunt on land, searching the shoreline rocks for insects (Gadd 1995). Ealey et al. (1979) describe water shrews as opportunistic feeders whose diet will vary with the area inhabited.

Estimates of the composition of diet:

1) (n=13), 78% insects (mostly terrestrial), 22% planarians and vegetation (Hamilton 1930)

2) (n=87), 49% aquatic insects, 13% spiders, fish, plants, and vertebrates (Conoway 1952)

3) (n=?), 30% carabid beetles and other insects, <20% assorted invertebrates, including snails (Buckner and Ray 1968)

4) (n=13), 30% insects, 50% slugs and earthworms, 10% assorted insects and vegetation (Whitaker and Schmeltz 1973)

Home Range:

The home range of a water shrew is approximately 75 to 200 m (M. Raine, pers. Comm.). Home range sizes are likely linear as water shrews inhabit streamside or waterside habitats.

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L /day):	
for shrew with mean mass (0.013 kg)	0.002
for shrew with minimum mass (0.00718 kg)	0.0012
standard deviation (SD)[b]	0.0005
Distribution: Normal[c]	

(a) Water ingestion rate estimated based on one allometric equation, Calder and Braun (1983).

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = cv x WI rate for mean mass shrew).

(c) Assumed to be the same as for body mass.

Time Spent On Site:

Shrews are active and present in the area year-round (Burt 1976, Smith 1993, Gadd 1995). Therefore shrews were assumed to be on-site 100% of the time.

Habitat Preferences:

Water shrews are seldom found away from water (Smith 1993). Creeks, ponds and lakes where there are overhanging banks or branches to provide cover are suitable locations for these shrews (Smith 1993). It builds its nest at the water's edge, often hidden among the sticks of a beaver dam or lodge (Gadd 1995).

General Information:

Water shrews are short-lived, surviving for approximately two summers (Gadd 1995, van Zyll de Jong 1983). Water shrews constantly build new nests (van Zyll de Jong 1983) which consist of lined depressions at the end of 10-12 cm long tunnels which they build themselves, digging with their forefeet and kicking loosened soil out of the tunnel with their hindfeet (Sorensen 1962). Damaged nests are repaired or reconstructed using its muzzle (van Zyll de Jong 1983).

Killdeer (*Charadrius vociferus*)

Body Weight:

Mean body mass[(a)]	0.0989
standard deviation (SD)	0.005
coefficient of variation (CV)	0.05
sample size (# studies)	2

Distribution: Normal

(a) Mean body mass calculated from data given in Dunning (1984) and Brunton (1988).

Food Ingestion Rate:

The bulk of the diet of the killdeer is composed of beetles and other invertebrates (Semenchuk (1993). Ehrlich et al. (1988) report a diet of 75% insects with the remainder of the diet consisting of a wide variety of invertebrates and 2% weed seeds. It forages from the ground surface and does not probe for food and will forage at dusk during the night as well as during the day (Semenchuk 1992). We assume a diet of 100% invertebrate prey.

Food ingestion rate[a] (FI rate) (kg/day):	
for birds with mean mass (0.0989 kg)	0.0154
for birds with minimum mass (0.0889 kg)	0.0142
standard deviation (SD)[b]	0.0008

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[c]

(a) Food ingestion rates estimate based on an allometric equation for field metabolic rates for passerines where FMR (kcal/day) = $2.123Wt^{0.749}$ where Wt is in (g). Food ingested per day based on an estimate of the metabolizable energy available to birds eating an a insectivorous diet (i.e. 4.30 kcal/g), Nagy (1987).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = cv x FI rate for mean mass bird).

(c) Assumed to be the same as for body mass.

Water Ingestion Rate

Water ingestion rate[a] (WI rate) (L/day):	
for birds with mean mass (0.0989 kg)	0.022
for birds with minimum mass (0.0889 kg)	0.020
standard deviation (SD)[b]	0.0011

Distribution: Given mean and standard deviation, MEI is a normal distribution.[c]

(a) Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = $0.059(\text{Body weight kg})^{0.67}$; Ohmart et al. (1970), WI (L/day) = $0.111(\text{Body weight kg})^{0.69}$; Thomas and Phillips (1975) WI (L/day) = $0.203(\text{Body Weight kg})^{0.81}$; Walter and Hughes (1978), WI (L/day) = $0.119(\text{Body Weight kg})^{0.75}$.

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = cv x WI rate for mean mass bird).

(c4) Assumed to be the same as for body mass.

Time Spent in Area:

Killdeer arrive in northern Alberta in mid-April and leave sometime between late November or early December (Semenchuk 1992, Pinel et al. 1991). Estimated total number of days in Alberta is in 233 days or 233/356 = 0.64.

Habitat Preferences:

Killdeer breed in open areas with minimal vegetative cover, not necessarily close to water (Semenchuk 1992). Its natural habitats include open grassy uplands, lakeshore clearings, river banks, woodland clearings, gravelly stream and river channels, and sedge and willow meadows with ponds and

streams (Semenchuk 1992, Holroyd and Van Tighem 1983). Killdeer will also use human-modified or disturbed habitats such as pastures, cultivated fields, roadsides, gravel pits, golf courses, parking lots, lawns landfills, borrow pits, sewage lagoons and rooftops (Semenchuk 1992, Holroyd and Van Tighem 1983). After nesting, it is more likely to frequent the margins of ponds and lakes and other muddy, moist places (Semenchuk 1992).

River Otter (*Lutra canadensis*)

Body Weight:

Mean body mass (kg)[a]	7.698
standard deviation (SD)	0.891
coefficient of variation (CV)	0.12
sample size (# studies)	5

Distribution: Normal

(a) Mean body mass for otter calculated from Soper (1973), Lauchachinda (1978), Smith (1993), Melquist and Hornocker (1983), and Gadd (1995).

Food Ingestion Rate:

Generally, throughout all four seasons, the diet consists mainly of fish (95 - 100%) (Stenson et al. 1984, Wilson and Toweill 1974, Melquist and Hornocker 1983, U.S. EPA 1993). However, Gilbert and Nancekivell (1982) observed that otters consume more waterfowl in northerly latitudes (presumably because of the ease of catching ducks during molt - if so, then this diet change would likely occur during late summer). Other than fish, otters may also take muskrats, small rodents, amphibians, insects and young or enfeebled beavers (Gadd 1995). Although they primarily feed in the water, they may also spend time on land, loping after meadow voles (Gadd 1995).

Food ingestion rate[a] (FI rate) (kg/day):	
for an otter with mean mass (7.698 kg):	0.368
for an otter with minimum mass (5.92 kg)	0.296
standard deviation (SD)[b]	0.043

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[c]

(a) Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight /day) = $0.0687(\text{Body weight g})^{0.822}$ (Nagy 1987).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = cv x FI rate for mean mass otter).

(c) Assumed to be the same as for body mass.

Home Range:

Mean home range[a] (km)	31
standard deviation (SD)	9.2
Distribution: not normal	

[a] Home range size estimate from Melquist and Hornocker (1983).

Home range for animals associated with streams or rivers are measured as distances travelled on waterways as otters tend to keep to water courses, making overland trips when looking for mates or moving, open water (Melquist and Hornocker 1983). Home range shape is determined by the drainage pattern and size and home ranges tend to overlap (Melquist and Hornocker 1983). In areas where aquatic habitat is not dominated by stream or river features, home range size varies between 400 and 1900 ha for breeding adult otters (Missouri, marshes and streams Erickson et al. 1984).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L /day):	
for an otter with mean mass (7.698 kg):	0.621
for an otter with minimum mass (5.92 kg)	0.490
standard deviation (SD)[b]	0.072
Distribution: Normal[c]	

[a] Water ingestion rate estimated an allometric equation, WI (L/day) = $0.099Wt^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

[b] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = cv x WI rate for mean mass otter).

[c] Assumed to be the same as for body weight.

Time Spent On Site:

River otter are on site year round and do not hibernate (Smith 1993, Gadd 1995).

Habitat Preferences:

River otters prefer rivers, creeks, lakes and ponds in northern forest (Smith 1993). They prefer clear water (i.e., water that is not silty or polluted) (Gadd 1995).

General Information:

River otters give birth in late March, early April and the family breaks up in November (Melquist and Hornocker 1983). Males tend to be larger than females (Melquist and Hornocker 1983). Otters tend to be in their aquatic habitat almost all of the time except during seasons where water becomes inaccessible (i.e. frozen) and are noted to be diurnal in winter and nocturnal in summer (Melquist and Hornocker 1983). Otters are well known for their habit of sliding either on muddy slopes into water or on snow during winter (Gadd 1995).

Otter families are close and may stay together for a relatively long time (Gadd 1995). Females are not reproductive until they are at least two years old, males are not ready until they are six or seven (Gadd 1995).

Great Blue Heron (*Ardea herodias*)

Body Weight:

Mean body mass adult female (kg)[a]	2.204
standard deviation (SD)	0.337
coefficient of variation (CV)	0.153
sample size	15

Distribution: Normal

[a] Mean body mass calculated from data given in Hartman (1961).

Food Ingestion Rate:

The diet of the great blue heron is composed primarily of fish, but birds will also take nestlings, small mammals and aquatic invertebrates (Erhlich et al. 1988). Herons will also take frogs, water snakes, and plant seeds Semenchuk 1992).

Food ingestion rate[a] (FI rate) (kg/day):	
for birds with mean mass (2.204 kg)	0.0976
for birds with minimum mass (1.53 kg)	0.0742
standard deviation (SD)[b]	0.0149

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[c]

(a) Food ingestion rates estimate based on an allometric equation for non-passerines (Nagy 1987): FI (g dry weight /day) = 0.301 (Body weight g)$^{0.751}$.

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = cv x FI rate for mean mass bird).

(c) Assumed to be the same as for body mass.

Foraging Home Range Size:

Mean home range size[a] (ha)	4.5
standard deviation (SD)	5.52
coefficient of variation (CV)	1.23
sample size (n)	2
Distribution: not normal	
Mean foraging distance from colony[b] (km)	5.3
standard deviation (SD)	3.11
coefficient of variation (CV)	0.59
sample size (n)	2

(27) Mean foraging home range size calculated from data given in Bayer (1978).
(28) Mean foraging distance from colony calculated from data given in Parnell and Soots (1978) and in Dowd and Flake (1985).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L/day):	
for birds with mean mass (2.204 kg)	0.223
for birds with minimum mass (1.53 kg)	0.169
standard deviation (SD)[b]	0.034

Distribution: Given mean and standard deviation, MEI is a normal distribution.[c]

(a) Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.
(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = cv x WI rate for mean mass heron).
(c) Assumed to be the same as for body mass.

Time Spent On Site:

Great Blue Herons arrive in Alberta the last half of March, early April and most leave by mid October (Semenchuk 1992). Thus, the estimated total number of days in the province is 213. Assuming that birds spend 100% of their time on site while in Canada, the maximum fraction of food and water from the contaminated sites would be 213/365 = 0.58 of their annual requirements.

Habitat Preferences:

Great Blue Herons are found in and about open shallow water at the edges of lakes, streams, rivers, ponds, sloughs, ditches, and mudflats (Semenchuk 1992). In the study area, these birds most often nest in dead aspen, balsam poplar and spruce (Semenchuk 1992).

Ruffed Grouse (*Bonasa umbellus*)

Body Weight:

Mean body mass adult female grouse (kg)[a]	
	0.543
standard deviation (SD)	0.0303
coefficient of variation (CV)	0.0558
sample size	12

Distribution: Normal

[a] Mean body mass for female ruffed grouse given in Bump et al. (1947) for New York, USA.

Food Ingestion Rate:

Primarily herbivorous, ruffed grouse consume 80% buds, leaves, flowers, seeds and fruit and the remaining 20% of their diet consists of insects, spiders, snails and young vertebrates (Ehrlich et al. 1988). Principal species of trees, shrubs and forbs consumed (i.e., buds, catkins, fruits and leaves) include aspen, poplar, apple, grape, sumac, beech and alder (Johnsgard 1983). Other plants include, clover, greenbrier, hazelnut blueberry, birches, chokecherry, maple, rosehips, dogwood fruits, willow buds, wild strawberry leaves and fruit, wintergreen leaves, saskatoon berries (see Johnsgard 1983). Ruffed grouse chicks consume primarily insects during the first week to 10 days of life (Bump et al. 1947). Approximately 70% of the food taken in the first 2 weeks consists of insects, as compared with 30% during the third and fourth weeks and dropping to 5% by the end of July (Bump et al. 1947). Ants are a frequent food item and other invertebrate species consumed include sawflies, ichneumons, beetles, spiders, grasshoppers and a variety of caterpillar species (Bump et al. 1947). Plant foods taken include sedge achenes and the fruits of strawberries, raspberries, blackberries and cherries (Bump et al. 1947).

Food ingestion rate[a] (FI rate) (kg/day): (dry weight - herbivorous diet)	
for birds with mean mass (0.532 kg)	0.0391
for birds with minimum mass (0.482 kg)	0.0362
Standard deviation[b]	0.0022

Distribution: Normal[c]

(a) Food ingestion rates estimate based on an allometric equation for all birds (Nagy 1987): FI (kg dry weight /day) = $0.0582(\text{Body weight kg})^{0.651}$.

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass bird).

(c) Assumed to be the same as for body mass.

Foraging Home Range Size:

Mean home range size[a] (ha)	11.3
standard deviation (SD)[b]	4.6
coefficient of variation (CV)	0.41
sample size[c]	3

Distribution: not normal[c]

(a) Mean foraging home range size calculated from three study groups (Godfrey 1975, Maxon 1978).

(b) Standard deviation calculated from the three studies.

(c) Distribution considered not normal due to variation given in Godfrey (1975).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L/day):	
for birds with mean mass (0.532 kg)	0.0780
for birds with minimum mass (0.482 kg)	0.0712
standard deviation (SD)[b]	0.0043

Distribution: Given mean and standard deviation, MEI is a normal distribution.[c]

(a) Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = $0.059(\text{Body weight kg})^{0.67}$; Ohmart et al. (1970), WI (L/day) = $0.111(\text{Body weight kg})^{0.69}$; Thomas and Phillips (1975) WI (L/day) = $0.203(\text{Body Weight kg})^{0.81}$; Walter and Hughes (1978), WI (L/day) = $0.119(\text{Body Weight kg})^{0.75}$.

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass grouse).

(c) Assumed to be the same as for body mass.

Time Spent On Site:

Ruffed grouse are present and active year-round in the study area (Semenchuk 1992).

Habitat Preferences:

In Alberta, ruffed grouse are most abundant in aspen-dominated and mixed wood forests (Semenchuk 1992). Small openings in the deciduous forest function as brood cover and represent an important part of their overall preferred habitat type (Johnsgard 1973). A heavy understory is needed for drumming sites (Johnsgard 1973).

General Information:

Alberta populations of ruffed grouse are quite healthy and populations generally vary on a 10 year cycle (Semenchuk 1992). High winter mortality is often experienced due to predators (i.e., raptors) and severe weather conditions (Semenchuk 1992).

Mallards (*Anas platyrhyncos*)

Body Weight:

Mean body mass adult female (kg)[(a)]	1.107
standard deviation (SD)	0.129
coefficient of variation (CV)	0.117
sample size (# studies)	3

Distribution: Normal

(a) Mean body mass calculated from data given in Owen and Cook (1977), Nelson and Martin (1953) and Krapu and Doty (1979).

Food Ingestion Rate:

Mallards are considered 'dabbling' ducks which means that they feed in shallow water tipping up and down while foraging on bulrush seeds, snails and invertebrates from the bottom (Gadd 1995). Infrequently, they may also ingest tadpoles or scavenge dead fish (Gadd 1995). Other items included in the diet are crustacea, annelids, various seeds, tubers and stems (Dillon 1959, Swanson et al. 1985).

Food ingestion rate[a] (FI rate) (kg/day): (dry weight - 75% invertebrates; 25% plant material)[b]	animal	plant
for birds with mean mass (1.107 kg)	0.0464	0.0157
for birds with minimum mass (0.849 kg)	0.039	0.0132
standard deviation (SD)[c]	0.0072	

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[d]

(a) Food ingestion rates estimate based on an allometric equation for all birds (Nagy 1987): FI (g dry weight /day) = 0.648 (Body weight g)$^{0.651}$.
(b) Diet composition from Swanson et al. (1985).
(c) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass bird).
(d) Assumed to be the same as for body mass.

Foraging Home Range Size:

Mean home range size[a] (ha)	468
standard deviation (SD)	159
coefficient of variation (CV)	0.34
sample size (n)	6

Distribution: not normal

(a) Mean foraging home range size calculated from data given in Dwyer et al. (1979) in North Dakota.

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L/day):	
for birds with mean mass (1.107 kg)	0.133
for birds with minimum mass (0.849 kg)	0.109
standard deviation (SD)[b]	0.016

Distribution: Given mean and standard deviation, MEI is a normal distribution.[c]

(a) Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.
(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass duck).
(c) Assumed to be the same as for body mass.

Time Spent On Site:

Mallards are migratory birds which breed in the study area during the summer months. Mallards arrive in Alberta in late March, early April and leave by late November (estimated number of days present is approximately 197) (Semenchuk 1992). Some birds may overwinter in Fort McMurray (Semenchuk 1992).

Habitat Preferences:

Habitat preferences for mallards are variable. They are adaptable birds that may use marshes, ponds, the margins of small and large lakes, islands, quiet waters of rivers, ditches, or flooded land in both treeless and wooded country (Semenchuk 1992).

Moose (*Alces alces*)

Body Weight:

Mean body mass (kg)[a]	381.17
standard deviation (SD)	35.14
coefficient of variation (CV)	0.0922
sample size (# studies)	3

Distribution: Normal

(a) Mean body mass for female moose calculated for data given in Doutt (1970), Smith (1993) and Stelfox (1993).

Food Ingestion Rate:

Common forages for moose include a variety of tree and shrub species, fallen leaves, bark, forbs, sedges and horsetail (Stelfox 1993).

Food ingestion rate[a] (FI rate) (kg/day):	
for moose with mean mass (381.17 kg)	6.59
for moose with minimum mass (310.88 kg)	5.68
standard deviation (SD)[b]	0.607

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[c]

(a) food ingestion rate calculated as a function of body mass using one allometric equation FI (g dry weight /day) = 0.577(Body weight g)$^{0.727}$ (Nagy 1987).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass moose).

(c) Assumed to be the same as for body mass.

Home Range:

Mean home range[30] (ha)	31055
Distribution: not normal	

[0] Home range calculated from data given in Ballard et al. (91) and from Harestad and Bunnell's (1979) allometric equation: Home range (ha) = 6.06 (Body weight kg)$^{0.91}$.

Water Ingestion Rate:

Water ingestion rate[(a)](WI rate) (L /day):	
for moose with mean mass (381.17 kg)	20.83
for moose with minimum mass (310.88 kg)	17.34
standard deviation (SD)[(b)]	1.92
Distribution: Normal[(c)]	

(a) Water ingestion rate estimated based on one allometric equation, Calder and Braun (1983).

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass moose).

(c) Assumed to be the same as for body mass.

Time Spent On Site:

Moose are present in the area year-round (Burt 1976, Smith 1993, Gadd 1995).

Habitat Preferences:

Preferred habitat of moose in Alberta is mixedwoods (Smith 1993). Moose are often found near the edges of lakes, bogs and streams (Smith 1993).

Snowshoe Hare (*Lepus americanus*)

Body Weight:

Mean body mass (kg)[a]	1.505
standard deviation (SD)	0.065
coefficient of variation (CV)	0.043
sample size(# studies)	4

Distribution: Normal

(a) Mean body mass for snowshoe hare based on data from four studies (Roman and Keith 1959, Soper 1973, Windberg and Keith 1976 and Smith 1993).

Food Ingestion Rate:

During summer, snowshoe hares feed on succulent vegetation and during winter, twigs, buds and bark (Burt 1976). Summer foods include grasses, wildflowers (especially pea-family plants and clover) and new leaves of aspen, willow and birch (Gadd 1995). In winter they eat the leaves of plants that stay green, such as kinnikinnick and wintergreen, the twig-ends and buds of shrubs and sometimes lichens (Gadd 1995).

Food ingestion rate[a] (FI rate) (kg/day):	
for hare with mean mass (1.505 kg)	0.118
for hare with minimum mass (1.376 kg)	0.110
standard deviation (SD)[b]	0.005

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[c]

(a) Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight /day) = $0.577(\text{Body weight g})^{0.727}$ (Nagy 1987).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass hare).

(c) Assumed to be the same as for body mass.

Home Range:

Mean home range[a] (ha)	4-7
Distribution: not normal	

(a) Home range size estimate given in the U.S. EPA (1993) and Gadd (1995); see also Burt (1976).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L /day):	
for snowshoe hare with mean mass (1.505 kg)	0.143
for snowshoe hare with min. mass (1.376 kg)	0.132
standard deviation (SD)[b]	0.006

Distribution: Normal[c]

(a) Water ingestion rate estimated an allometric equation, WI (L/day) = $0.099Wt^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass hare).

(c) Assumed to be the same as for body mass.

Time Spent On Site:

Snowshoe hares are resident year round on the study area (Burt 1976, Smith 1993, Gadd 1995).

Habitat Preference:

Snowshoe hares prefer forests and shrubby areas and will use open areas only rarely and only if a quick route to brushy cover is available (Smith 1993). Daytime resting spots are called 'forms' which consist of a beaten-down spot under the drooping, thickly needled lower branches of spruce trees, sometime in dense brush and long grass, or under a log in a tangle of fallen trees (Gadd 1995).

General Information:

Generally, snowshoe hares are common throughout their range although populations may fluctuate dramatically (Smith 1993).

Beaver (*Castor canadensis*)

Body Weight:

Mean body mass (kg)[a]	18.275
standard deviation (SD)	2.62
coefficient of variation (CV)	0.165
sample size (# studies)	4

Distribution: Normal

(a) Mean body mass for beaver calculated from four estimates in three studies (Soper 1973, Lancia et al. 1978 and Smith 1993).

Food Ingestion Rate:

Preferred food includes, the cambium layer of aspen, poplar, birch, maple, willow and alder. Beaver also feed on leaves, bark and small twigs and they will store branches and small sections of logs underwater near their lodge (Burt 1976, Gadd 1995). They will also eat the seeds of some water plants (Gadd 1995).

Food ingestion rate[a] (FI rate) (kg/day):	
for beaver with mean mass (18.275 kg)	0.724
for beaver with minimum mass (12.232 kg)	0.541
standard deviation (SD)[b]	0.120

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[c]

(a) Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weigh /day) = 0.577(Body weight g)$^{0.727}$ (Nagy 1987).

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass beaver).

(c) Assumed to be the same as for body mass.

Home Range:

Mean home range[a] (ha)	4.5
Distribution: not normal	

(a) Home range size estimated based on a family unit of 7 kits and two adult beavers and a requirement of 0.5 ha per beaver to support it for one year (Gadd 1995).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L /day):	
for beaver with mean mass (18.275 kg)	1.353
for beaver with minimum mass (12.232 kg)	0.943
standard deviation (SD)[b]	0.224

Distribution: Normal[c]

(a) Water ingestion rate estimated an allometric equation, WI (L/day) = 0.099Wt$^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass beaver).

(c) Assumed to be the same as for body weight.

Time Spent On Site:

Beaver are on site year round and do not hibernate (Smith 1993, Gadd 1995).

Habitat Preference:

Beavers require water. Areas attracting beavers include sloughs, rivers, creeks and lakes with trees (for foraging) within easy access (Smith 1993). Aspen is a favoured forage species (Gadd 1995).

Deer Mouse (*Peromyscus maniculatus*)

Body Weight:

Mean body mass (kg)[(a)]	0.0187
standard deviation (SD)	0.0043
coefficient of variation (CV)	0.23
sample size (n)	73

Distribution: Normal

(a) Mean body mass for pre-parous female in the Kananaskis region of Alberta (Millar et al. 1992).

Food Ingestion Rate:

Generally, deer mice diets vary with the time of year. For example, during spring deer mice rely heavily on invertebrates. During summer, they largely consume seeds and some insects; and throughout winter, it believed that deer mice rely entirely on cached and gathered seeds (pers. commun. S. Sharpe, B.C.M.O.E., Smithers, B.C.). Based on this information, deer mice diet is assumed to be composed as reported below.

Diet Composition:

May through June:	100% insects
July through Sept.:	25% insects, 75% seeds
Oct. through April:	100% seeds

Food ingestion rate[a](FI rate) (kg/day):	
for mouse with mean mass (0.0187 kg)	0.00324
for mouse with minimum mass (0.0101 kg)	0.0023
standard deviation (SD)[b]	0.0007

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[c]

(a) Food ingestion rate calculated as a function of body mass using Nagy's (1987) allometric equation for rodents, FI (g dry weight /day) = 0.621(Body weight g)$^{0.564}$.

(b) Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass deer mouse).

(c) Assumed to be the same as for body mass.

Home Range:

Mean home range[a] (ha)	0.223
standard deviation (SD)	0.222
coefficient of variation (CV)	1
sample size (n)	10

Distribution: not normal

(a) Home range calculated from data given in Banfield (1987), Mullican (1988) and King (1968).

Water Ingestion Rate:

Water ingestion rate[a] (WI rate) (L /day):	
for mouse with mean mass (0.0187 kg)	0.0028
for a mouse with minimum mass (0.0101 kg)	0.0016
standard deviation (SD)[b]	0.000634

Distribution: Normal[c]

(a) Water ingestion rate estimated one allometric equation, Calder and Braun (1983).

(b) Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass deer mouse).

(c) Assumed to be the same as for body mass.

Time Spent in Area:

Deer mice are present on site year round and are active year round (Burt 1976, Gadd 1995). *Peromyscus maniculatus* is active throughout the year in Alberta (Robinson and Bolen 1989).

Habitat Preference:

Deer mice are found in almost all habitats in the province from human habitation to open sand dunes, dense northern forests, alpine meadows and open grasslands (Smith 1993). A common species, the deer mouse is likely the most abundant mammal in the province (Smith 1993).

Black Bears (*Ursus americanus*)

Body Weight:

Mean body mass kg[(a)]	129.7
standard deviation (SD)	5.69
sample size (# studies)	3

Distribution: Normal

(a) Mean body mass for black bears calculated from data given in Tietje et al. (1986), Soper (1973).

Food Ingestion Rate:

Black bears are omnivorous however, 75% of their diet is vegetarian. Throughout the early spring, black bears feed on newly emergent vegetation such as grasses, buds and leaves. With the progression of summer, there is a need to increase the intake of foods high in sugars in order to gain weight for hibernation. Dietary preferences at this time switches to berries and fruit. The remaining 25% of the black bear diet is composed of carrion (10-15%), insects (5-10%) and small mammals and fish (<1%). (Gadd, 1995; Towers, 1980).

Food ingestion rate[(a)] (FI rate) (kg/day):	
for black bear with mean mass (129.7 kg)	3.01
for black bear with minimum mass (118.32 kg)	2.81

Distribution: Distribution: Normal[4]

(a) Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight/day)=0.577(Body weight g)$^{0.727}$ (Nagy, 1987).

Home Range:

Mean home range[(a)] (ha)	20,000

Distribution: not normal

(a) Ranges of male black bears range through overlapping areas in the mountains. This figure varies depending on the bear's age, population density, and the availability of food. Home ranges of sows are smaller and non-overlapping (Gadd, 1995).

Water Ingestion Rate:

Water ingestion rate[(a)] (WI rate) (L /day):	
for black bears with mean mass (129.7 kg)	7.89
for black bears with minimum mass (118.32 kg)	7.27

Distribution: Normal

(a) Water ingestion rate estimated based on one allometric equation, $WI(L/day) = 0.099Wt^{0.90}$ where Wt is body weight in (kg) Calder and Braun (1983).

Time Spent On Site

In the Canadian Rockies, nearly all bears are in hibernation by the end of October until emergence in mid-April. Denned bears do not eat, drink or eliminate waste during this time (Gadd, 1995; Towers, 1980). Considering that bears are hibernating for 5 months of the year, they are foraging for only 7 months per year (or 58% of the available calendar days).

Habitat Preferences

Habitat selection is closely related to food availability, particularly the availability of berries. Black bears prefer areas with dense tree and shrub cover in order to escape from predators. Since bears also climb trees to escape predators, areas with tree diameters large enough to support the weight of a climbing bear are favored (Gadd, 1995).

General Information

Black bears are active day and night (unless hibernating), constantly searching for food. They are generally solitary animals, except for females with cubs, but will share large berry patches if necessary (Gadd, 1995).

After a 220-day gestation period, cubs are born in mid-January or February. They stay with there mother until their second spring. The species

generally breeds every other year with breeding taking place between June 20 to July 10 (Gadd, 1995). The average life span for a black bear is twelve years (Towers, 1980).

For hibernation, each bear digs a simple shelter, under a tree or tall shrub. During hibernation, body temperatures decrease from 38°C to 34-31°C. This ensures that muscles stay warm enough so that they can become active quickly if required. The black bears use 1 kJ of energy per day during hibernation which is converted from fat reserves and from protein which is converted from urea (Gadd, 1995).

VI.4.3 Human Receptor Parameters

Exposure pathways considered for the human health risk assessment included ingestion of water (intentional and incidental during swimming); ingestion of plant material and wild game; transdermal absorption of waterborne chemicals during swimming; and inhalation of airborne chemicals. Exposure scenarios and equations for human receptors are described in the main text of the report. The exposure parameters and values employed for the calculations are presented here, in Tables VI.4-4 and VI.4-5.

In addition to the receptor exposure parameters, several additional items respecting the exposure assessment should be noted:

1. For the exposure assessment involving inhalation of petroleum hydrocarbons, the exposure was conducted with consideration of the approach recently reported by the Total Petroleum Hydrocarbon Criteria Working Group in the U.S. (TPHCWG 1997). Briefly, this approach recognizes that petroleum hydrocarbon exposures often involve complex hydrocarbon mixtures for which the majority of compounds have no toxicity data. To accommodate this, the approach involves grouping the known chemicals and mass concentrations into groups defined by general structure such as aliphatics (i.e., alkanes and alkenes) and aromatics, and additionally by carbon chain length and boiling point. The TPHCWG then proposed that exposures to these grouped chemicals be compared to toxicity reference values for these various groups. The toxicity reference values were based on consideration of the most potent substance known in a group, or toxicity data from bioassays involving applicable mixtures (discussed further in Appendix VI.5.2).

2. Therefore, for the inhalation exposure assessment presented here, aliphatics and aromatics were segregated into groups with carbon chain lengths typically involving C1-C10 (aliphatics) and C5-8 or C9-C18 (aromatics, excluding benzene which was assessed separately). For aliphatics this grouping spans two of the TPHCWG categories (C5-C8, and C8-C10), and includes several high emission substances, such as methane and ethylene, which are very low in toxicity and normally left out of the TPHCWG approach. Therefore, by adopting this slightly modified approach, the exposure assessment becomes very conservative in that the C1-C5 substance are included in the exposure assessment, and are effectively treated as more potent substances in the C6-C10 range. This conservative approach to the petroleum hydrocarbon inhalation exposure assessment would therefore overestimate exposure and associated risks.

3. The chemical groupings, exposure concentrations and resultant exposure estimates for the airborne petroleum hydrocarbons are presented for each emission source in Table VI-***.

4. For airborne substances that were non-carcinogenic aldehydes or ketones, the exposure assessment was conducted by collectively adding the exposure concentrations according to the chemical family, and then expressing the total aldehyde or ketone concentration as equivalent to the most toxic surrogate substance for that group. This approach allowed for assessment of some substances for which toxicity is not well defined, and was also a conservative strategy which treated less toxic substances as the more toxic group surrogate. For aldehydes and ketones, the surrogates were acrolein and acetone, respectively.

5. For non-carcinogenic polycyclic aromatic hydrocarbons (PAHs), substances were grouped as derivatives of either naphthalene, fluorene , fluoranthene or pyrene, The total concentration for each group was then used for the exposure assessment and the group surrogates used to define the associated exposure and health risk. Several PAHs did not readily fit into these categories based on structural differences, and additionally were poorly defined for toxic potency (including lack of confirmed carcinogenic potential); therefore these substances were grouped and the collective exposure treated conservatively as pyrene, the most potent non-carcinogenic PAH from the above surrogates.

6. For carcinogenic PAHs, these substances were treated as equivalents of benzo(a)pyrene with an adjustment for potency in carcinogenic potential. For ease in calculations, an adjusted exposure rate was derived by adjusting the exposure concentration of the carcinogenic PAH according to the substance's toxicity equivalence factor (TEF), relative to benzo(a)pyrene. For example, if the TEF was 0.1, then the exposure concentration was adjusted by this factor, then summed to that of benzo(a)pyrene. The resultant exposure estimate for carcinogenic PAHs was then treated as benzo(a)pyrene during risk estimation. Table VI-** lists the carcinogenic PAHs with their corresponding TEFs.

Table VI.4-4 Human Receptor Parameters

Parameter	Child	Adult	Source
Operation and Closure Scenario: Swimming			
Body Weight (kg)	13	70	Health Canada (1994)
Incidental Water Ingestion Rate while swimming (L/hr)	0.05	0.05	assumed
Surface Area for dermal contact (m^2)	0.94	1.82	Health Canada (1994)
Exposure Time (hr/event)	2.5	1	assumed
Exposure Frequency (events/yr)	16	16	assumed
Exposure Duration (yr)	3.5	50	assumed
Averaging Time - Non-carcin. (yr)	3.5	50	assumed
Averaging Time - Carcinogen (yr)	70	70	Health Canada (1994)
Operation and Closure Scenario: Recreational Activities (eg., hiking, boating)			
Body Weight (kg)	13	70	Health Canada (1994)
Water Ingestion Rate (L/d)	0.8	1.5	Health Canada (1994)
Exposure Frequency (d/yr)	104	104	assumed
Exposure Duration (yr)	3.5	50	assumed
Averaging Time - Non-carcin. (yr)	3.5	50	assumed
Averaging Time - Carcinogen (yr)	70	70	Health Canada (1994)
Operational Scenario: Air Inhalation			
Body Weight (kg)	27	70	Health Canada (1994)
Air Inhalation Rate (m^3/d)	12	23	Health Canada (1994)
Exposure Frequency (d/yr)	365	365	assumed
Exposure Duration (yr)	7	50	assumed
Averaging Time - Non-carcinogen (yr)	7	50	assumed
Averaging Time - Carcinogen (yr)	70	70	Health Canada (1994)
Operational Scenario: Local Plant, Meat and Fish Ingestion			
Body Weight (kg)	13	70	Health Canada (1994)
Blueberry Ingestion Rate (kg/day) Labrador Tea/Cattail Root Ingestion Rate (kg/day)	0.02 0.005	0.015 0.005	assumed, based on information for Ft. McKay, Ft. Smith and Ft. Chipewyan (Wein, 1989; Fort McKay Environmental Services, 1996d; 1997a; pers. comm.)
Fish Ingestion Rate (kg/day)	0.094	0.217	Richardson (1997)
Meat Ingestion Rate (kg/day)	0.067	0.1	assumed, based on information for Ft. McKay, Ft. Smith and Ft. Chipewyan (Wein, 1989; Fort McKay Environmental Services, 1996d; 1997a)
Exposure Frequency - blueberries and meat (days/yr)	365	365	assumed
Exposure Frequency - Labrador tea and cattail root (days/yr)	52	52	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)
Closure Scenario: Reclaimed Landscape			
Body Weight	13	70	Health Canada (1994)
Water Ingestion Rate (L/d)	n/a	1.5	Health Canada (1994)
Meat Ingestion Rate (kg/d)	0.0225	0.046	Health Canada (1994; 25% of daily requirements)
Plant Ingestion Rate (kg/d)	0.008	0.011	Health Canada (1994; 10% of daily requirements in the summer)
Exposure Frequency (days/yr)	365	365	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)

Table VI.4-5 Dermal Permeability Constants (Kp) for Water

Chemical	Kp (m/hr)[a]
Aluminum	0.00001
Antimony	0.00001
Barium	0.00001
Boron	0.00001
Cadmium	0.00001
Chromium	0.00002
Copper	0.00001
Lead	0.00000004
Molybdenum	0.00001
Nickel	0.000001
Selenium	0.00001
Strontium	0.00001
Vanadium	0.00001
Zinc	0.000006
Benzo[a]pyrene	0.012
Benzo[a]anthracene	0.0081

[a] Source: EPA, 1992b.

VI.5 TOXICITY ASSESSMENT

VI.5 TOXICITY ASSESSMENT

The following condensed toxicological profiles describe the key studies and dose-response relationships upon which the toxicity reference values are based.

VI.5.1 Toxicity Assessment for Wildlife Health

VI.5.1.1 Toxicity Reference Values for Metals

Antimony

No specific data were identified regarding the oral toxicity of antimony to mammalian wildlife. A LOAEL of 1.25 mg/kg-day was reported for lifespan and longevity in laboratory mice that were exposed to antimony in drinking water for one lifetime (Schroeder et al. 1968). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL of 0.125 mg/kg-day. Exposure was considered to be chronic because it was throughout the entire lifespan.

For this assessment, the chronic NOAEL for mice was used to estimate a receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in the Sample et al. (1996) and summarized in Table VI.1-2. For moose, snowshoe hare, and black bear, receptor-specific NOAELs of 0.012, 0.047, and 0.015 mg/kg-day, respectively, were derived.

Barium

No specific data were identified regarding the oral toxicity of barium to mammalian wildlife. A NOAEL of 5.06 mg/kg-day was reported for effects on growth, food and water consumption and hypertension in laboratory rats that were exposed to barium chloride in drinking water for 16 months (Perry et al. 1983). Exposure was considered to be chronic because it was greater than one year.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in the Sample et al. (1996) and summarized in Table VI.1-2. For deer mouse, moose, water shrew, snowshoe hare and black bear, receptor-specific NOAELs of 11.1, 0.93, 12.2, 3.7, 1.2 mg/kg-day respectively, were derived.

No specific data were identified regarding the oral toxicity of barium to avian wildlife. A NOAEL of 208.26 mg/kg-day was reported for mortality for day-old chicks that were exposed to barium hydroxide in the diet for four weeks

(Johnson et al. 1960). An uncertainty factor of 10 was applied to the NOAEL to extrapolate from subchronic to chronic exposure resulting in a chronic NOAEL of 20.826 mg/kg-day.

For this assessment, the chronic NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer, mallard and grouse, a NOAEL of 20.8 mg/kg-day was used in the current assessment.

Boron

No specific data were identified regarding the oral toxicity of boron to mammalian wildlife. A NOAEL of 28 mg/kg-BW/day was reported for effects on reproduction in laboratory rats that were exposed to boric acid in the diet for 3 generations (Weir and Fisher 1972). Exposure was considered to be chronic because it occurred for over a year and throughout critical lifestages.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for moose by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. A receptor-specific NOAEL of 4.9 mg/kg-day was derived for moose.

Cadmium

No specific data were identified regarding the oral toxicity of cadmium to mammalian wildlife. A LOAEL of 1.913 mg/kg-day was reported for reproductive effects (i.e., reduced survival and congenital deformities) in laboratory mice that were exposed to cadmium for two generations (Schroeder and Mitchener 1971). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL resulting in an RfD of 0.1913 mg/kg-day. This study was selected by Opresko et al. (1994) as an appropriate RfD to use for mammalian wildlife risk assessments. However, after further review of the toxicological data for cadmium in 1996, it was determined that the RfD derived from the Schroeder and Mitchener (1971) study was too conservative as it frequently predicted risks in uncontaminated areas (Sample et al. 1996). Therefore, Sample et al. (1996) selected an alternative RfD from a study by Sutou et al. (1980), which was considered to be more appropriate for use in wildlife risk assessments. In this study, a NOAEL of 1.0 mg/kg-day was reported for reproductive effects (i.e., reduced fetal implantation and survivorship, increased fetal resorptions) in laboratory rats that were exposed to cadmium for six weeks throughout mating and gestation periods. Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL of 1.0 mg/kg-day for laboratory rats was used to estimate a receptor-specific NOAEL for moose by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For moose and snowshoe hare, receptor-specific NOAELs of 0.018 and 0.7 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of cadmium to avian wildlife. A NOAEL of 1.45 mg/kg-day was reported for reproduction of mallard ducks that were exposed to cadmium in the diet for 90 days (White and Finley 1978). Exposure was considered to be chronic because it occurred during a critical lifestage and for greater than ten weeks.

For this assessment, the chronic NOAEL for mallard ducks was used as the NOAEL for ruffed grouse with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the ruffed grouse, a NOAEL of 1.45 mg/kg-day was used in the current assessment.

Chromium

No specific data were identified regarding the oral toxicity of chromium to avian wildlife. A NOAEL of 1 mg/kg-day was reported for reproduction for black ducks that were exposed to chromium in the diet for ten months (Haseltine et al. unpublished). Exposure was considered to be chronic because it occurred during a critical lifestage and for greater than ten weeks.

For this assessment, the chronic NOAEL for black ducks was used as the NOAEL for killdeer with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer, a NOAEL of 1 mg/kg-day was used in the current assessment.

Cobalt

No specific data were identified regarding the oral toxicity of cobalt to mammalian wildlife. A maximum tolerable level of 10 mg/kg diet was determined to be suitable for cattle (NAS 1980). Considering an average body weight and food ingestion rate for cattle of 318 kg and 7.95 kg/day, this maximum tolerable level was converted to a NOAEL of 0.25 mg/kg-day.

For this assessment, the NOAEL for cattle was used to estimate receptor-specific NOAELs for water shrews by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized

in Table VI.1-2. For moose and snowshoe hare, receptor specific NOAELs of 0.23 and 0.92 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of cobalt to avian wildlife. A maximum tolerable level of 10 mg/kg diet was determined to be suitable for chicks (NAS 1980). Considering an average body weight and food ingestion rate for chickens of 1.5 kg and 0.106 kg/day, this maximum tolerable level was converted to a NOAEL of 0.7 mg/kg-day.

For this assessment, the NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer and grouse, a NOAEL of 0.7 mg/kg-day was used in the current assessment.

Copper

No specific data were identified regarding the oral toxicity of copper to mammalian wildlife. A NOAEL of 11.7 mg/kg-BW/day was reported for effects on reproduction (kit survivorship) in laboratory minks that were exposed to copper sulfate in their diet for 357 days (Aulerich et al. 1982). Exposure was considered to be chronic because it was approximately one year in duration and occurred during a critical lifestage (i.e. during reproduction).

For this assessment, the chronic NOAEL for mink was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For moose, water shrew, snowshoe hare and black bear, receptor-specific NOAELs of 2.7, 34.6, 10.6, and 3.5 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of copper to avian wildlife. A NOAEL of 47 mg/kg-day was reported for mortality for day-old chicks that were exposed to copper oxide in the diet for ten weeks (Mehring et al. 1960).

For this assessment, the chronic NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer and grouse, a NOAEL of 47 mg/kg-day was used in the current assessment.

Manganese

No specific data were identified regarding the oral toxicity of manganese to mammalian wildlife. A NOAEL of 88 mg/kg-day was reported for effects reproduction (i.e. litter size, ovulations, resorptions, preimplantation death, and fetal weights) in laboratory rats that were exposed to manganese oxide in their diet throughout gestation (224 days) (Laskey et al. 1982). Exposure was considered to be chronic because it occurred during a critical life stage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For snowshoe hare, black bear, water shrew, and moose, receptor-specific NOAELs of 61.1, 20.0, 200.5 and 15.3 mg/kg -day, respectively, were derived.

Mercury

No specific data were identified regarding the oral toxicity of mercury to mammalian wildlife. A NOAEL of 1 mg/kg-day was reported for effects reproduction (i.e. kit weight, fertility and kit survival) in laboratory minks that were exposed to mercuric chloride in their diet throughout gestation (six months) (Aulerich et al. 1974). Exposure was considered to be chronic because it occurred during a critical life stage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For deer mouse, receptor-specific NOAELs of 2.7, mg/kg-day, respectively, was derived.

Molybdenum

No specific data were identified regarding the oral toxicity of molybdenum to mammalian wildlife. A LOAEL of 2.6 mg/kg-BW/day was reported for reproductive effects (i.e. reduced reproductive success, high incidence of runts) in laboratory mice that were exposed to molybdenum in water for three generations (Schroeder and Mitchener, 1971). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL resulting in an RfD of 0.26 mg/kg-day. Exposure was considered to be chronic because it was greater than one year and occurred during a critical lifestage.

For this assessment, the chronic NOAEL for laboratory mice was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For moose, deer mouse, snowshoe hare and black bear, receptor-specific NOAELs of 0.024, 0.29, 0.1 and 0.03 mg/kg-day, respectively, were derived.

Nickel

No specific data were identified regarding the oral toxicity of nickel to mammalian wildlife. A NOAEL of 80 mg/kg-BW/day was reported for reproductive effects (i.e. offspring body weights) in laboratory rats that were exposed to nickel sulfate hexahydrate in diet for three generations (Ambrose et al. 1976). Exposure was considered to be chronic because it was greater than one year and occurred during a critical lifestage.

For this assessment, the chronic NOAEL for laboratory rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For deer mouse, a receptor-specific NOAEL of 83.2 mg/kg-day, was derived.

Selenium

No specific data were identified regarding the oral toxicity of selenium to mammalian wildlife. A NOAEL of 0.2 mg/kg-BW/day was reported for reproductive effects (i.e. decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to potassium selenate in the diet for one year through two generations (Rosenfeld and Beath 1954). Exposure was considered to be chronic because it occurred during a critical lifestage and was one year in duration.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for moose and deer mouse by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For moose and deer mouse, receptor-specific NOAEL of 0.035 and 0.4 mg/kg-day respectively were derived.

No specific data were identified regarding the oral toxicity of selenium to avian wildlife. A NOAEL of 0.5 mg/kg-day was reported for reproduction of mallard ducks that were exposed to selenium in the diet for 78 days (Heinz et al. 1987). Exposure was considered to be chronic because it occurred during a critical lifestage and for greater than ten weeks.

For this assessment, the chronic NOAEL for mallard ducks was used as the NOAEL for ruffed grouse with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the ruffed grouse, a NOAEL of 0.5 mg/kg-day was used in the current assessment.

Strontium

No specific data were identified regarding the oral toxicity of strontium to mammalian wildlife. A NOAEL of 263 mg/kg-BW/day was reported for body weight and bone changes in laboratory rats that were exposed to strontium chloride in the diet for three years (Skoryna 1981). Exposure was considered to be chronic because it was one year in duration.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for deer mouse by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For deer mouse, a receptor-specific NOAEL of 547 mg/kg-day was derived.

Vanadium

No specific data were identified regarding on the oral toxicity of vanadium to mammalian wildlife a LOAEL of 2.1 mg/kg-day was reported for reproductive effects (i.e. decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to sodium metavanadate by oral gavage for 60 days prior to gestation, during gestation, delivery and lactation (Domingo et al. 1986). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL, resulting in an RfD of 0.21 mg/kg-day. Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For moose, deer mouse, black bear, beaver and snowshoe hare, receptor-specific NOAELs of 0.034, 0.41, 0.04, 0.07 and 0.14 mg/kg-day, respectively, were derived.

Zinc

No specific data were identified regarding the oral toxicity of zinc to mammalian wildlife. A NOAEL of 160 mg/kg-day was reported for reproductive effects (i.e. fetal resorption and reduced fetal growth rates) in laboratory rats that were exposed to zinc oxide in the diet during days 1 through 16 of gestation (Schlicker and Cox 1968). Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAELs for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table VI.1-2. For water shrew and deer mouse, receptor-specific NOAELs of 347 and 333 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of zinc to avian wildlife. A NOAEL of 14.5 mg/kg-day was reported for reproductive effects in leghorn hens that were exposed to zinc sulphate in the diet for 44 weeks (Stahl et al. 1990). Exposure was considered to be chronic because it was greater than 10 weeks and it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for leghorn hens was used as the NOAEL for killdeer in this assessment, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for killdeer, grouse and mallard, a NOAEL of 14.5 mg/kg-day was used in the current assessment.

VI.5.2 Toxicity Assessment for Human Health

VI.5.2.1 Toxicity Reference Values for Metals

Antimony

An oral reference dose (RfD) of 0.0004 mg/kg-day was established for antimony by the US EPA (1997), based on a chronic study in rats (Schroeder et al. 1968). A lowest observed adverse effect level (LOAEL) of 0.35 mg/kg-day was reported in this study, based on effects on longevity, blood glucose and cholesterol. An uncertainty factor of 1000 was applied to the LOAEL for derivation of the RfD.

Arsenic

Arsenic has been classified as a Type A or Group 1 carcinogen indicating that arsenic is a probable human carcinogen based on sufficient evidence from human evidence (U.S. EPA 1997, HWC 1990). An oral slope factor of 1.5 $(mg/kg\text{-}day)^{-1}$ was developed based on skin cancer (U.S. EPA 1997), resulting in an RsD of 6.7×10^{-6} mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000. CCME adopted this RsD for development of Canadian soil quality guidelines (CCME 1997).

Barium

An oral RfD of 0.07 mg/kg-day was established for barium by the US EPA (1997), based on studies of humans exposed to barium via drinking water. Populations exposed to barium levels of between 2 and 10 mg/L compared to populations exposed to low levels (0.02 mg/L or less) showed higher mortality rates for cardiovascular disease. From a sub-chronic study involving human volunteers, a no observed adverse effect level (NOAEL) of 10 mg/L was determined. An uncertainty factor of 3 was applied to the NOAEL for derivation of an RfD.

Beryllium

Berylium has been classified as a Type B2 carcinogen indicating that beryllium is a probable human carcinogen based on sufficient evidence from animal experiments but inadequate or limited evidence from human exposure data. An oral slope factor of 4.3 $(mg/kg\text{-}day)^{-1}$ was developed based on tumour incidence in rats (US EPA 1997), resulting in an RsD of 2.3×10^{-6}, based on an acceptable cancer risk level of 1 in 100, 000.

Boron

US EPA (1997) has established an oral RfD for boron and borates of 0.09 mg/kg-day based on a two year study in dogs. Testicular atrophy and spermatogenic arrest was observed in dogs exposed to borax and boric acid in the diet. The study identified 350 ppm, or 8.8 mg/kg-day, as a NOAEL. Testicular effects were also observed in a chronic bioassay in rats, but dogs appear to be more sensitive. An uncertainty factor of 100 was applied to the NOAEL from the dog study to derive the RfD. Health Canada (1990) derived an RfD of 0.0175 mg/kg-day from the same study, using an uncertainty factor of 500. The Health Canada RfD was used in the current assessment.

Cadmium

Heath Canada has set an oral tolerable daily intake (TDI) of 0.00081 mg/kg-day (Barry Jessiman pers. comm. 1994). This is the highest cadmium level not associated with significant kidney disease (Health Canada 1990). US EPA has established an oral RfD for cadmium in water of 0.0005 mg/kg-day which is adjusted to 0.001 mg/kg-day if cadmium is consumed in food. US EPA employed a toxicokinetic model to identify the highest level of cadmium in the human renal cortex that was not associated with significant proteinuria. The resulting value was used to derive the RfD. The oral absorption factor was set at different levels in the toxicokinetic model depending on the source of the metal (*i.e.*, food vs. drinking water).

Chromium

An oral reference dose of (RfD) 1 mg/kg/day was established by the US EPA (1997), based on a chronic study in rats (Ivankovic and Preussmann 1975). A NOAEL of 1468 mg/kg/day was reported in this study, based on effects on longevity.

Copper

The safe and adequate dietary requirements for copper are estimated by Health Canada to be 0.05 to 0.1 mg/kg-day for children aged 3 to 10 years (CCME 1997, Health and Welfare Canada 1990). The value of 0.1 mg/kg-day was used as the TDI in the derivation of the CCME (1997) human health soil quality guideline, and was selected as the oral toxicity reference value for the current assessment.

Lead

A TDI of 0.00357 mg/kg-day was established for children by the World Health Organization. This TDI was used to establish Canadian drinking

water standards for lead (CCME 1987), and it is considered sufficient to protect against neurobehavioural effects and anemia in children. The TDI was based on the results of metabolic studies using infant subjects which showed that an intake of 3 to 4 μg/kg-day was not associated with an increase in blood lead levels while an intake of 5 μg/kg-day or more was associated with lead retention. A TDI of 0.00714 mg/kg-day was used for adults.

Molybdenum

Molybdenum is an essential dietary nutrient which has established "Estimated Safe and Adequate Daily Intake" values of 0.002-0.004 mg/kg-day for infants, 0.002-0.005 mg/kg-day for children, and 0.002 - 0.004 mg/kg-day for adults (NRC 1989). U.S. EPA (1997) developed an oral RfD of 0.005 mg/kg-day for people exposed to molybdenum. This value is based on a LOAEL of 0.14 mg/kg-day in humans exposed to molybdenum orally, with effects including increased uric acid levels, pain and swelling of the joints, and decreased copper levels in the blood (Koval'skiy et al. 1961). The epidemiological study was based on people in a community in Armenia exposed to high concentrations of molybdenum in soils and plants, An uncertainty factor of 30 was applied to the LOAEL to establish the RfD (i.e., a factor of 10 for extrapolation from a LOAEL to NOAEL, and a factor of 3 for protection of sensitive members of the population).

Nickel

An oral RfD for nickel of 0.02 mg/kg-day, established by the US EPA (1997), was used for this assessment. The US EPA derived the RfD based on a chronic study in rats administered nickel in the diet for a two-year period (Ambrose et al. 1976). A NOAEL of 100 ppm in the diet (equivalent to 5 mg/kg-day) was identified, based on decreased body and organ weights at a LOAEL of 1000 ppm nickel in the diet. An uncertainty factor of 300 was applied to the NOAEL (10 for interspecies extrapolation, 10 for intraspecies extrapolation, and 3 for inadequacies in the reproduction studies) to derive the RfD of 0.02 mg/kg-day.

Selenium

An oral reference dose (RfD) of 0.005 mg/kg/day was established for selenium by the US EPA (1997), based on a data from a human epidemiological study (Yang et al. 1989). A no observed adverse effect level (NOAEL) of 0.015 mg/kg/day was reported in this study, based on the diagnosis of clinical selenosis (relation between selenium intake and the manifestation of clinical signs and certain biochemical alterations in blood and urine). An uncertainty factor of 3 was applied to the NOAEL for derivation of the RfD.

Vanadium

An RfD of 0.007 mg/kg-day was reported by US EPA (1995) based on a lifetime exposure drinking water study in rats (Schroeder *et al.* 1970). An uncertainty factor of 100 was applied to the NOAEL of 5 ppm to derive this RfD.

VI.5.2.2 Toxicity Reference Values for Organic Chemicals

Various organic compounds associated with petroleum hydrocarbons (PAHs, aliphatics and aromatics) have recently been reviewed by the Total Petroleum Hydrocarbon Working Group (TPHWG 1997). That review has been used here for the toxicity assessment. Some of the following profiles have been reproduced from the TPHWG document and are indicated by the reference to TPHCWG (1997).

Acetaldehyde

Acetaldehyde has been reviewed by the US EPA (1997) and is considered a potential human carcinogen via inhalation. The definitive animal data relates to the production of nasal squamous cell carcinomas and adenocarcinomas in rats (males). The potency has been defined through designation of a unit risk of $2.2x10^{-6}$. The unit risk factor was used to back calculate a slope factor based on an inhalation rate of $23m^3$/day and body weight of 70 kg and then applied to the estimated daily intake via inhalation.

Acetone

The US EPA (1997) have reviewed acetone and assigned an oral RfD, but insufficient data exists to develop a toxicity reference value for exposure via inhalation (i.e., RfC). An oral RfD of 0.1 mg/(kg*day) was assigned based on data from a subchronic rat study where increased liver and kidney weights and nephrotoxicity were noted at a dose of 500mg/(kg*day), but not at 100mg/(kg*day). Using an uncertainty factor of 1000 to accommodate inter- and intra-species uncertainties and uncertainties associated with the subchronic data, the NOEL was extrapolated to the RfD noted above. For the purposes of this assessment, the oral RfD was employed to assess the exposure via inhalation.

Acrolein

Acrolein was reviewed by the US EPA (1997) and was assigned and RfC of $2x10^{-5}$ mg/m^3. Acrolein is a reactive compound which reacts readily at the point of contact and consequently evokes its effects in the nasal epithelium. A subchronic study involving rats resulted in no detection of the NOAEL, only a LOAEL which was based on squamous metaplasia and neutrophilic

infiltration of nasal epithelium at an equivalent exposure concentration of 0.02 mg/m3. An uncertainty factor of 1000 was applied to accommodate the inter- and intra-species variability, subchronic nature of the study, lack of a NOAEL and lack of reproductive toxicity data., resulting in the above noted RfC.

Anthracene (C_{14}) (TPHCWG 1997)

Anthracene was administered to groups of 20 male and female CD-1 (ICR) BR mice by oral gavage at doses of 0, 250, 500, and 1000 mg/kg/day for at least 90 days (USEPA 1989c). Mortality, clinical signs, body weights, food consumption, opthalmology findings, hematology and clinical chemistry results, organ weights, organ-to-body weight ratios, gross pathology, and histopathology findings were evaluated. No treatment-related effects were noted. The no observed-effect level (NOEL) is the highest dose tested (1000 mg/kg/day).

The RfD of 0.3 mg/kg/day was calculated using the NOAEL of 1 000 mg/kg/day. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (1000 mg/kg/day) to obtain 0.3 mg/kg/day.

US EPA. 1989. Subchronic Toxicity in Mice with Anthracene. Final Report. Hazelton Laboratories America, Inc. Prepared for the Office of Solid Waste, Washington, DC.

Benzene

The U.S. EPA (1996) has proposed an inhalation slope factor of 2.9E-2 $(mg/kg\text{-}d)^{-1}$ for benzene. Benzene is classified as a human carcinogen based on increased incidence of leukemia in workers exposed to benzene via inhalation. The slope factor was identified based on reports from studies by Rinsky et al. (1981), Ott et al. (1978), and Wong et al. (1983). The U.S. EPA also reported increased neoplasia in rodents exposed to benzene by inhalation and gavage.

Benzo(a)anthracene

Although benzo(a)anthracene has been classified as a B2 carcinogen indicating that benzo(a)anthracene is a probable human carcinogen, a slope factor has not been developed for benzo(a)anthracene (U.S. EPA 1997). The carcinogenic potency of certain PAHs, such as benzo(a)anthracene, can be estimated by using toxicity equivalency factors (TEFs). TEFs are unitless factors which indicate the carcinogenic potency of carcinogenic PAHs relative to benzo(a)pyrene, for which sufficient toxicity information is available for derivation of a slope factor. The TEF for benzo(a)anthracene used in this report (0.1) was provided by the U.S. EPA (1992) memo "Risk Assessment for Polyaromatic Hydrocarbons: Interim Region IV Guidance". The oral slope factor for benzo[a]anthracene was then calculated by multiplying the oral slope factor for benzo(a)pyrene by the associated TEF for benzo[a]anthracene (i.e., 0.1). Thus, the slope factor for benzo(a)anthracene is 7.3 $(mg/kg\text{-}day)^{-1}$ x 0.1 = 0.73 $(mg/kg\text{-}day)^{-1}$, resulting in an RsD of $1.4x10^{-5}$ mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000 (i.e., $1x10^{-5}$ ÷ 0.73 $(mg/kg\text{-}day)^{-1}$ = 1.4 x 10^{-5} mg/kg-day).

Benzo(b)fluoranthene (TPHCWG 1997)

Classified as a B2 carcinogen - use B (a) P slope factor and a potency factor. Seven PAHs (benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, cyclopentadieno(cd)pyrene, and coronene) were tested at varying concentrations to determine their dose-response relationships as carcinogens when applied topically to the backs of female NMRI mice two times a week for the lifetime of the animal (40 mice/dose) (Habs et al.,1980). At death, all animals were dissected and their dorsal skin examined histologically for tumor formation. A clear dose-response relationship was observed at the site of application for benzo(a)pyrene. Benzo(b)fluoranthene showed a clear carcinogenic effect. Benzo(j)fluoranthene exhibited weak carcinogenic effects, while benzo(k)fluoranthene and indeno(1,2,3-cd) pyrene showed no carcinogenic effect. In this study, the results were reported as tumors and no other distinction was defined. However, it is assumed that the tumors were all carcinomas based on this statement from the study, "Animals at an advanced state of macroscopically clearly infiltrative growth were killed".

Benzo(a)pyrene, benzo(b)fluoranthene, benz(j)fluoranthene, benzo(k) fluoranthene at concentrations between 0.01% and 0.5% dissolved in acetone were applied to the clipped backs of female Swiss mice (20/dose/chemical) three times per week for the lifetime of the animals (Wynder and Hoffmann, 1959). Results show that benzo(a)pyrene, benzo(b)fluoranthene, and benzo(j)fluoranthene produced high incidences of skin papillomas and carcinomas at all dose levels. Benzo(k)fluoranthene produced a limited number of papillomas only at the high dose level (0.5%). There were no control groups in the study.

Habs, M., Schmahl, D., and Misfeld, J. (1980). Local carcinogenicity of some environmentally relevant polycyclic aromatic hydrocarbons after lifelong topical application to mouse skin. Arch. Geschwulstforsch. 50:266-274.

Wynder, E.L. and Hoffmann, D. (1959). The carcinogenicity of benzo(b)fluoranthene. Cancer. 12:1194.

Benzo(a)pyrene

Benzo(a)pyrene has been classified as a B2 carcinogen indicating that benzo(a)pyrene is a probable human carcinogen based on sufficient evidence from animal experiments but inadequate or limited evidence from human exposure data. An oral slope factor of 7.3 $(mg/kg\text{-}day)^{-1}$ was developed based on stomach tumours (U.S. EPA 1997), resulting in an RsD of $1.4x10^{-6}$ mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000.

2-Butene (TPHCWG 1997)

Male and female Wistar rats were exposed to 2-butene (42.4% cis-2-butene; 55.3% trans-2-butene) in a combined repeat dose and reproductive/developmental toxicity study. Animals were exposed at nominal concentrations of 0, 2500 and 5000 ppm 2-butene, 6 hours/day, 7 days/week. Actual concentrations were 0, 2476 and 5009 ppm or 0, 5.7 and 11.5 g/m^3, respectively. Exposure of mated females ended after treatment on day 19 of gestation. A significant decrease in body weight was noted in the high dose females during premating weeks 0 to 2, and one day after parturition. Food consumption was decreased for this group in the first pre-mate week. In males, total white blood cell count and lymphocyte number were significantly increased. However, this increase did not follow a dose relationship and was within historical control values. Plasma Ca-levels were significantly decreased in males at 11.5 g/m^3. No reproductive effects were observed in the parental animals. No effects were observed on the number of pups born, sex ratio or viability index. The NOAEL was 5.7 g/m^3 for the P generation and > 11.5 g/m^3 for the F_1 generation.

Koten-Vermeulen, J.E.M.v., Plassche, E.J. vd. 1992. SIDS Dossier on the HPV Pl Chemical: 2-Butene, RIVM, Rijksinstituut Voor Volksgezondheid en Milieuhygiene National Inst.

Chrysene (TPHCWG 1997)

Classified as a B2 carcinogen - use B (a) P slope factor and a potency factor.

Cyclohexane (TPHCWG 1997)

Under TSCA Section 4, the EPA and cyclohexane producers entered into an Enforceable Consent Agreement in November 1994 to conduct the

following studies: 2-generation reproduction study (in progress, report to CMA 2/97); 90-day inhalation study in mice (report to CMA 6/96); 90-day neurotoxicity study in rats (report to CMA 6/96); 90-day inhalation study in rats (in progress, report to CMA 1/97); and a developmental study in rats (pilot completed, study start 3/96). In the inhalation developmental pilot study conducted under TSCA Section 4, rats were exposed to 0, 3000, 6000 or 9000 ppm cyclohexane. At 6000 and 9000 ppm, maternal weight gain and overall food consumption was reduced. There was an increased incidence of "stain chin" and "stain face," and generally diminished response of the animals to a sound stimulus while being exposed. No statistically significant differences were noted between control and treated groups in fertility, number of implants, number of resorptions, number of live fetuses, sex ratio, or mean fetal weight. There were no external fetal alterations noted.

Bevan, C. J. (Draft Document). 1995. Cyclohexane Testing Program Update.

Rabbits exposed to 786 ppm cyclohexane, 6 hours/day, 5 days/week for 10 weeks showed microscopic changes in the liver and kidney. No effects occurred in rabbits exposed to 434 ppm for either 10 or 26 weeks. No treatment related effects occurred in monkeys exposed at 1243 ppm cyclohexane for 10 weeks.

Treon, J.F, Crutchfield, W.E., Jr., and Kitzmiller, KV. 1943. The physiological response of animals to cyclohexane, methylcyclohexane, and certain derivatives of these compounds. J. Ind. Hyg. Toxicol. 25:323-347.

In a study to assess the neurotoxic potential of cyclohexane, rats were exposed to a vapor of 1500 or 2500 ppm, 3 to 10 hours/day, 5 to 6 days/week, for periods up to 30 weeks. No histopathologic effects were detected in the peripheral nervous system; however, the central nervous system was not evaluated.

Frontali, N., Amantini, M.C., Spagnoto, A., Guarcini, A.M., Saltari, M.C., Burgnone, F., and Perbillini, L. Experimental neurotoxicity and urinary metabolites of C_5-C_7 aliphatic hydrocarbons used as glue solvents in shoe manufacture. Clinical Toxicol., 18(12):1357-1367, 1981.

N-Decane (TPHCWG 1997)

Rats were exposed to 540 ppm n-decane vapor 18 hours/day, 7 days/week for a total of 123 days. There was a significant weight gain and increase in total leukocyte count compared to controls. No changes were noted in polymorphonuclear lymphocyte ratios, in bone marrow composition, and no significant gross or microscopic organ changes were noted. No information was given as to whether the hematological changes were within normal biological variation. Some rats held for one month without additional exposure did not differ from the controls.

Nau, C.A., Neal, J., and Thornton, M. 1966. C_9-C_{11} fractions obtained from petroleum distillates. Arch Environ. Health 12: 382-393.

Dibenz(a,h)anthracene (TPHCWG 1997)

Classified as a B2 carcinogen - use B(a)P slope factor and a potency factor.

Ethylbenzene (TPHCWG 1997)

The chosen study is a rat 182-day oral bioassay in which ethylbenzene was given 5 days/week at doses of 13.6, 136, 408, or 680 mg/kg/day), in olive oil gavage (Wolf et al., 1956). There were 10 albino female rats/dose group and 20 controls. The criteria considered in judging the toxic effects on the test animals were growth, mortality, appearance and behavior, hematologic findings, terminal concentration of urea nitrogen in the blood, final average organ and body weights, histopathologic findings, and bone marrow counts. The LOAEL of 408 mg/kg/day is associated with histopathologic changes in liver and kidney.

The RfD of 0.1 mg/kg/day was calculated using the NOAEL of 136 mg/kg, which was converted to 97.1 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) was applied to the NOAEL (97.1 mg/kg/day) to obtain 0.1 mg/kg/day.

Fluoranthene (TPHCWG 1997)

Male and female CD-1 mice (20/sex/group) were gavaged for 13 weeks with 0, 125, 250, or 500 mg/kg/day fluoranthene (USEPA, 1988). A fifth group of mice (30/sex) was established in the study for baseline blood evaluations. Body weight, food consumption, and hematological and serum parameter values were recorded at regular intervals during the experiment. At the end of 13 weeks, the animals were sacrificed and autopsied, which included organ weight measurement and histological evaluation. All treated mice exhibited nephropathy, increased salivation, and increased liver enzyme levels in a dose-dependent manner. However, these effects were either not significant, not dose-related, or not considered adverse at 125 mg/kg/day. Mice exposed to 500 mg/kg/day had increased food consumption and increased body weight. Mice exposed to 250 and 500 mg/kg/day had statistically increased SGPT values and increased absolute and relative liver weights. Compound-related microscopic liver lesions (indicated by pigmentation) were observed in 65 and 87.5% of the mid- and high-dose mice, respectively. Based on increased SGPT levels, kidney and liver pathology, and clinical and hematological changes, the LOAEL is considered to be 250 mg/kg/day, and the NOAEL is 125 mg/kg/day.

The RfD of 0.04 mg/kg/day was calculated using the NOAEL of 125 mg/kg/day. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (125 mg/kg/day) to obtain 0.04 mg/kg/day.

US EPA. 1988. 13-Week mouse oral subchronic toxicity study. Prepared by Toxicity Research Laboratories, Ltd., Muskegon, MI for the Office of Solid Waste, Washington, DC.

Fluorene (TPHCWG 1997)

Fluorene (C_{13}) has an RfD of 0.04 mg/kg/day that is on IRIS. This value is based on an oral 13-week study in mice. Mice (25/sex/group) were exposed to 0, 125, 250, or 500 mg/kg/day of fluorene suspended in corn oil by gavage for 13 weeks (USEPA, 1989b). A significant decrease in the red blood cell count and packed cell volume were observed in females in the 250 mg/kg/day group and in males and females at the 500 mg/kg/day dose level. In both high dose males and females, there was a significant decrease in BUN and a significant increase in total serum bilirubin. At 250 and 500 mg/kg/day, there was a significant increase in liver weight. A significant increase in spleen and kidney weight was observed in males and females at 500 mg/kg/day and males at 250 mg/kg/day. Increases in liver and spleen weights in high dose animals were accompanied by histopathological increases in the amounts of hemosiderin in the spleen and Kupffer cells of the liver. The LOAEL is 250 mg/kg/day based on hematological effects and the NOAEL is 125 mg/kg/day.

The RfD for fluorene was calculated by taking the NOAEL of 125 mg/kg/day and applying an uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) and a modifying factor of 3 for lack of adequate toxicity data in a second species and reproductive/developmental data.

US EPA. 1989. Mouse oral subchronic toxicity study. Prepared by Toxicity Research Laboratories, LTD., Muskegon, MI for the Office of Solid Waste, Washington, DC.

Formaldehyde

Formaldehyde has been demonstrated to be a probable human carcinogen (US EPA 1997), when exposure is via inhalation. The definitive animal data relates to the production of squamous cell carcinomas in the nasal turbinates of rats (males and females). The US EPA (1997) defined the potency of formaldehyde using the linearized multistage model on the rat data resulting in a unit risk of $1.3x\ 10^{-5}$, and also specified a risk-specific (10^{-5}) concentration of $8x10^{-4}$ $\mu g/m^3$. For risk estimation purposes, the slope factor was back calculated from the unit risk using an inhalation rate of 23 m^3/day and body mass of 70kg, then applied to the estimated daily intake

Isopropylbenzene (Cumene) (TPHCWG 1997)

Rats were exposed to cumene vapor at concentrations of 0, 100, 500 and 1200 ppm (0, 0.50, 2.48 and 6.01 mg/L), 6 hours/day, 5 days/week for 13 weeks. A satellite group received a single 6-hour exposure, in order to evaluate neurobehavior. Alterations in functional observational battery (FOB) were observed in the satellite group at 500 and 1200 ppm, at 1 and 6 hours post exposure, but not at 24 hours post exposure. Effects included abnormal gaits, increased activity, decreased rectal temperature, and decreased toe pinch withdrawal reflexes. Necropsies were not performed in the single exposure study. In the 13 week inhalation study, no exposure related deaths occurred. No differences were observed in mean body weight; however, decreased food consumption was noted Week 1 for females exposed at 500 and 1200 ppm. A consistent increase in water consumption was noted in males exposed at 500 and 1200 ppm from week 2 onward. These groups also demonstrated changes in several hematologic and clinical chemistry parameters. No exposure-related changes were seen in brain measurements, functional observational battery, or nervous system histopathology. Motor activity decreased in males exposed to 500 and 1200 ppm. This effect was not observed in a subsequent 13 week inhalation study, reported by the same author. There were no exposure-related effects on spermatogenesis. Liver, kidney and adrenal gland weights were increased in the 500 and 1200 ppm groups. Renal proximal tubular cell hypertrophy, hyperplasia, and hyaline droplet formation was evident in males exposed to 500 and 1200 ppm cumene. Cataracts were observed, however, in a non-dose dependent manner and in both exposed and control animals. Cumene was not considered neurotoxic. The NOAEL for this study was determined at 100 ppm.

Cushman, J.R., Norris, J.C., Dodd, D.E., Darmer, K.I., and Morris, C.R. 1995. Subchronic inhalation toxicity and neurotoxicity assessment of cumene in Fischer 344 rats. J. Am. Coll. Tox. 14(2): 129-147.

In a second 13 week inhalation study, conducted to assess the high incidence of cataracts observed in the first study, rats were exposed to cumene vapor, 6 hours/day, 5 days/week at concentrations of 0, 50 (permissible exposure limit),100, 500 and 1200 ppm (0, 0.25, 0.50, 2.50 and 6.00 mg/L), with a 4 week recovery period. No animals died during the study. Body weights were unremarkable. Although some relative and absolute liver, kidney and adrenal gland weights were increased in rats exposed at 500 or 1200 ppm, no histopathological evaluations were conducted. The eyes were the only tissue evaluated histopathologically. No treatment related ophthalmic effects were observed. No serum chemistry or hematological evaluations were conducted. No changes in functional observational battery, auditory brain stem response, or motor activity were observed in any dose group. No treatment related neurotoxic or ototoxic effects were noted. The NOAEL for this study is 100 ppm, and is in agreement with the initial 13 week study conducted by Cushman et al. (1995).

Cushman, J.R., Norris, J.C., Dodd., D.E., Darmer, K.I., and Morris, C.R. 1995. Subchronic inhalation toxicity and neurotoxicity assessment of cumene in Fischer 344 rats. J. Am. Coil. Tox. 14(2): 129-147.

Rats were exposed to cumene vapor at concentrations of 0, 105, 300, or 599 ppm (0, 0.53, 1.5 and 3.0 mg/L), 6 hours/day, 5 days/week for approximately 28 days. No animals died during the study. Hypoactivity and irritation effects were noted during exposure. Absolute and relative liver and/or kidney weights were increased. No changes were reported in mean body weight, clinical, gross or microscopic pathology findings. The NOAEL was > 3 mg/L.

EUCLID Data Sheet: Cumene. 1995. Section 5.4 Repeated Dose Toxicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Female rats were exposed to 0, 100, 500 or 1200 ppm cumene vapor, 6 hours/day, on days 6 - 15 of gestation. No dams died, aborted or delivered early. However, body weight gain was significantly reduced throughout the exposure period in dams in the 1200 ppm group, and maternal food consumption was reduced at 1200 and 500 ppm. Gross observations, body weight, and organ weights were unremarkable except for a significant increase in relative liver weight at 1200 ppm. No significant changes were noted in gestational parameters and no increased incidence of either malformations or variations were noted. The NOEL for developmental toxicity was greater than 1200 ppm.

EUCLID Data Sheet: Cumene. 1995. Section 5.9 Developmental Toxicity/Teratogenicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Female rabbits were exposed to 0, 500, 1200 or 2300 ppm cumene vapor, 6 hours/day on days 6 - 18 of gestation. Maternal toxicity occurred in all three treatment groups as evidenced by maternal deaths, reduced relative liver weight (2300 ppm), and reduced maternal weight gain and food consumption during the exposure period. There were no significant changes in gestational parameters and no increased incidence of malformations or variations. However, one significant variation, ecchymosis of the head, was observed at 500 ppm but was within range of historical control values. The NOEL for developmental toxicity was greater than 2300 ppm.

EUCLID Data Sheet: Cumene. 1995. Section 5.9 Developmental Toxicity/Teratogenicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Groups of 10 female Wistar rats were administered 139 doses of cumene by gavage in olive oil at 154, 462, or 769 mg/kg/day over a 194-day period; 20 rats given olive oil served as controls (Wolf et al., 1956). Body weights were measured throughout the study. Most hematological evaluations were conducted after the 20, 40, 80, and 130th doses, and blood urea nitrogen determinations, and gross and histological examinations (lungs, heart, liver, kidneys, testes, spleen, adrenals, pancreas, femoral bone marrow) were

conducted at the end of the study. Effects were not observed at 154 mg/kg/day but a "slight" but significant increase in average kidney weight occurred at 462 mg/kg/day. A "moderate' increase in average kidney weight occurred at 769 mg/kg/day. Therefore, 154 mg/kg/day is the NOAEL and 462 mg/kg/day is the LOAEL based on increased kidney weight.

The RfD of 0.04 mg/kg/day was calculated using the NOA.EL of 154 mg/kg, which was converted to a 110 mg/kg/day based dosing schedule of 139 doses in 194 days. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (110 mg/kg/day) to obtain 0.04 mg/kg/day.

Methylcyclohexane (TPHCWG 1997)

Rats, mice, hamsters and dogs were exposed to a vapor of methylcyclohexane at 0, 400 or 2000 ppm, 6 hours/day, 5 days per week for 19 months. At 12 months, some of the rats, mice, and hamsters were terminated. The remaining rodents were held an additional year and the dogs for five years. There was no increase in tumors in any of the exposed animals. The only treatment related finding was kidney nephropathy in the 2000 ppm exposed rats. Hemolysis of blood samples prohibited clinical chemistry evaluations for the female rats.

Kinkead, E.R., Haun, C.C., Schneider, M.G., Vemot, E.H., and Macewen, J.D. (1985) Chronic inhalation exposure of experimental animals to methylcyclohexane. Air Force Aerospace Medical Research Report AFAMRL-TR-85-03.

Rabbits were exposed to a vapor of methylcyclohexane for 10 weeks. Liver and kidney effects were reported in rabbits exposed to 2880 ppm; however, there were no effects at 1200 ppm. No treatment related effects were reported in a monkey exposed to 370 ppm methylcyclohexane for 10 weeks.

Treon, J.F., Crutchfield, W.E., Jr., and Kitzmiller, K.V. (1943). The physiological response of animals to cyclohexane, methylcyclohexane, and certain derivatives of these compounds. J. Ind. Hyg. Toxicol. 25:323-347.

Naphthalene (TPHCWG 1997)

Rabbits exposed to naphthalene by oral route at doses up to 400 mg/kg/day, on gestation days 6 to 18 showed no apparent adverse reproductive effects (or signs of developmental toxicity).

Pharmakon Research International (PRI), Inc. 1986. Developmental toxicity study in rabbits: Naphthalene. Report to Texaco, Inc. Beacon, NY. PH 329-TX-001-85.

Mice exposed to naphthalene (in corn oil) at a dose of 300 mg/kg/day on days 7 to 14 of gestation had a decreased number of live pups per litter. No congenital abnormalities were observed.

Plasterer, M.R., Bradshaw, W.S., Booth, G.M., et al. 1985. Developmental toxicity of nine selected compounds following prenatal exposure in the mouse: naphthalene,12-nitrophenol, sodium selenite, dimethyl phthalate, ethylene thiourea and four glycol ether derivatives. Toxicol. Environ. Health 15:25-38.

In a 90 day oral gavage study, mice were administered 5.3, 53 or 133 mg/kg naphthalene. No treatment-related mortalities or body weight changes were reported in either sex, and no organ weight changes were observed in males. A significant decrease in absolute brain, liver and spleen weight was noted for females at the highest dose; however, organ to body weight ratios were significantly different only for the spleen. Although spleen weight decreased, there was no evidence of immunotoxicity in any treatment group for either sex. No histopathologic evaluations were performed in this study. Exposed mice showed no alterations in hematology. Several serum chemistry parameters including BUN levels in females (all doses) and total serum protein in both sexes (53 and 133 mg/kg), showed significant dose-related changes. A corresponding increase in albumin levels was noted in males, and an increase in globulin levels was noted in both males and females. Electrolyte values were generally unaffected by treatment, except for decreased calcium levels in males administered 53 or 133 mg/kg naphthalene. Although there were some changes, serum chemistry parameters gave little evidence of significant toxicity at any dose level.

Shopp, G.M., White, K.L., Jr., Holsapple, M.R, et al., 1984. Naphthalene toxicity in CD-1 mice: General toxicology and immunotoxicology. Fund. App. Toxicol. 4:406-419.

Naphthalene was not teratogenic to pregnant rats administered up to 450 mg/kg/day, by gavage, on gestation days 6 to 15. However, there was a trend toward a dose-related increase in malformations.

National Toxicology Program (NTP). 1991a. Developmental toxicity of naphthalene (CAS No. 91-20-3) administered by gavage to Sprague-Dawley (CD) rats on gestational days 6 through 15. Research Triangle Park, NC: National Toxicology Program, National Institute of Environmental Health Sciences, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. TER-91006.

In a 13 week subchronic oral study, rats and mice exposed to naphthalene at doses up to 400 and 200 mg/kg/day, respectively, showed no evidence of cardiovascular, gastrointestinal, respiratory, neurologic, renal or hepatic effects. No histopathological lesions of the testes were noted in mice or rats at any dose level.

Battelle's Columbus Laboratories (Battelle). 1980a. Subchronic toxicity study: Naphthalene (C52904) $B_6C_3F_1$ mice. Report to U.S. Department of Health and Human Services, National Toxicology Program, Research Triangle Park, NC.

Battelle's Columbus Laboratories (Battelle). 1980b. Subchronic toxicity study: Naphthalene (C52904), Fischer 344 rats. Report to U.S. Department of Health and Human Services, National Toxicology Program, Research Triangle Park, NC.

B6C3F1 mice were exposed to naphthalene vapors at 10 or 30 ppm, 6 hours/day, 5 days/week for a 2 year period. Both sexes displayed chronic inflammation and metaplasia of the olfactory epithelium, hyperplasia of the respiratory epithelium, and a dose-related increase in inflammatory lesions of the lungs. No treatment- related effects were observed for gastrointestinal, hematological, renal, hepatic, immunological or neurological systems. Female (but not male) mice exposed to 30 ppm naphthalene for a lifetime exhibited a significant increase in pulmonary alveolar/bronchiolar adenomas. NTP concluded no incidence of carcinogenicity in males and limited evidence in female mice based on increased incidence of pulmonary alveolar/bronchiolar adenomas.

National Toxicology Program (NTP). 1992a. Technical report series No. 410. Toxicology and carcinogenesis studies of naphthalene (CAS No. 91-20-3) in $B_6C_3F_1$ mice (inhalation studies). Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. NIH Publication No. 92-3141.

In a 13 week subchronic dermal study, rats treated with up to 1000 mg/kg/day naphthalene, 6 hours/day, 5 days/week, showed an increased incidence of excoriated skin lesions and papules. Similar lesions were seen in the control and low dose groups. At the high dose, naphthalene exacerbated the severity of the lesions. No reported respiratory, cardiovascular, gastrointestinal, hematological, hepatic or renal effects.

Frantz, S.W., VanMilier, J.R, and Jengler, W.C. 1986. Ninety-day (subchronic) study with naphthalene in albino rats. Report to Texaco, Inc., Beacon, NY, by Bush Run Research Center Union Carbide, Export,PA. Project No. 49-539 revised (unpublished).

A provisional RfD for naphthalene of 0.04 mg/kg/day was developed by the USEPA. This RfD was based on an oral subchronic NTP unpublished study (NTP, 1980). In this study, rats were administered naphthalene by gavage 5 days/week for 13 weeks. The dose levels used in this study were not published in any of the available summaries. However, the NOEL was identified to be 50 mg/kg/day. The critical effect was decreased body weight. Using the gavage schedule of 5 days/week, the 50 mg/kg/day is converted to 35.7 mg/kg/day. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) is used to calculate the RfD of 0.04 mg/kg/day. This provisional RfD is not on IRIS nor is it in HEAST. This value was on IRIS but was pulled pending further review. The value was also removed from HEAST due to the uncertainty in the calculation of the RfD.

Naphthenic Acids

No regulatory toxicity reference values are available for naphthenic acids. Thus, an extensive literature search was performed to identify toxicity

information on naphthenic acids that would be applicable to human and ecological health risk assessment. The following is a summary of the toxicity data available.

Acute Toxicity Studies

An oral (gavage) dose of 3,500 mg/kg and an intraperitoneal dose of 860 mg/kg of naphthenic acid each resulted in 50% mortality (LD_{50}) in young male white mice. These lethal doses also demonstrated symptoms of toxicity including central nervous depression (without analgesia), corneal eye opacity, dryness of mouth, convulsions and diarrhea. Death was due to respiratory arrest (Pennisi and dePaul Lynch 1977).

The acute oral toxicities of two naphthenic acid fractions and seven commercial metal naphthenates were determined in rats using oral gavage. A fraction of naphthenate derived from crude kerosene acids produced 50% mortality at a dose of 3,000 mg/kg and a fraction derived from mixed crude acids proved lethal at 5,200 mg/kg. The metal naphthenates, with their respective metal contents (calcium, 4%; cobalt, 6%; copper, 8%; lead, 24%; mercury, 10 %; manganese, 6% and zinc, 8%) produced 50% mortality at various concentrations. Four of the metal salts (Mn, Cu, Zn and Ca) possessed an LD_{50} greater than 6,000 mg/kg, while lead was slightly below at 5,100 mg/kg and cobalt was at 3,900 mg/kg. Only the phenyl mercury naphthenate proved to be more toxic than the naphthenic acids at 390 mg/kg. Symptomatically, the deaths appeared to result from gastrointestinal disturbances including anorexia, diarrhea, and severe weakness (Rockhold 1955). This study also included an investigation of the subchronic toxicity of lead naphthenate administered orally. Rats received 20 daily doses of 1% (as Pb) solution of lead naphthenate over a four week period. No abnormal characteristics in either action or appearance were observed. No deaths occurred and no changes were noted during gross and histopathological examinations conducted on animals sacrificed on termination of the 30 day experimentation period.

Table VI.5-1 compares the doses of naphthenates that cause 50% mortality in various species.

Table VI.5-1 Acute Toxicity Values for Naphthenates

Chemical	LD_{50} rat	LD_{50} mice	Reference
naphthenic acids	3,000 mg/kg	3550 mg/kg	Rockhold 1955, Pennisi & dePaul Lynch 1977
calcium naphthenate	>6,000 mg/kg	NA	Rockhold 1955
cobalt naphthenate	3,900 mg/kg	NA	Rockhold 1955
copper naphthenate	>6,000 mg/kg	NA	Rockhold 1955
lead naphthenate	5,100 mg/kg	NA	Rockhold 1955
phenyl mercury naphthenate	390 mg/kg	NA	Rockhold 1955
manganese naphthenate	>6000 mg/kg	NA	Rockhold 1955
zinc naphthenate	>6000 mg/kg	NA	Rockhold 1955

Subchronic Toxicity Studies

A daily oral (gavage) dose of 1,000 mg/kg-day repeated for 30 days produced central nervous system depression (without loss of analgesia), hematological changes, weight loss and death due to respiratory arrest. Gross morphological changes in the liver and stomach were noted as well as histopathological changes in a few selected organs (Pennisi and dePaul Lynch 1977).

Developmental Toxicity Studies

A developmental and teratogenic toxicity study evaluated zinc naphthenate administered to pregnant rats during the major period of fetal organogenesis. Maternal toxicity was confined to the highest dose group (938 mg/kg/day) and indicated symptoms of lethargy and reduced body weight gain. That dosage also produced a higher incidence of resorptions and lower average fetal body weight. Dams receiving 94.0 or 188 mg/kg/day were not affected, nor were their developing fetuses. It was concluded that zinc naphthenate only affected the developing fetus at a dosage level which produced signs of maternal toxicity (Angerhofer et al. 1991).

Chronic Toxicity Studies

No chronic studies assessing the effects of naphthenic acids were available in the literature.

Human Toxicity Studies

Insufficient data regarding the effects of naphthenic acids on human health were available in the literature. There was also insufficient evidence to suggest that naphthenic acids are carcinogenic to humans.

Studies were identified that assessed the acute toxicity of naphthenic acids as well as the acute and subchronic toxicity of various naphthenic compounds. These investigations did not, however, provide a range of data adequate to derive human health criteria. Therefore, an RfD was not derived for naphthenic acids.

N-Nonane (TPHCWG 1997)

Harlan-Wistar rats were exposed by inhalation to 0, 1900, 3100 or 8400 mg/m^3 (0, 360, 590, or 1600 ppm) n-nonane 6 hours/day, 5 days/week for 13 weeks. Two deaths resulted at 1600 ppm. Exposure to 1600 ppm produced excessive salivation, mild coordination loss, and fine tremors throughout the first 4 days of exposure. Salivation and lacrimation continued throughout the study. Mean body weights or mean body weight changes were significantly lower in the 1600 ppm group. There were no hematological, serum chemistry or histopathologic changes that were considered treatment-related. No effects were observed at 360 or 590 ppm.

Carpenter et al. 1975. Petroleum hydrocarbon toxicity studies XVII. Animal response to n-nonane vapor. Toxicol. Appl. Pharmacol. 44: 53-61.

Petroleum Hydrocarbon--Airborne Mixtures (TPHCWG 1997)

Airborne mixtures of petroleum hydrocarbons were assessed for exposure by way of grouped compounds as previously noted in Appendix X.4.2, using the approach of TPHCWG (1997). Consequently, the toxicity reference values for this complex mixture were also taken from TPHCWG (1997), however a slight conservative modification was made. As noted in the previous section, the petroleum hydrocarbon categories involved aliphatics and aromatics , segregated into groups with carbon chain lengths typically involving C1-C10 (aliphatics) and for aromatics, C5-C8 (excluding benzene which was assessed separately) or C9-C18. For aliphatics this grouping spans two of the TPHCWG categories (C5-C8, and C8-C10), and includes several high emission substances, such as methane and ethylene, which are very low in toxicity and normally left out of the TPHCWG approach.

The modification employed here simply involved the use of the more conservative toxicity reference value if more than one was available because of the amalgamation of two groups. Thus, for C1-C19 aliphatics, the toxicity reference value (RfC) employed was $1.0mg/m^3$ (normally

applicable to C8-C16, for protection against hepatic and hematological changes), which is about 18-fold more potent than the reference value ascribed to the C5-C8 fraction regarding neurotoxicity (TPHCWG 1997). For the aromatic fractions C5-C8 and C8-C10, the toxicity reference values employed were 0.4 and 0.2 mg/m^3 for hepatotoxicity and decreased body weight, respectively.

Pyrene (THPCWG 1997)

An oral RfD of 0.03 mg/kg/day for pyrene is currently on IRIS. This value was based on a subchronic oral gavage study in mice (USEPA, 1989d). Groups of 20 mice/sex/group were administered pyrene in corn oil at levels of 0, 75, 125, or 250 mg/kg for 13 weeks. Nephropathy was present in 4 (control), 1 (75 mg/kg/day),1 (125 mg/kg/day), and 9 (250 mg/kg/day) male mice. Similar lesions were seen in female mice: 2 (control), 3 (75 mg/kg/day), 7 (125 mg/kg/day), and 10 (250 mg/kg/day). Decreased kidney weights were observed in the 125 and 250 mg/kg/day dose groups. The NOAEL was determined to be 75 mg/kg/day and the LOAEL was 125 mg/kg/day for nephropathy and decreased kidney weights.

The RfD for pyrene was calculated by taking the NOAEL of 75 mg/kg/day and applying an uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) and a modifying factor of 3 for lack of adequate toxicity data in a second species and reproductive/ developmental data.

US EPA. 1989. Mouse Oral Subchronic Toxicity of Pyrene. Study conducted by Toxicity Research Laboratories, Muskegon, MI for the Office of Solid Waste, Washington, DC.

1,3,5-Trimethylbenzene (TPHCWG 1997)

Sprague Dawley rats (10/sex/dose group) were administered 1,3,5 trimethylbenzene in corn oil by oral gavage for a 14 day period at concentrations of 0, 60, 150 and 600 mg/kg/day at a constant volume of 5mL/kg/day. A high dose recovery group was retained an additional 14 days. All animals survived treatment. No adverse clinical signs or treatment-related effects were observed in body weight, body weight gain or food consumption. Ophthalmic and necropsy findings were unremarkable. An increase in cholesterol levels was noted in mid- and high-dose females. An increase in white blood cell counts with corresponding increases in neutrophils and lymphocytes was noted in high dose males. At treatment termination, relative liver weights were significantly increased for mid- and high dose females and high dose males. In addition, relative adrenal weight was significantly increased in high dose males. All high dose animals exhibited centrilobular hepatic hypertrophy following treatment. All noted effects reversed by the end of the 14-day recovery period. The NOEL for this study was determined at 60 mg/kg,

based on increased cholesterol levels and liver weight at 150 and 600 mg/kg.

IIT Research Institute. 14-Day Oral Gavage Toxicity Study of 1,3,5-Trimethylbenzene in Rats with a Recovery Group. IITRI Project No. L08512. Study1. February 1995.

Sprague Dawley rats (10/sex/dose group) were administered 1,3,5-trimethylbenzene in corn oil by oral gavage, 5 days per week for a 90 day period at concentrations of 0, 50, 200 and 600 mg/kg/day at a constant volume of 5mL/kg/day. A high dose recovery group was retained an additional 28 days without treatment. All tissues from the control and high dose groups underwent microscopic examination. Lesions and limited tissues were evaluated in the low and mid-dose groups. No histologic evaluations were conducted for the recovery group. All animals survived treatment. No statistically significant effects were reported for body weight, body weight gain or food consumption. However, cumulative body weight gain decreased by 11% in high dose males. Ophthalmic exams were unremarkable. Phosphorus levels increased for high dose females. Also, a significant increase in absolute and relative liver weight was reported for high dose females at treatment termination. In males, relative liver and kidney weights were significantly increased at treatment termination. No treatment-related microscopic lesions were observed in any animal. Any treatment-related effect was absent by the end of the 28-day recovery period. A NOEL was established at 200 mg/kg based on increased phosphorous levels, liver and kidney weight reported at 600 mg/kg/day.

IIT Research Institute. 90-Day Oral Gavage Toxicity Study of 1,3,5-Trimethylbenzene in Rats with a Recovery Group. IITRI Project No. L0851. Study May 1995.

Toluene (TPHCWG 1997)

An oral RfD of 0.2 mg/kg/day for toluene is currently on IRIS. This value is based on a subchronic oral gavage study in rats (NTP 1989). Groups of 10 rats/sex/group were administered toluene in corn oil at levels of 0, 312, 625, 1250, 2500, or 5000 mg/kg for 5 days/week for 13 weeks. All animals in the 5000 mg/kg dose group died within the first week. At the 2500 mg/kg dose level, one female and 8 males died; however, two of these deaths were attributed to gavage errors. No significant changes in hematology or urinalysis were observed in the treated animals at any dose level. In females, liver, kidney and brain weights were all significantly increased at doses of 1250 mg/kg or greater. In males, liver and kidney weights were significantly increased at the 625 mg/kg dose level and above. Lesions in the liver and nephrosis were observed in animals at 2500 and 5000 mg/kg. Histopathological changes were also observed in the brain and urinary bladder at 1250, 2500, and 5000 mg/kg dose levels. The NOAEL for this study is 312 mg/kg based on liver and kidney weight changes in the male rats at 625 mg/kg.

The RfD of 0.2 mg/kg/day was calculated using the NOAEL of 312 mg/kg, which was converted to 223 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) was applied to the NOAEL (223 mg/kg/day) to obtain 0.2 mg/kg/day.

NTP (National Toxicology Program). 1989. Toxicology and Carcinogenesis Studies of Toluene in F344/N rats and B6C3F1 mice. Technical Report Series No. 371. Research Triangle, NC.

Xylenes (TPHCWG 1997)

Groups of 50 male and 50 female Fischer 344 rats and 50 male and 50 female B6C3F1 mice were given gavage doses of 0, 250, or 500 mg/kg/day (rats) and 0, 500, or 1000 mg/kg/day (mice) for 5 days/week for 103 weeks (NTP 1986). The animals were observed for clinical signs of toxicity, body weight gain, and mortality. All animals that died or were killed at sacrifice were given gross necropsy and comprehensive histologic examinations. There was a dose-related increased mortality in male rats, and the increase was significantly greater in the high-dose group compared with controls. Although increased mortality was observed at 250 mg/kg/day, the increase was not significant. Although many of the early deaths were caused by gavage error, NTP (1986) did not rule out the possibility that the rats were resisting gavage dosing because of the behavioral effects of xylene. Mice given the high dose exhibited hyperactivity, a manifestation of CNS toxicity. There were no compound related histopathologic lesions in any of the treated rats or mice. Therefore, the high dose is a FEL and the low dose a NOAEL.

The RfD of 2 mg/kg/day was calculated using the NOAEL of 250 mg/kg, which was converted to 179 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 100 (10 for animal to human and 10 for most sensitive) was applied to the NOAEL (179 mg/kg/day) to obtain 2 mg/kg/day.

NTP (National Toxicology Program). 1986. Technical Report on the Toxicology and Carcinogenesis Studies of Xylenes (mixed) in F344/N rats and B6C3F1 mice. NIH Publ. No. 86-2583. Research Triangle, NC.

VI.6 RISK ESTIMATION RESULTS

VI.6 RISK ESTIMATION RESULTS

VI.6.1 Risk Estimation Results for Wildlife Health

Pursuant to the methods and equations outlined in the previous sections for Exposure and Effects Assessments, the following section provides the resultant exposure estimates and exposure ratios, according to the key questions analyzed in Tables VI.6-1 to VI.6-6. For each medium, the chemical exposure concentrations, estimated daily intake rates (EDI) and exposure ratios (ER) for wildlife receptors are presented.

Table VI.6-1 Baseline: Ingestion of Plants

Chemical	Plant Species	Plant Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Moose				
Antimony	blue Lab cattail	nd 0.68 nd	0.0039	0.33
Barium	blue Lab cattail	15.5 120 47.3	1.06	1.13
Boron	blue Lab cattail	7 25 29	0.35	0.072
Cadmium	blue Lab cattail	0.09 0.09 0.17	0.002	0.11
Cobalt	blue Lab cattail	nd 0.31 5.24	0.032	0.14
Copper	blue Lab cattail	4.6 74 14.4	0.54	0.20
Manganese	blue Lab cattail	576 1070 541	12.6	0.83
Molybdenum	blue Lab cattail	0.11 0.12 1.7	0.011	0.46
Selenium	blue Lab cattail	nd nd 0.7	0.004	0.12
Vanadium	blue Lab cattail	nd 0.15 7.16	0.042	1.24
Hare				
Antimony	blue Lab	nd 0.68	0.027	0.57
Barium	blue Lab	15.5 120	5.33	1.44
Copper	blue Lab	4.6 74	3.09	0.29
Manganese	blue Lab	576 1070	64.74	1.06
Black Bear				
Antimony	blue Lab	nd 0.68	0.0059	0.39
Barium	blue Lab	15.5 120	1.18	0.98
Copper	blue Lab	4.6 74	0.68	0.20
Manganese	blue Lab	576 1070	14.3	0.72
Molybdenum	blue Lab	0.11 0.12	0.002	0.067
Ruffed Grouse				
Barium	blue Lab	15.5 120	5.0	0.24
Copper	blue Lab	4.6 74	2.9	0.087

blue = blueberries; Lab = Labrador tea leaves; cattail = cattail root

Table VI.6-2 Project Impacts: Ingestion of Water During Operational Phase(W-2)

Chemical	Maximum Water Concentrations (mg/L)	EDI	ER
Water Shrew			
Barium	0.08 (Shipyard)	0.012	0.001
Copper	0.004 (all)	0.00062	0.000018
Manganese	0.4 (Athabasca)	0.062	0.00031
Zinc	0.04 (McLean)	0.0062	0.000017
Killdeer			

Chemical	Maximum Water Concentrations (mg/L)	EDI	ER
Barium	0.08 (Shipyard)	0.018	0.00085
Chromium	0.004 (Athabasca)	0.00089	0.00089
Copper	0.004 (all)	0.00089	0.000019
Manganese	0.4 (Athabasca)	0.089	0.000091
Zinc	0.04 (McLean)	0.0089	0.00061
Moose			
Antimony	0.000045 (McLean)	0.0000025	0.00021
Barium	0.08 (Shipyard)	0.0044	0.0047
Boron	0.35 (Shipyard)	0.019	0.004
Cadmium	0.003 (McLean)	0.00016	0.00082
Copper	0.004 (all)	0.00022	0.000081
Manganese	0.4 (Athabasca)	0.022	0.0014
Molybdenum	0.036 (Shipyard)	0.002	0.082
Selenium	0.001 (McLean)	0.000055	0.0016
Vanadium	0.007 (Shipyard)	0.00038	0.011
Snowshoe Hare			
Antimony	0.000045 (McLean)	0.0000043	0.000091
Barium	0.08 (Shipyard)	0.0076	0.0021
Copper	0.004 (all)	0.00038	0.000036
Manganese	0.4 (Athabasca)	0.038	0.00062
Molybdenum	0.036 (Shipyard)	0.0034	0.034
Black Bear			
Antimony	0.000045 (McLean)	0.0000027	0.00018
Barium	0.08 (Shipyard)	0.0049	0.0041
Copper	0.004 (all)	0.00024	0.00007
Manganese	0.4 (Athabasca)	0.024	0.0012
Molybdenum	0.036 (Shipyard)	0.0022	0.073
Deer Mouse			
Molybdenum	0.036 (Shipyard)	0.0054	0.019
River Otter			
Molybdenum	0.036 (Shipyard)	0.0029	0.048
Beaver			
Molybdenum	0.036 (Shipyard)	0.0027	0.053
Ruffed Grouse			
Barium	0.08 (Shipyard)	0.011	0.00055
Copper	0.004 (all)	0.00057	0.000012

Table VI.6-3 Project Impacts: Ingestion of Invertebrates (W-2)

Chemical	Invertebrate Concentrations (mg/kg)	EDI	ER
Water Shrew			
Barium	29	27.6	2.26
Cobalt	1.4	1.3	0.44
Copper	45	42.8	1.24
Manganese	314	298.3	1.49
Zinc	133	126.4	0.35
Killdeer			
Barium	29	4.5	0.22
Chromium	10.5	1.6	1.63
Cobalt	1.4	0.22	0.31
Copper	45	7.0	0.15
Manganese	314	48.9	0.05
Zinc	133	20.7	1.43

Table VI.6-4 Project Impacts: Ingestion of Water after Closure (W-3)

Chemical	Years	Maximum Water Concentrations (mg/L)	EDI	ER
Moose				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0017 0.0034	0.073 0.14
Snowshoe Hare				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0031 0.006	0.031 0.06
Black Bear				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0019 0.0038	0.065 0.13
Deer Mouse				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0048 0.0094	0.017 0.033
River Otter				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0026 0.005	0.043 0.085
Beaver				
Molybdenum	2030 far future	0.032 (Shipyard) 0.063 (McLean)	0.0024 0.0047	0.047 0.093

Table VI.6-5 Project Impacts:Ingestion of End Pit Lake Water after Closure(W-3)

Chemical	Years	EPL Water Concentrations (mg/L)	EDI	ER
Moose				
Molybdenum	2044-2052 far future	0.74 0.095	0.04 0.0052	1.69 0.22
Snowshoe Hare				
Molybdenum	2044-2052 far future	0.74 0.095	0.071 0.0091	0.71 0.09
Black Bear				
Molybdenum	2044-2052 far future	0.74 0.095	0.045 0.0058	1.5 0.19
Deer Mouse				
Molybdenum	2044-2052 far future	0.74 0.095	0.11 0.014	0.38 0.049
River Otter				
Molybdenum	2044-2052 far future	0.74 0.095	0.06 0.0077	1.0 0.13
Beaver				
Molybdenum	2044-2052 far future	0.74 0.095	0.055 0.007	1.1 0.14

Table VI.6-6 Project Impacts: Reclaimed Landscape Exposure (W-3)

Chemical	Median ER	90th % ER
Moose		
Barium	0.36	0.72
Boron	0.12	1.0
Cobalt	0.003	0.43
Molybdenum	1.3	10
Selenium	0.001	0.043
Vanadium	0.57	7.0
Snowshoe Hare		
Barium	0.35	0.81
Cadmium	0.001	0.075
Cobalt	0.0007	0.25
Molybdenum	0.23	2.26
Vanadium	0.29	0.97
Beaver		
Vanadium	0.76	6.6
Mallard		
Barium	0.051	0.14
Zinc	0.21	0.3
Ruffed Grouse		
Boron	0.011	0.42
Cadmium	0.01	0.07
Cobalt	0.0007	0.22
Selenium	0.007	0.04
Zinc	0.15	0.58
Deer Mouse		
Barium	1.16	1.44
Mercury	0.0014	0.002
Molybdenum	0.51	1.0
Nickel	0.0017	0.0071
Selenium	0.023	0.068
Strontium	0.0001	0.008
Vanadium	2.9	3.5
Zinc	0.011	0.081

VI.6.2 Risk Estimation Results for Human Health

Pursuant to the methods and equations outlined in the previous sections for Exposure and Effects Assessments, the following section provides the resultant exposure estimates and exposure ratios, according to the key questions analyzed in Tables VI.6-7 to VI.6-22. For each medium, the chemical exposure concentrations, estimated daily intake rates (EDI) and exposure ratios (ER) for child, adult and composite receptors are presented.

Table VI.6-7 Baseline: Water (Swimming Exposure)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Barium	A: 1997	0.07	0.000035	0.014
	A: 2000-2025	0.07	0.000035	0.014
	A: 2030	0.07	0.000035	0.014
	A: far future	0.07	0.000035	0.014
	S: 1997-2004	0.047	0.000024	0.0096
Boron	A: 1997	0.05	0.000025	0.0014
	A: 2000-2025	0.05	0.000025	0.0014
	A: 2030	0.06	0.00003	0.0017
	A: far future	0.06	0.00003	0.0017
	S: 1997-2004	0.19	0.000095	0.0054
Cadmium	A: 1997	0.001	0.0000005	0.00084
	A: 2000-2025	0.001	0.0000005	0.00084
	A: 2030	0.001	0.0000005	0.00084
	A: far future	0.001	0.0000005	0.00084
	S: 1997-2004	0.000002	0.000000001	0.0000017
Molybdenum	A: 1997	0.0028	0.000001	0.0002
	A: 2000-2025	0.0049	0.000002	0.0004
	A: 2030	0.0049	0.000002	0.0004
	A: far future	0.0015	0.0000006	0.0001
	S: 1997-2004	0.000005	0.000000002	0.0000004
Vanadium	A: 1997	0.01	0.000005	0.00076
	A: 2000-2025	0.007	0.0000035	0.00053
	A: 2030	0.007	0.0000035	0.0053
	A: far future	0.004	0.000002	0.00003
	S: 1997-2004	0.000006	0.000000003	0.0000005
Adult				
Barium	A: 1997	0.07	0.000003	0.00003
	A: 2000-2025	0.07	0.000003	0.00003
	A: 2030	0.07	0.000003	0.00003
	A: far future	0.07	0.000003	0.00003
	S: 1997-2004	0.047	0.000002	0.00002
Boron	A: 1997	0.05	0.000002	0.00012
	A: 2000-2025	0.05	0.000002	0.00012
	A: 2030	0.06	0.000003	0.00015
	A: far future	0.06	0.000003	0.00015
	S: 1997-2004	0.19	0.000008	0.00046
Cadmium	A: 1997	0.001	0.0000004	0.00004
	A: 2000-2025	0.001	0.0000004	0.00004
	A: 2030	0.001	0.0000004	0.00004
	A: far future	0.001	0.0000004	0.00004
	S: 1997-2004	0.000002	8.5e-11	0.00000008
Molybdenum	A: 1997	0.0028	0..00000009	0.00002
	A: 2000-2025	0.0049	0.0000002	0.00003
	A: 2030	0.0049	0.0000002	0.00003
	A: far future	0.0015	0.00000005	0.00009
	S: 1997-2004	0.000005	1.6e-10	0.00000003
Vanadium	A: 1997	0.01	0.0000004	0.00008
	A: 2000-2025	0.007	0.0000003	0.00005
	A: 2030	0.007	0.0000003	0.00005
	A: far future	0.004	0.0000002	0.00003
	S: 1997-2004	0.000006	2.6e-10	0.00000005
Composite				
Arsenic	A: 1997	0.0012	0.0000001	0.02
	A: 2000-2025	0.0017	0.0000002	0.029
	A: 2030	0.0014	0.0000001	0.024
	A: far future	0.0013	0.0000001	0.022
	S: 1997-2004	0.00039	0.00000004	0.0066

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Beryllium	A: 1997	0.001	0.0000001	0.044
	A: 2000-2025	0.001	0.0000001	0.044
	A: 2030	0.001	0.0000001	0.044
	A: far future	0.001	0.0000001	0.044
	S: 1997-2004	0.000025	2.6e-9	0.0011
Benzo(a)pyrene	A: 1997	0.0000007	0.00000002	0.013
	A: 2000-2025	0.0000014	0.00000003	0.025
	A: 2030	0.0000013	0.00000003	0.023
	A: far future	0.0000006	0.00000002	0.011
Benzo(a) anthracene	A: 1997	0.0000015	0.00000003	0.0018
	A: 2000-2025	0.0000044	0.00000007	0.0053
	A: 2030	0.0000048	0.00000008	0.0058
	A: far future	0.0000048	0.00000008	0.0058

A=Athabasca River; S=Shipyard Lake

Table VI.6-8 Baseline: Water (Recreational Exposure)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Barium	A: 1997	0.07	0.0013	0.032
	A: 2000-2025	0.07	0.0013	0.032
	A: 2030	0.07	0.0013	0.032
	A: far future	0.07	0.0013	0.032
	S: 1997-2004	0.047	0.00085	0.021
Boron	A: 1997	0.05	0.00088	0.051
	A: 2000-2025	0.05	0.00088	0.051
	A: 2030	0.06	0.0011	0.061
	A: far future	0.06	0.0011	0.061
	S: 1997-2004	0.19	0.0033	0.19
Cadmium	A: 1997	0.001	0.000018	0.036
	A: 2000-2025	0.001	0.000018	0.036
	A: 2030	0.001	0.000018	0.036
	A: far future	0.001	0.000018	0.036
	S: 1997-2004	0.000002	0.00000004	0.00007
Molybdenum	A: 1997	0.0028	0.00005	0.01
	A: 2000-2025	0.0049	0.000088	0.018
	A: 2030	0.0049	0.000088	0.018
	A: far future	0.0015	0.000027	0.0054
	S: 1997-2004	0.000005	0.00000009	0.00002
Vanadium	A: 1997	0.01	0.00018	0.026
	A: 2000-2025	0.007	0.00013	0.018
	A: 2030	0.007	0.00013	0.018
	A: far future	0.004	0.000072	0.01
	S: 1997-2004	0.000006	0.0000001	0.000016
Adult				
Barium	A: 1997	0.07	0.00043	0.0061
	A: 2000-2025	0.07	0.00043	0.0061
	A: 2030	0.07	0.00043	0.0061
	A: far future	0.07	0.00043	0.0061
	S: 1997-2004	0.047	0.00029	0.0041
Boron	A: 1997	0.05	0.00031	0.017
	A: 2000-2025	0.05	0.00031	0.017
	A: 2030	0.06	0.00037	0.021
	A: far future	0.06	0.00037	0.021
	S: 1997-2004	0.19	0.0012	0.067
Cadmium	A: 1997	0.001	0.000006	0.0076
	A: 2000-2025	0.001	0.000006	0.0076
	A: 2030	0.001	0.000006	0.0076
	A: far future	0.001	0.000006	0.0076
	S: 1997-2004	0.000002	0.00000001	0.000015
Molybdenum	A: 1997	0.0028	0.000017	0.0034
	A: 2000-2025	0.0049	0.00003	0.006
	A: 2030	0.0049	0.00003	0.006
	A: far future	0.0015	0.0000092	0.0018
	S: 1997-2004	0.000005	0.00000003	0.000006
Vanadium	A: 1997	0.01	0.00006	0.0088
	A: 2000-2025	0.007	0.00004	0.0062
	A: 2030	0.007	0.00004	0.0062
	A: far future	0.004	0.00002	0.0035
	S: 1997-2004	0.000006	0.00000004	0.000005
Composite				

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Arsenic	A: 1997	0.0012	0.000009	1.45
	A: 2000-2025	0.0017	0.00001	2.05
	A: 2030	0.0014	0.00001	1.69
	A: far future	0.0013	0.000009	1.57
	S: 1997-2004	0.00039	0.000003	0.47
Beryllium	A: 1997	0.001	0.000007	3.15
	A: 2000-2025	0.001	0.000007	3.15
	A: 2030	0.001	0.000007	3.15
	A: far future	0.001	0.000007	3.15
	S: 1997-2004	0.000025	0.000002	0.08
Benzo(a)pyrene	A: 1997	0.0000007	0.00000002	0.015
	A: 2000-2025	0.0000014	0.00000004	0.032
	A: 2030	0.0000013	0.00000004	0.030
	A: far future	0.0000006	0.00000002	0.014
Benzo(a) anthracene	A: 1997	0.0000015	0.00000004	0.0026
	A: 2000-2025	0.0000044	0.0000001	0.0075
	A: 2030	0.0000048	0.0000001	0.0082
	A: far future	0.0000048	0.0000001	0.0082

Table VI.6-9 Baseline: Ingestion of Plants

Chemical	Plant Species	Plant Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Child				
Barium	blue	15.5	0.0048	0.068
	Lab	120	0.0013	0.019
	cattail	47.3	0.00052	0.0074
	TOTAL			**0.094**
Boron	blue	7	0.0022	0.024
	Lab	25	0.00027	0.003
	cattail	29	0.0035	0.0035
	TOTAL			**0.031**
Cadmium	blue	0.09	0.00003	0.027
	Lab	0.09	0.000001	0.001
	cattail	0.17	0.000002	0.002
	TOTAL			**0.03**
Copper	blue	4.6	0.0014	0.0028
	Lab	74	0.00081	0.0016
	cattail	14.4	0.00016	0.00032
	TOTAL			**0.0076**
Lead	blue	0.3	0.000092	0.026
	Lab	2.9	0.00003	0.0089
	cattail	2.5	0.000027	0.0077
	TOTAL			**0.043**
Molybdenum	blue	0.11	0.000034	0.0068
	Lab	0.12	0.0000013	0.00026
	cattail	1.7	0.000019	0.0037
	TOTAL			**0.011**
Nickel	blue	0.99	0.0003	0.015
	Lab	0.15	0.0000016	0.00023
	cattail	10.9	0.00012	0.006
	TOTAL			**0.02**
Vanadium	blue	nd	n/a	n/a
	Lab	0.15	0.0000003	0.000044
	cattail	7.16	0.000078	0.011
	TOTAL			**0.011**
Adult				
Barium	blue	15.5	0.0066	0.094
	Lab	120	0.00024	0.0033
	cattail	47.3	0.000096	0.0014
	TOTAL			**0.099**
Boron	blue	7	0.003	0.033
	Lab	25	0.000051	0.00056
	cattail	29	0.000059	0.00066
	TOTAL			**0.034**
Cadmium	blue	0.09	0.000039	0.039
	Lab	0.09	0.00000018	0.00018
	cattail	0.17	0.00000035	0.00035
	TOTAL			**0.040**
Copper	blue	4.6	0.002	0.0039
	Lab	74	0.00015	0.0003

	cattail TOTAL	14.4	0.000029	0.000059 **0.0043**
Lead	blue Lab cattail TOTAL	0.3 2.9 2.5	0.00013 0.0000059 0.0000051	0.018 0.00023 0.00071 **0.019**
Molybdenum	blue Lab cattail TOTAL	0.11 0.12 1.7	0.000047 0.00000024 0.000035	0.0094 0.000049 0.00069 **0.01**
Nickel	blue Lab cattail TOTAL	0.99 0.15 10.9	0.00042 0.000014 0.000022	0.021 0.0007 0.0011 **0.023**
Vanadium	blue Lab cattail TOTAL	not detected 0.15 7.16	n/a 0.0000031 0.000015	n/a 0.000044 0.0021 **0.0021**

blue = blueberries; Lab = Labrador tea leaves; cattail = cattail root

Table VI.6-10 Baseline: Ingestion of Meat

Chemical	Animal Species	Animal Tissue Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Child				
Barium	rodent bison	24.7 0.4 (meat) 2.8 (liver)	0.038 0.00099	0.55 0.014
Cadmium	rodent bison	1.2 0.03 (meat) 0.27 (liver)	0.0019 0.00008	1.86 0.083
Chromium	rodent bison	31 nd	0.048	0.05
Copper	rodent bison	15.1 5.4 (meat) 52.4 (liver)	0.023 0.016	0.23 0.16
Lead	rodent bison	5.4 nd	0.0083	2.34
Nickel	rodent bison	2.1 0.4 (meat) 0.3 (liver)	0.0032 0.00071	0.16 0.036
Selenium	rodent bison	nd 0.2 (meat) 1.0 (liver)	0.00043	0.087
Vanadium	rodent bison	6.0 nd	0.0093	1.33
Adult				
Barium	rodent bison	24.7 0.4 (meat) 2.8 (liver)	0.011 0.00027	0.15 0.0039
Cadmium	rodent bison	1.2 0.03 (meat) 0.27 (liver)	0.00051 0.000023	0.51 0.023
Chromium	rodent bison	31 nd	0.013	0.013
Copper	rodent bison	15.1 5.4 (meat) 52.4 (liver)	0.0065 0.0043	0.065 0.043
Lead	rodent bison	5.4 nd	0.0023	0.65
Nickel	rodent bison	2.1 0.4 (meat) 0.3 (liver)	0.0009 0.0002	0.045 0.0099
Selenium	rodent bison	nd 0.2 (meat) 1.0 (liver)	0.00012	0.024
Vanadium	rodent bison	6.0 nd	0.0026	0.37

nd=not detected or not measured

Table VI.6-11 Project Impacts: Recreational Exposures During Operational Phase (HH-4, Athabasca River)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Antimony	2000-2025	0.00001	0.0000002	0.0001
Barium	2000-2025	0.07	0.0013	0.018
Boron	2000-2025	0.05	0.0009	0.052
Cadmium	2000-2025	0.001	0.000018	0.036
Chromium	2000-2025	0.004	0.00007	0.014
Copper	2000-2025	0.004	0.00007	0.00072
Lead	2000-2025	0.000089	0.000016	0.00045
Molybdenum	2000-2025	0.0027	0.00005	0.0097
Nickel	2000-2025	0.0005	0.000009	0.00045
Selenium	2000-2025	0.0004	0.000007	0.0014
Vanadium	2000-2025	0.006	0.00011	0.015
Adult				
Antimony	2000-2025	0.00001	6.1e-8	0.00015
Barium	2000-2025	0.07	0.00043	0.0061
Boron	2000-2025	0.05	0.00031	0.018
Cadmium	2000-2025	0.001	0.000006	0.012
Chromium	2000-2025	0.004	0.00002	0.0049
Copper	2000-2025	0.004	0.00002	0.00024
Lead	2000-2025	0.000089	0.0000005	0.000076
Molybdenum	2000-2025	0.0027	0.000017	0.0033
Nickel	2000-2025	0.0005	0.000003	0.00015
Selenium	2000-2025	0.0004	0.000002	0.00049
Vanadium	2000-2025	0.006	0.00004	0.0053
Composite				
Arsenic	2000-2025	0.0017	1.5	2.05
Beryllium	2000-2025	0.001	3.1	3.15
Benzo(a)pyrene	2000-2025	0.00000061	1.7e-8	0.012
Benzo(a) anthracene	2000-2025	0.0000014	3.3e-8	0.0024

Table VI.6-12 Project Impacts: Recreational Exposures During Operational Phase (HH-1, HH-4, Shipyard Lake)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Barium	2000-2025	0.08	0.0014	0.021
Boron	2000-2025	0.27	0.005	0.28
Cadmium	2000-2025	0.001	0.000018	0.036
Chromium	2000-2025	0.004	0.00007	0.014
Copper	2000-2025	0.004	0.00007	0.00072
Lead	2000-2025	0.000029	0.0000005	0.00015
Molybdenum	2000-2025	0.00045	0.0000081	0.0016
Nickel	2000-2025	0.002	0.000036	0.0018
Strontium	2000-2025	0.4	0.007	0.012
Selenium	2000-2025	0.0002	0.0000036	0.00072
Vanadium	2000-2025	0.004	0.000054	0.01
Adult				
Barium	2000-2025	0.08	0.00049	0.007
Boron	2000-2025	0.27	0.0017	0.095
Cadmium	2000-2025	0.001	0.000006	0.012
Chromium	2000-2025	0.004	0.000025	0.0049
Copper	2000-2025	0.004	0.000025	0.00025
Lead	2000-2025	0.000029	0.00000018	0.000025
Molybdenum	2000-2025	0.00045	0.0000028	0.00055
Nickel	2000-2025	0.002	0.000012	0.00061
Strontium	2000-2025	0.4	0.0024	0.0041
Selenium	2000-2025	0.0002	0.000001	0.00025
Vanadium	2000-2025	0.004	0.000025	0.0035
Composite				
Arsenic	2000-2025	0.0011	0.000008	1.33
Beryllium	2000-2025	0.001	0.000007	3.15

Table VI.6-13 Project Impacts: Swimming Exposures During Operational Phase (HH-1, Shipyard Lake)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Boron	2000-2025	0.27	0.00014	0.0077
Vanadium	2000-2025	0.004	0.000002	0.00029
Adult				
Boron	2000-2025	0.27	0.000012	0.00066
Vanadium	2000-2025	0.004	0.0000002	0.00002
Composite				
Arsenic	2000-2025	0.0011	0.0000001	0.019
Beryllium	2000-2025	0.001	0.0000001	0.044

Table VI.6-14 CEA: Recreational and Swimming Exposures at Closure (CHH-1, Athabasca River)

Chemical	Exposure Scenario	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Molybdenum	Recreational Swimming	0.013	0.00023 0.000007	0.05 0.0013
Adult				
Molybdenum	Recreational Swimming	0.013	0.00008 0.0000006	0.02 0.00011
Composite				
Arsenic	Recreational Swimming	0.0015	0.000011 0.0000002	1.8 0.025

Table VI.6-15 Project Impacts: Ingestion of Fish (HH-4)

Chemical	Fish Tissue Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Child			
Barium	0.5	0.00031	0.0044
Copper	2	0.0012	0.0025
Nickel	2	0.0012	0.062
Adult			
Barium	0.5	0.00015	0.0022
Copper	2	0.0006	0.0012
Nickel	2	0.0006	0.03

Table VI.6-16 Project Impacts: Swimming Exposures after Closure (HH-5, Part A, Shipyard Lake)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Boron	2030-2045 far future	0.25 0.19	0.00013 0.000095	0.0072 0.0054
Adult				
Boron	2030-2045 far future	0.25 0.19	0.000011 0.000008	0.00061 0.00046
Composite				
Arsenic	2030-2045 far future	0.0011 0.001	1.1e-7 1.0e-7	0.019 0.017
Beryllium	2030-2045 far future	0.0009 0.0008	9.1e-8 8.1e-8	0.04 0.035

Table VI.6-17 Project Impacts: Recreational Exposures after Closure (HH-5, Part A, Shipyard Lake)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Boron	2030-2045 far future	0.25 0.19	0.0045 0.0034	0.26 0.20
Adult				
Boron	2030-2045 far future	0.25 0.19	0.0015 0.0012	0.088 0.067
Composite				
Arsenic	2030-2045 far future	0.0011 0.001	0.000008 0.000007	1.3 1.2
Beryllium	2030-2045 far future	0.0009 0.0008	0.0000065 0.0000058	2.8 2.5

Table VI.6-18 Project Impacts: Swimming Exposures after Closure (HH-5, Part A, with End Pit Lake Water)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Antimony	2045-2052	0.0009	4.5e-7	0.0011
	far future	0.0001	5.0e-8	0.00013
Barium	2045-2052	0.109	0.000055	0.00078
	far future	0.05	0.000025	0.00036
Boron	2045-2052	2.17	0.0011	0.062
	far future	0.45	0.00023	0.013
Lead	2045-2052	0.01	0.0000042	0.0012
	far future	0.0013	0.00000055	0.00015
Molybdenum	2045-2052	0.71	0.00036	0.071
	far future	0.095	0.000048	0.0095
Strontium	2045-2052	1.14	0.00057	0.00095
	far future	0.297	0.00015	0.00025
Vanadium	2045-2052	0.086	0.000043	0.0062
	far future	0.012	0.000006	0.00085
Adult				
Antimony	2045-2052	0.0009	3.8e-8	0.000096
	far future	0.0001	4.3e-9	0.000011
Barium	2045-2052	0.109	0.0000047	0.000067
	far future	0.05	0.0000022	0.000031
Boron	2045-2052	2.17	0.000093	0.0053
	far future	0.45	0.000019	0.0011
Lead	2045-2052	0.01	3.1e-7	0.000044
	far future	0.0013	4.1e-8	0.0000057
Molybdenum	2045-2052	0.71	0.00003	0.0061
	far future	0.095	0.000004	0.00081
Strontium	2045-2052	1.14	0.000049	0.000081
	far future	0.297	0.000013	0.000021
Vanadium	2045-2052	0.086	3.7e-6	0.00052
	far future	0.012	5.1e-7	0.000073
Composite				
Arsenic	2045-2052	0.0041	4.1e-7	0.069
	far future	0.001	1.0e-7	0.017
Beryllium	2045-2052	0.0033	3.3e-7	0.14
	far future	0.00052	5.2e-8	0.022
Benzo(a)pyrene	2045-2052	0.000024	6.0e-7	0.43
	far future	1.8e-22	4.5e-24	3.2e-18
Benzo(a) anthracene	2045-2052	0.000099	1.7e-6	0.12
	far future	4.0e-18	6.7e-20	4.8e-15

Table VI.6-19 Project Impacts: Recreational Exposures after Closure (HH-5, Part A, with End Pit Lake Water)

Chemical	Years	Water Concentrations (mg/L)	EDI (mg/kg/day)	ER
Child				
Antimony	2045-2052 far future	0.0009 0.0001	0.000016 0.0000018	0.041 0.0045
Barium	2045-2052 far future	0.109 0.05	0.002 0.00091	0.028 0.013
Boron	2045-2052 far future	2.17 0.45	0.039 0.0081	2.24 0.46
Lead	2045-2052 far future	0.01 0.0013	0.00018 0.000023	0.05 0.0065
Molybdenum	2045-2052 far future	0.71 0.095	0.013 0.0017	2.56 0.34
Strontium	2045-2052 far future	1.14 0.297	0.021 0.0054	0.034 0.0089
Vanadium	2030 far future	0.086 0.012	0.0016 0.00021	0.22 0.03
Adult				
Antimony	2045-2052 far future	0.0009 0.0001	5.5e-6 6.1e-7	0.014 0.0015
Barium	2045-2052 far future	0.109 0.05	0.00067 0.00031	0.0096 0.0044
Boron	2045-2052 far future	2.17 0.45	0.013 0.0028	0.76 0.16
Lead	2045-2052 far future	0.01 0.0013	0.000031 0.000008	0.0086 0.0011
Molybdenum	2045-2052 far future	0.71 0.095	0.0044 0.00058	0.87 0.12
Strontium	2045-2052 far future	1.14 0.297	0.007 0.0018	0.012 0.003
Vanadium	2045-2052 far future	0.086 0.012	0.00053 0.000073	0.076 0.01
Composite				
Arsenic	2045-2052 far future	0.0041 0.001	0.000032 0.00003	4.95 1.21
Beryllium	2045-2052 far future	0.0033 0.00052	0.000025 0.000024	10.3 1.6
Benzo(a)pyrene	2045-2052 far future	0.000024 1.8e-22	7.7e-7 5.8e-24	0.55 4.1e-18
Benzo(a) anthracene	2045-2052 far future	0.000099 4.0e-18	0.0000024 9.5e-20	0.17 6.8e-15

Table VI.6-20 Reclaimed Landscape Exposure (HH-5, Part B, with Athabasca River Water)

Chemical	Media	Exposure Concentrations	EDI (mg/kg/day)	ER
Child				
Barium	plants (mg/kg) meat (mg/kg)	17.4 0.64	0.012	0.17
Boron	plants (mg/kg) meat (mg/kg)	49.8 nd	0.031	1.75
Cadmium	plants (mg/kg) meat (mg/kg)	0.35 0.054	0.00031	0.31
Chromium	plants (mg/kg) meat (mg/kg)	0.85 0.31	0.0011	0.21
Copper	plants (mg/kg) meat (mg/kg)	3.05 10.1	0.019	0.19
Lead	plants (mg/kg) meat (mg/kg)	0.24 nd	0.00015	0.04
Molybdenum	plants (mg/kg) meat (mg/kg)	0.79 0.56	0.0015	0.29
Selenium	plants (mg/kg) meat (mg/kg)	0.11 0.28	0.00055	0.11
Strontium	plants (mg/kg) meat (mg/kg)	37 1.7	0.026	0.042
Vanadium	plants (mg/kg)	1.7	0.001	0.15

Chemical	Media	Exposure Concentrations	EDI (mg/kg/day)	ER
	meat (mg/kg)	nd		
Adult				
Barium	plants (mg/kg) meat (mg/kg) water (mg/L)	17.4 0.64 0.07	0.0047	0.067
Boron	plants (mg/kg) meat (mg/kg) water (mg/L)	49.8 nd 0.29	0.014	0.8
Cadmium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.35 0.054 0.001	0.00011	0.13
Chromium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.85 0.31 0.004	0.00042	0.085
Copper	plants (mg/kg) meat (mg/kg) water (mg/L)	3.05 10.1 0.004	0.007	0.072
Lead	plants (mg/kg) meat (mg/kg) water (mg/L)	0.24 nd 0.000077	0.000039	0.011
Molybdenum	plants (mg/kg) meat (mg/kg) water (mg/L)	0.79 0.56 0.002	0.00054	0.11
Selenium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.11 0.28 0.0002	0.00021	0.041
Strontium	plants (mg/kg) meat (mg/kg) water (mg/L)	37 1.67 0.22	0.012	0.019
Vanadium	plants (mg/kg) meat (mg/kg) water (mg/L)	1.65 nd 0.004	0.00035	0.049
Composite				
Arsenic	plants (mg/kg) meat (mg/kg) water (mg/L)	0.06 nd 0.001	0.000027	4.6
Beryllium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.02 nd 0.001	0.000019	8.4
Benzo(a)pyrene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.002 nd 0.00000061	0.00000041	0.29
Benzo(a) anthracene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.0098 nd 0.0000047	0.000002	0.15

nd=not detected

Table VI.6-21 Reclaimed Landscape Exposure (HH-5, Part B, with End Pit Lake Water)

Chemical	Media	Exposure Concentrations	EDI (mg/kg/day)	ER
Child				
Barium	plants (mg/kg) meat (mg/kg)	17.4 0.64	0.012	0.17
Boron	plants (mg/kg) meat (mg/kg)	49.8 nd	0.031	1.8
Cadmium	plants (mg/kg) meat (mg/kg)	0.35 0.054	0.00031	0.31
Chromium	plants (mg/kg) meat (mg/kg)	0.85 0.31	0.0011	0.21
Copper	plants (mg/kg) meat (mg/kg)	3.05 10.1	0.019	0.19
Lead	plants (mg/kg) meat (mg/kg)	0.24 nd	0.00015	0.041
Molybdenum	plants (mg/kg) meat (mg/kg)	0.79 0.56	0.0015	0.29
Selenium	plants (mg/kg) meat (mg/kg)	0.11 0.28	0.00055	0.11
Strontium	plants (mg/kg) meat (mg/kg)	37 1.7	0.026	0.04
Vanadium	plants (mg/kg) meat (mg/kg)	1.7 nd	0.001	0.15
Adult				
Barium	plants (mg/kg) meat (mg/kg) water (mg/L)	17.4 0.64 0.05	0.0042	0.06
Boron	plants (mg/kg) meat (mg/kg) water (mg/L)	49.8 nd 0.45	0.017	1.0
Cadmium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.35 0.054 0.0007	0.00014	0.12
Chromium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.85 0.31 0.0016	0.00037	0.074
Copper	plants (mg/kg) meat (mg/kg) water (mg/L)	3.05 10.1 0.0038	0.0072	0.072
Lead	plants (mg/kg) meat (mg/kg) water (mg/L)	0.24 nd 0.0013	0.000066	0.018
Molybdenum	plants (mg/kg) meat (mg/kg) water (mg/L)	0.79 0.56 0.095	0.0026	0.51
Selenium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.11 0.28 0.0003	0.00021	0.042
Strontium	plants (mg/kg) meat (mg/kg) water (mg/L)	37 1.67 0.30	0.013	0.022
Vanadium	plants (mg/kg) meat (mg/kg) water (mg/L)	1.65 nd 0.012	0.00051	0.073
Composite				
Arsenic	plants (mg/kg) meat (mg/kg) water (mg/L)	0.06 nd 0.001	0.000027	4.6
Beryllium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.02 nd 0.00052	0.000012	5.2
Benzo(a)pyrene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.002 nd 1.8e-22	0.0000004	0.29
Benzo(a) anthracene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.0098 nd 4.0e-18	0.000002	0.14

nd=not detected

Table VI.6-22 Baseline, Project Impacts and CEA: Air Inhalation

Chemical	Scenario	Air Concentrations	EDI (mg/kg/day)	ER
Fort McKay - Child and Adult Residents				
C2-C8 Aliphatics	Baseline	0.051	0.023	0.0028
	Project	0.09	0.04	0.0049
	CEA	0.092	0.041	0.005
C9-C12 Aliphatics	Baseline	0.04	0.018	0.04
	Project	0.051	0.023	0.051
	CEA	0.077	0.034	0.077
C6-C8 Aromatics	Baseline	0.0055	0.0025	0.014
	Project	0.0091	0.0041	0.023
	CEA	0.0095	0.0042	0.024
C9-C12 Aromatics	Baseline	0.0021	0.00093	0.011
	Project	0.0034	0.0015	0.017
	CEA	0.0036	0.0016	0.018
Fort McKay - Composite Resident				
Benzene	Baseline	0.00036	0.0000091	0.027
	Project	0.00049	0.000012	0.036
	CEA	0.00057	0.000014	0.042
Fort McMurray - Child and Adult Residents				
C2-C8 Aliphatics	Baseline	0.024	0.011	0.0013
	Project	0.042	0.019	0.0023
	CEA	0.041	0.018	0.0022
C9-C12 Aliphatics	Baseline	0.019	0.0083	0.019
	Project	0.024	0.011	0.024
	CEA	0.035	0.015	0.035
C6-C8 Aromatics	Baseline	0.0026	0.0012	0.0065
	Project	0.0043	0.0019	0.011
	CEA	0.0043	0.0019	0.011
C9-C12 Aromatics	Baseline	0.00099	0.00044	0.0049
	Project	0.0016	0.0007	0.0079
	CEA	0.0016	0.00071	0.008
Fort McMurray - Composite Resident				
Benzene	Baseline	0.00017	0.0000042	0.012
	Project	0.00023	0.0000058	0.017
	CEA	0.00025	0.0000064	0.019
Fort Chipewyan - Child and Adult Residents				
C2-C8 Aliphatics	Baseline	0.0034	0.0015	0.00018
	Project	0.0065	0.0029	0.00035
	CEA	0.0077	0.0034	0.00042
C9-C12 Aliphatics	Baseline	0.0027	0.0012	0.0026
	Project	0.0037	0.0016	0.0037
	CEA	0.0064	0.0029	0.0064
C6-C8 Aromatics	Baseline	0.00037	0.00016	0.00091
	Project	0.00066	0.00029	0.0016
	CEA	0.00079	0.00035	0.002
C9-C12 Aromatics	Baseline	0.00014	0.000062	0.0007
	Project	0.00024	0.00011	0.0012
	CEA	0.0003	0.00013	0.0015
Fort Chipewyan - Composite Resident				
Benzene	Baseline	0.000024	0.0000006	0.0018
	Project	0.000036	0.0000009	0.0026
	CEA	0.000047	0.0000012	0.0035
Lower Camp - Adult Hunter/Trapper				
C2-C8 Aliphatics	Baseline	0.34	0.056	0.019
	Project	0.56	0.091	0.03
	CEA	0.50	0.082	0.027
C9-C12 Aliphatics	Baseline	0.27	0.044	0.27
	Project	0.32	0.052	0.32
	CEA	0.42	0.069	0.42
C6-C8 Aromatics	Baseline	0.037	0.0061	0.093
	Project	0.057	0.0093	0.14
	CEA	0.052	0.0084	0.13
C9-C12 Aromatics	Baseline	0.014	0.0023	0.071
	Project	0.021	0.0034	0.1
	CEA	0.019	0.0032	0.097
Benzene	Baseline	0.002	0.0004	1.2
	Project	0.003	0.0005	1.5
	CEA	0.003	0.0005	1.5

VI.7 VEGETATION FIELD STUDY

VI.7 VEGETATION FIELD STUDY

VI.7.1 Field Methods

A vegetation sampling program was conducted specifically for the purpose of addressing stakeholder concerns regarding aboriginal consumption of locally harvested berries, leaves and roots for nutritional and medicinal purposes. Samples of three species of locally harvested plants (i.e., blueberries, Labrador tea leaves and cattail roots), along with corresponding soil and/or sphagnum samples at the base of the plants, were collected during August, 1997 in four areas:

- Suncor Lease 25 (within zone of influence of current air emissions);
- Muskeg River Mine Project area (baseline chemical concentrations);
- Mariana Lakes area, approximately 65 km south of Fort McMurray (control location); and
- West of Syncrude, outside the zone of influence of air emissions (control location).

Collection of plant and soil samples on Suncor Lease 25 and control locations was conducted by Golder Associates. Collection on the Muskeg River Mine Project site was conducted by Golder Associates in collaboration with Fort McKay Environmental Services Ltd. Although an attempt was made to also collect ratroot, no ratroot plants were observed during field investigations and therefore no samples were harvested. In the current assessment, it was assumed that chemical concentrations in ratroot would be equivalent to chemical concentrations in the cattail root samples collected in this field study. All plant species were analysed for metals and PAHs.

Soil or sphagnum samples were collected at the base of each plant that was sampled. Soil samples were collected to assist in determining if there are any significant accumulations of metals or PAH in soils, a condition that may lead to bioaccumulation into vegetation.

Detailed Methods

Five suitable test locations within the test and control sites for blueberries, labrador tea and cattail were chosen, where possible. For each sample, only the relevant parts (i.e., fruit (blueberries), leaves (labrador tea) and roots (cattail)) from three different plants of the same species were placed into one sample container. The material was thoroughly mixed and divided into two sample Whirlpak® bags, one each for metals and PAH analyses. Gloves were used at all times when handling samples. All plant samples

were stored in a cooler while in the field and were placed in a freezer until shipment to the laboratory.

The rooting media of the plants (i.e., soil, sediment or sphagnum) was also sampled. Sphagnum samples were collected and treated according to the methods described for plant samples above. Soil samples were collected using a stainless steel scoop from the surface layer (top 2-3 cm) at the base of each of the three plants sampled in each location.

The scoop was wiped with a clean cloth, rinsed with distilled water and then alcohol. Gloves were used at all times when handling samples. Sediment samples at the base of cattails were collected using an Ekman grab sampler, which was cleaned between samples according to the method described for the soil scoop above. Soil and sediment samples were placed in glass jars, stored in a cooler while in the field and were placed in a freezer until shipment to the laboratory.

VI.7.2 Analytical Results

Analytical results of the vegetation study are summarized in Table VI-48.

Table VI.7-1 Chemical Concentrations in Plant Tissue Samples [a]

Chemical	Blueberries			Labrador Tea Leaves			Cattail Root		
	Control Areas	Shell Lease 13 West	Potentially Impacted Areas	Control Areas	Shell Lease 13 West	Potentially Impacted Areas	Control Areas	Shell Lease 13 West	Potentially Impacted Areas
PAHs and SUBSTITUTED PAHS (maximum detected concentrations)									
Naphthalene/Methyl Naphthalene	<0.02	<0.02	<0.02	0.1	0.2	0.25	<0.02	<0.02	<0.02
Phenanthrene/ Anthracene	<0.01	<0.01	<0.01	0.21	0.04	<0.01	<0.01	<0.01	<0.01
INORGANICS (mean concentrations)									
Aluminum	49	0	28	29	5.60	26.4	91	315.375	295.4
Antimony	<0.04	<0.04	<0.04	0.37	<0.04	0.498	<0.04	<0.04	<0.04
Arsenic	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.9	0.62	0.95
Barium	16	9.72	6.4	68.05	89.76	87.76	12.7	25.68	19.96
Beryllium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	6	4.8	5	18.08	16.8	20.4	9.6	11	10.8
Cadmium	<0.08	0.09	<0.08	<0.08	0.08	0.09	<0.08	0.13	0.09
Calcium	1,037.67	944.4	760.5	5,171.67	5,147.6	5,330	3,306	13,148	7,170
Chromium	<0.2	<0.5	<0.2	<0.2	<0.5	0.4	0.45	0.75	0.93
Colbalt	<0.08	<0.08	<0.08	0.0975	0.2	0.1175	0.54	1.546	0.948
Copper	1.8	3.566	3.3	4.7	18.142	9.78	3.08	2.344	5.225
Iron	17	13.6	12.5	37.5	59	110.2	2,063	4,178	2,521
Lead	<0.1	<0.4	0.3	0.2	1.65	0.53	0.97	1.2	1.04
Magnesium	462	373.2	309	1,318.33	1,062	1,244	1,530	1,432	1,606
Manganese	354.67	330.6	287.5	685.67	702	650.4	290.62	143.56	279.76
Mercury	0.02	0.0175	0.015	0.03	0.026	0.034	0.038	0.032	0.04
Molybdenum	0.31	<0.4	0.105	0.086	<0.4	0.096	0.822	<0.4	0.698
Nickel	0.445	0.564	0.66	2.10	3.732	2.762	30.672	2.902	23.47
Phosphorus	1,026	736.6	645.5	1085.17	988.8	934	2,348	533	1,457.4
Potassium	4,550	4,162	1,473	4,526.67	4,620.2	4,318	17,244	6,153.6	16,620
Selenium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.2	0.6
Silver	<1	<0.08	<1	<0.08	<0.08	<0.08	<1	<0.08	<1
Sodium	<2	11.5	4	12.8	7.5	15.8	2,650	766.4	2,622
Strontium	1.17	1.328	1.05	8.52	7.794	9.54	13.5	18.996	25.46
Sulphur	675	570.6	579.5	1,143.33	987.4	1,054	1,050.8	1,820.2	1,894
Thallium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.12	0.04	<0.04
Tin	0.3	<0.08	<0.1	0.17	0.18	0.16	0.2	<0.08	<0.08
Vanadium	<0.08	<0.08	<0.08	<0.08	<0.08	0.15	0.49	2.934	3.22
Zinc	4.33	1	7	19.2	21.62	23.8	30.4	17.225	22.2

[a] Collected during 1997 vegetation study.

APPENDIX VII

CURRENT SOCIO-ECONOMIC CONDITIONS

Organization	**Municipality of Wood Buffalo - Community Services: Family and Community Support Services**
Program/Service	• Personal and family counselling services to residents of the Municipality. • Employee & Family Assistance Program (EFAP) to municipal workers and their families, external EFAP services on contract locally and out of the province. • Provision of assistance for seniors and seniors' care givers, including Meals on Wheels, Seniors' Outreach Program. • Resource and referral services for physicians, 'other EFAP programs and community agencies. • Critical incident stress intervention services; and public education.
Resources	• One team leader/counsellor, one part-time senior family counsellor, three family counsellors (one full-time and two part-time) and one program assistant. • Some programs and services have a significant volunteer input. • FCSS is a division of the Community Services Department of the Regional Municipality of Wood Buffalo; the other two divisions are Parks and Recreation and Community Development.
Key Indicator(s)	• Individual counsellor caseloads is high sometimes exceeding a full case load of 30-35 families • New cases (1996 January though July): 167 • New cases (1997 January though July): 179
Issues	• FCSS is getting more referrals from other agencies and the client base is increasing. Figures for the first half of 1997 indicate a 7% increase in new cases compared to the same time in 1996. • Face-to-face client/counsellor contact increased by 165 between 1995 and 1996 (the increase over the two-year period between 1994 and 1996 was 405. The increase in new clients between 1995 and 1996 was approximately 3%. • Fort McMurray has lost three psychologists in the last 3 months, putting added pressure on the community's other counseling resources, including FCSS. • Employee and Family Assistance program is increasingly been used probably because of greater awareness on the part of municipal employees. • Role of FCSS has expanded; More training workshops are offered and service area has expanded to include the rural areas since the municipal amalgamation.
Contact Name	Jacqueline Twining (Family Counsellor); Kathy Anderson (Family Counsellor)

Organization	**Alberta Family and Social Services**
Program/Service	• Child welfare, including the investigation and handling of child abuse and neglect cases. • Foster care, permanent wards and adoption services. • Administration and caseload management of Social Assistance program. • Coordination of services for persons with disabilities. • Administration of family maintenance agreements. • Administration and management of the Jobs Corps program.
Resources	
Key Indicator(s)	• Caseload (1996/97): 600 Employed (insufficient earnings): 19% Available for work (require intervention): 23% Unavailable for work (temporary): 21% Unable to work (permanent disability): 12% Assured Income for Severely Handicapped: 25%
Issues	• Welfare caseload has decreased over the past five years, but caseloads have increased over the last six months. • Shortage of housing and overcrowding are problems that are reflected in caseloads. • Some welfare recipients have moved to students financing. • Need for work experience placement programs. Oil sands companies could become more active in this area. • Social housing needs are critical in the community. • Lack of visible involvement by the Municipality concerning social needs.
Contact Name	Lori Cooper (Assistant Manager) & Susan Shave (Employment Services and job Corps Supervisor)

Organization	**Fort McMurray Food Bank Association**
Program/Service	• Short-term food relied through food hampers. • In cooperation with other community organizations, it delivers a new educational program called GAPS (Grocery Awareness Program Services) focusing on choice, personal responsibility, and maximizing the nutritional value of food choices.
Resources	• Core staff of 4-5 in addition to a pool of approximately 75 to 80 volunteers. • Its annual budget is approximately $200,000, funded in part by the United Way; extensive reliance on individual donations.
Key Indicator(s)	
Issues	• Number of first time users is on the rise. • Increasing rent and house prices is reducing the resources low income individuals and families have available for food purchases. • Project announcements have been vague and do not state clearly the type of jobs available and skills required to work on these projects. • Many individuals with limited skills and no resources arrive in Fort McMurray, seeking jobs which are not available. An estimated 40%-50% of clients have no real marketable skills. • Demand for Food Bank services is expected to increase from persons and families with low incomes, who may face higher living costs in the community as the oil sands projects come on stream.
Contact Name	Larry Henry (president) & Jeannine Colley (Executive Director)

Organization	**Fort McMurray Family Crisis Centre**
Program/Service	Services to women and children in crisis including: ◦ Unity House shelter program (temporary housing, food, and clothing for up to 21 days); ◦ Sexual assault program; "Adults molested as children" group program; ◦ Public education ◦ SHARE group for social interaction, friendship, and mutual support; ◦ Other non-residential services (Men's program, Family Violence Group; and ◦ Follow-up program.
Resources	◦ 15 staff + approximately 120 volunteers ◦ Shelter with 21 beds (15 of which are funded, the balance are added to meet demand). ◦ Funded in part by the United Way.
Key Indicator(s)	Number of clients served (August 1996-July 1997): ◦ Shelter program: 646 ◦ Sexual assault program: 214 ◦ Public education program: 2577 ◦ SHARE group: 418
Issues	◦ Wide range of clients, with approximately 65% consisting of low-income aboriginal women, most with children under 12. ◦ An increasing number of calls and shelter clients reveal multiple not single issues, including homelessness, mental health problems, loneliness, lack of extended family, and family violence. ◦ Difficulty to recruit and retain staff related to the comparatively low wages and benefits and the high levels of stress associated with working in the non-governmental social service sector. ◦ Difficulty to raise funds in view of the increased competition for charitable contributions. ◦ Difficulty to attract health care professionals (physicians, psychologists) to Fort McMurray places additional demands on community agencies to provide services and reduces their ability to refer clients. ◦ Resources are stretched with the current demand for services, which is expected to increase as population increases.
Contact Name	Lauri Antonichuk, Executive Director

Organization	**Fort McMurray Salvation Army**
Program/Service	• Shelter for the homeless; • Thrift store • START program for mentally handicapped individuals, which focuses on parent education & support, workshops, community access training, independent living support, job training support, respite care, funding information, and behaviour management • The Salvation Army works closely with other service agencies in the community.
Resources	• Staff of 36. • Thrift store facility. • New emergency shelter has overnight shelter capacity for 32 persons.
Key Indicator(s)	• In 1996, food, emergency accommodation, and transportation assistance was provided to 315 persons (127 adults with 149 children) and 39 single persons. • Christmas assistance packages were provided to 53 families. • Old shelter with 24 beds was virtually always full.
Issues	• Client base is very wide, especially at the Thrift Store. • The organization does not receive block funding from the province to provide specific services. Rather it relies on funding that is directly related to the individual or family that receives the service. • Unskilled individuals with no resources are the segment of population most likely requiring assistance from social and community agencies; There are indications that there is an influx of such persons into the community. • Availability of interim assistance (i.e. before employment is found or social assistance is received) is a concern. Need for a single entry point for individuals with social and financial difficulties to simplify access to services. • Need to know the specific work force requirements for the various projects announced. This will help identify potential housing needs.
Contact Name	Iris Pasareno & Bonnie Misseghers

Organization	**Alberta Alcohol and Drug Abuse Commission**
Program/Service	• Drug, alcohol, and problem gaming counselling to adolescent and adults. • Detox centre, funded by AADAC (90%) and the United Way (10%). • Public education and awareness program.
Resources	• Approximate budget for Regional Office: $170,000.
Key Indicator(s)	Rate of Admission to AADAC or agencies funded by AADAC: • Adult clients per 1,000 persons 18 years and over: 32.69 • Adolescent clients per 1,000 persons between 12 and 18: 18.57 • No of liquor stores per 1,000 persons 25 years and over: 0.43 (provincial average: 0.27)
Issues	• Intake of regional office is up by 30% over the previous year. • Increase in population, increasing difference in income levels in the community, and increased number of persons per dwelling all increase the likelihood of drug and alcohol abuse, leading to increased client load for AADAC. • Addiction touches upon many areas (health, social services, justice) stressing the need for inter-agency cooperation. • Need for educational intervention at an increasingly early age; AADAC involved with collaborative effort to introduce appropriate curriculum materials for grades 4-6.
Contact Name	George McBeth, Area Supervisor

Organization	**Municipality of Wood Buffalo -- Community Services Department: Parks and Recreation and Community Development**
Program/Service	• Parks and Recreation operates, maintains, and provides programming for a number of municipally-owned facilities, including the pool, playgrounds, tennis courts, and park areas. • Community Development works with private-sector contractors and community groups to provide a range of services including running the three arenas.
Resources	• Parks and Recreation: approximately 25 full-time equivalent positions (FTE) • Community Development: 6 full-time equivalent positions
Key Indicator(s)	• Number of partnership agreements: 16 • Number of contractual relationships: 17
Issues	• Increased enrollment in some programs (e.g. youth soccer, adult slowpitch) is putting a strain on available facilities. • Need for increased security at recreational and sports facilities to combat vandalism. • Shifting demographics may change the type of recreational facilities that are demanded by the community. • Community Services relies heavily on volunteers, which does not to increase at the same rate as the population. It is the stable, long-term population that provides the volunteer base. • Volunteerism is expected to decline relative to total population as more temporary and short-term residents enter the region.
Contact Name	Ms. Bev Fedoruk, Ms. Kim Howell

Organization	**Golden Years Society**
Program/Service	• Range of services to seniors residing in the Municipality of Wood Buffalo, including transportation
Resources	• One executive director; society relies extensively on approximately 60-70 volunteers. • Society has a 15-passenger seat van. The Municipality operates two handi-buses, 65 and over travel free.
Key Indicator(s)	• Current membership is approximately 200, 40 of which are over 80 while the rest are between 50 and 80 years old.
Issues	• Shortage of affordable housing for seniors in the community: current rental situation is critical for seniors on fixed incomes. • There are no intermediate facilities (e.g. seniors' lodge); Plans to build a 40 unit lodge are in early stages of development • Increasing number of seniors are staying in or are moving back to the city to be close to their children. However, a high proportion of seniors do not have extended family support.
Contact Name	Sylvia Avery (Executive Director)

Organization	**The Fort McMurray Housing Coalition:** an inter-agency group that focuses on housing issues. Participants in the Coalition include: The Fort McMurray Housing Authority, Alberta Municipal Affairs, Municipality of Wood Buffalo and others.
Program/Service	• The Fort McMurray Housing Authority manages housing units and administers a rent supplement program to assist household in need to obtain suitable and affordable housing. • The Metis/Urban Housing provides affordable housing for to Metis and First Nations persons in Fort McMurray. • Unity House and the Salvation Army provide emergency shelter on a short term basis.
Resources	• The Fort McMurray Housing Authority has a volunteer board and 4.5 paid staff members • The Landlord and Tenant Advisory Board has one paid staff member. • The Fort McMurray Housing Strategies Task Force -- a volunteer ad hoc group -- prepared a housing strategies report for the Regional Municipality of Wood Buffalo in early 1997.
Key Indicator(s)	• The Fort McMurray Housing Authority has 181 housing units under direct management; all, except 4 self-contained seniors units, are located in Fort McMurray. • The Rent Supplement Program has 126 private sector rental units owned by 12 different landlords. • Metis/Urban Housing administers 21 units in Fort McMurray. • Waiting list for Housing Authority housing is approximately 120 families.
Issues	• Increasing rents and decreasing vacancies in the rental market makes it difficult for low income families to obtain suitable accommodation. • There is no single agency with the exclusive mandate for housing for low income persons. Housing issues cross many agency boundaries, making inter-agency cooperation essential. • Need to educate the community at large particularly in the area of social housing needs. 'Need to market the rent supplement program to landlords, partnership approach required.
Contact Name	Glenda Adams

Organization	**Fort McMurray School District; Fort McMurray Roman Catholic Separate School District**
Program/Service	• Elementary and secondary education. • Both systems provide French Immersion and French as a second language programming. • The Public School Board cooperates with the Francophone Coordinating Committee to provide a French school; • The Catholic school system includes a charter school. • There is one small Christian private school.
Resources	• Fort McMurray School District: 11 schools; 225 professional and 150 support staff • Fort McMurray Roman Catholic Separate School District: 8 schools ; 189 administrative and instructional staff and 75 support staff.
Key Indicator(s)	• Fort McMurray Public School enrollment (Sept. 1996): 4,542 Fort McMurray Public School enrollment (mid September 1997): 4,746 • Fort McMurray Catholic School enrollment (Seat. 1996): 3,659 Fort McMurray Catholic School enrollment (mid September 1997): 3,679
Issues	• Some schools, especially in the down town area are experiencing greater student turnover than in the past. An estimated 25% of the student population in one downtown school changed as the 1996/97 school year progressed. • Qualified staff are becoming increasingly hard to recruit, especially in specialty areas -- music, science, guidance counsellors -- for the higher grades. Recruitment issues may become more pronounced as a number of current staff reach retirement age. • Fort McMurray school authorities experienced a roughly one-third decline in revenues as part of the shift from local to province-wide education financing. • The current funding formula does not reflect the higher cost of living in Wood Buffalo as compared to the rest of the province. • Fort McMurray School District has 1 school building in excess of current needs. Facilities are likely sufficient for expected enrollment through 2000. However, some busing may be needed, especially at the high school level. • Fort McMurray Catholic School District has recently expanded their high school, freeing up space that was used by high school students in other schools. There will likely be a need for additional facilities (e.g. portables) in the Timberlea schools in 1999.
Contact Name	Fort McMurray School District; Mr. Marv Tkachuk, Superintendent of Schools.

Organization	**Keyano College**
Program/Service	• Academic upgrading. • Career certificate and diploma programs. • Trades and technology programs. • University studies, including some degree programs. • Range of non-credit programs of both a employment and personal development nature. • Customized training for employers.
Resources	• 325 full and part time employees • Total budget (1996/97): $22,500,000 • Operates three campuses: Clearwater and Mackenzie in Fort McMurray and one in Fort Chipewyan • Athabasca University and other universities (U. of A., U. of C.) provide distance education services in the Wood Buffalo region. Athabasca University operates a satellite campus in Fort McMurray.
Key Indicator(s)	• 1995/96 enrollment: 2,407 full-time; 1,329 part-time; and 5,406 non credit students. • 1996/97 enrollment: 2,507 full-time; 1,149 part-time; and 5,748 non-credit students. • Economic impacts on northeastern Alberta: wages and benefits are estimated at $15.5 million and purchase of supplies and services at $6.97 million.
Issues	• High demand for trades (particularly in heavy equipment) and business/computer training. • Anticipated increase in 1997/98 enrollment: 5% (on full-time equivalency basis). • Increasing number of female students. • College needs specific information about the cumulative employment opportunities and corresponding skill development requirements in order to respond with appropriate programs.
Contact Name	Doug MacRae, President

Organization	**Northern Lights Regional Health Services**
Program/Service	• Community/Preventive health services • Diagnostic and therapeutic services • Acute care (on an emergency, in-patient, and out-patient basis) • Continuing care • Home Care (long and short term, including palliative care)
Resources	• Modern 86-bed hospital with medical staff of 22 persons, covering all areas of specialization. • Continuing Care Centre with 30 long-term bed and 1 respite bed. • Total 1996/1997 budget (including capital): $28.3 million.
Key Indicator(s)	• Emergency room visits (1995/96):33,780 Emergency room visits (1996/97):39,200 • Total admissions (1995/96): 3,644 Total admission (1996/97: 3,828
Issues	• Difficulty in recruiting and retaining qualified medical staff. Currently the medical staff of the Northern Lights Regional Health Services is short by an estimated 19 positions. The shortage is most acute in Family Medicine. • Population-based funding is inappropriate for the NLRHC due to the dynamic nature of the population in the area. Existing population estimates, including the 1996 census, are not an accurate reflection of the current population. • The NLRH receives relatively less per person (young population), although health delivery in the region is more expensive than elsewhere in the province (geographical isolation, % of population in small aboriginal communities)
Contact Name	Mr. Dalton Russell, Chief Executive Officer

Organization **Royal Canadian Mounted Police**

Program/Service
- Crime prevention and investigation.
- Next of kin notification.
- Court services, including victim impact statements.
- Highway patrol and municipal traffic enforcement.
- Victim services, including family violence and sexual assault prevention.

Resources
- 45 officers in the urban services areas; likely to be expanded to 52 by the end of 1997
- 13 officers in the rural services area: additional funding for 4 positions has been requested.
- 9 auxiliary constables (civilian volunteers), spending on average 160 hours each per year.
- The Community Policing and Victim Services programs have two part-time positions and 30-35 volunteers. Total volunteer effort in 1996: 30,000 hours.

Key Indicator(s)

	1995	**1996**
Assault on persons:	985	1289
Robbery	25	26
Break and enter	377	485
Motor vehicle theft	199	234

Issues
- Project work force requirements and timing of construction activities are not always relayed to the RCMP in advance of their occurrence. One month lead time should be the norm.
- As compared to the 1st half of 1996, the incidence of crime has increased in the first half of 1997, ranging from assault (up 7%) to traffic violations (up 29%) and impaired driving charges (up 30%).
- Property damage has remained relatively stable over the same time period.
- Demands for police services precede the expected increases in property tax revenue as new projects come on stream, creating a financial challenge to the municipality.

Contact Name Constable Nagel and Tracy Horvath (Community Policing/Victim Services)

Organization	**Fort McMurray Fire Department**
Program/Service	• Fire suppression including airport emergency response. • Ground and air ambulance services. • Safety code and fire inspections. • Emergency 9-1-1 dispatching for police, fire, and ambulance services.
Resources	• Three fire halls in urban services area, plus an airport emergency response truck at the airport. • 42 fire fighters , 29 of whom are also emergency medical technicians; 4 senior managers (Fire Chief, Deputy Fire Chief, Fire District Chief, and Chief Training Officer); 7 Emergency 9-1-1 dispatchers, 3 of whom are part-time; 4 office support staff. • Emergency response agreements with Suncor and Syncrude. • Volunteer fire department in Fort Chipewyan, Fort McKay, Saprae Creek, Anzac and Conklin. • Total budget of $5.5 million, of which $4.9 million is supported by taxes.
Key Indicator(s)	• Total emergency calls (fire and ambulance) 1995: 2,230 • Total emergency calls (fire and ambulance) 1996: 2,544 • Total emergency calls (fire and ambulance) 1997 (Jan-Jul): 1,755
Issues	• Emergency call volumes are increasing, reflecting an increase in population and the social/health effects of an improved regional economy, such more "partying", and more overtime. • Additional manpower demands are anticipated (8 additional fire fighter/EMTs, a Medical Services Officer, a Fire Safety Officer, and 1.5. additional support staff). • Additional housing development in the Timberlea area may require expanding Fire Hall #3 or building a new fire hall. • Ongoing difficulty to retain highly trained fire fighter/EMTs.
Contact Name	Harvey Marchand, Fire Chief

Organization	**Human Resources Development Canada**
Program/Service	• Administration of the Employment Insurance and other income security programs. • Employment counselling and placement. • Labour market analysis.
Resources	• Total staff complement: 12 • Number of counsellors: 3 • Number of needs determination counsellors: 2
Key Indicator(s)	• Unemployment rate: August 1997: 3.6% Number of job inquiries from across Canada has increased dramatically over the last year.
Issues	• Most of the services currently offered by the department will be handled by the provincial government by the end of 1997. The department will continue to provide labour market information. • Project announcements need to be more specific regarding the timing of projects and the number and skills of workers required to counter the unrealistic expectations of many individuals regarding work in the oil sands industry. • Generally high skill levels required for work at the oil sands plants, limiting the opportunities to place entry-level workers. • Labour market information gathered by the department is not specific to Fort McMurray or Wood Buffalo. It covers the whole northeastern part of the province from the NWT border down to Camrose.
Contact Name	Darrel Monson, Acting Manager and Pat Browning

Organization	**Alberta Advanced Education and Career Development**
Program/Service	• Career counselling, including courses in resume preparation and job search methods. • Short-term skills training programs. • Administration of the Apprenticeship program.
Resources	• 2 career counsellors • 2 apprenticeship consultants • 1 manager • administrative support.
Key Indicator(s)	• 85% increase in new apprenticeship applications over the past year.
Issues	• Resources stretched with the current work load. • Federal programs with respect to human resources training are being transferred to the provinces. • No plans to increase resources to meet Increased demand related to resource development; transfer of federal training programs to AE&CD is expected to lead to increased efficiencies. • Project announcements need to be more specific regarding the timing of projects and the number and skills of workers required to increase the ability of AE&CD to direct and train people for the job opportunities.
Contact Name	Dan Szoo, Area Manager

Organization	**Northeastern Alberta Aboriginal Business Association**
Program/Service	• Promotion of aboriginal businesses. • Facilitation of training and employment placement for aboriginal persons.
Resources	• Executive Director and administrative support.
Key Indicator(s)	• Member companies employ more than 500 people. • On average, 1/4 to 1/3 of member companies work force are of aboriginal ancestry. The work force of some companies is close to 80% aboriginal.
Issues	• Need for early communication (start of project planning process) between the association and the oil sands companies, allowing member companies to identify business opportunities and sufficient time to prepare bids. • Would like to receive bidding package at the same time as other organizations in the region. • Business and employment opportunities created by the oil sands companies should focus on local resources. • 13% Aboriginal employment is an appropriate target for oil sands companies to achieve. Syncrude is meeting the goal while Suncor is trying. Other proponents should endorse the 13% target.
Contact Name	Rose Bilou, executive director and Doug Goloski.

Organization	**Regional Business Development Centre (a program of Western Diversification)**
Program/Service	• Personal counselling services to residents of the Municipality, Employee & Family Assistance Program (EFAP) to municipal workers and their families, external EFAP services on contract locally and out of the province. • Business library in support of small business development. • Ad hoc initiatives in support of small business development; current involvement includes housing and doctor recruitment.
Resources	• Total number of employees: 9 • Loan fund of $3 million. (maximum loan amount is $70,000, average outstanding loan is $37,000)
Key Indicator(s)	• Number of loan applications: First Quarter 1997: 8 • Outstanding loan amount: $2 million.
Issues	• Number of loan inquiries up substantially over the past year. • Quality of proposals is up, which is providing the Business Development Centre with the opportunity to build a quality loan portfolio. • Resources of the Regional Business Development Centre are becoming overloaded; there may be a need for additional loan officers.
Contact Name	Mr. Bryan Bailey, Executive Director

Organization	**Fort McMurray Visitors' Bureau**
Program/Service	• Marketing and promotion of local and regional tourism amenities. • Provision of tourism information. • Production of a community directory. • Organization of two annual trade shows.
Resources	• Member-based organization with annual budget of about $100,000. • Staff include an Executive Director and seasonal tourist information personnel. • Port of Entry visitor centre.
Key Indicator(s)	• 1996 Visitor Bureau statistics: Number of information requests: 530 Number of Guest Book entrees: 412 Number of bus tours: 675 • Trade show attendance is in excess of 25.000 persons.
Issues	• Use of local campgrounds by non-tourists (i.e. people waiting for fixed roof accommodation in the City) limits the ability of the Visitors' Bureau to expand the tourism industry in the area. • Increased traffic on Highway 63 and particularly the increased number of oversized and heavy loads increases the barriers to road-based tourism traffic. • Need to upgrade tourist facilities particularly campgrounds. • Several local motels and hotels have begun -- or have recently completed -- major renovations, which may alleviate the situation of very low vacancy rates in fixed roof accommodation, which is a barrier to further expansion of the tourism industry..
Contact Name	Angele Dobie, Executive Director

Issue Area	**Housing**
Description	• Provision of single and multi-family housing by private sector developers.
Resources	• In early 1996, the urban service area of Fort McMurray had 11,382 occupied and 585 unoccupied dwellings. An estimated 63% consists of single family houses, 23% apartments, and 14% mobile homes. • Saprae Creek is a rural residential subdivision in close proximity to the urban services area of Fort McMurray.
Key Indicator(s)	• Housing starts: • 1997 (to mid August): 306, including 50 starts in Saprae Creek • 1996: 106 • 1995: 22
Issues	• Development is currently focused on single family dwellings. There is little or no activity with respect to multi-family dwellings. • Fort McMurray has become one of the most expensive real estate markets in the province, with the average house prices in excess of $150,000. • The rental market is experiencing near zero vacancy rates, and there is upward pressure on the rental rates. • There are concerns regarding the ability to obtain additional land for development in view of the fact that most land outside the urban service area of Fort McMurray is crown land. • Some question of the ability of private sector to develop large tracts of land for housing beyond the land already developed with all or just deep services.
Contact Name	Greg Walsh, President, Fort McMurray Real Estate Board.

Issue Area	**Municipal Services**
Description	• Water treatment and distribution • Sewage collection and treatment • Solid waste collection and disposal.
Resources	• Relatively new water treatment plant in Fort McMurray with capacity for about 60,000 persons. • Sewage plant is capable of handling a population of around 55,000. • Landfill site nearing capacity.
Key Indicator(s)	• Municipal water production (ML) 1996: 5,100 1995: 4,673 1994: 5,035
Issues	• A new water supply line and booster system may be required in the near term to accommodate the housing expansion in the Timberlea area. • New landfill is under development.

Issue Area	**Power and natural gas**
Description	• Alberta Power is the main provider of electrical power. • Northwestern Utilities (NWU) provides natural gas services to residential and commercial customers throughout Wood Buffalo.
Resources	• NWU has 15 full-time and an additional 10-15 seasonal employees (summer months)
Key Indicator(s)	• NWU: 10,500 customers in Wood Buffalo
Issues	• Tight labour market in the region may drive up the cost of servicing by means of local wage inflation and the need to bring in workers from outside the area. • Need to know timing of construction activities to be able to meet demand for residential services.

Issue Area	**Air Transportation**
Description	• Scheduled air service to Edmonton and Calgary provided by Canadian Regional and Air BC. • Scheduled air services to Fort Chipewyan provided by Contact Air. • Charter aircraft services (fixed wing, helicopter) provided by a number of companies in Fort McMurray.
Resources	• Fully equipped airport with runway capable of accommodating jet traffic. • Air BC and Canadian Regional use turboprop planes to provide passenger services between Edmonton/Calgary and Fort McMurray. • Contact Air has a fleet of nine planes to provide scheduled and charter service.
Key Indicator(s)	• Air BC has 2 daily flights from Edmonton + 1 non-stop flight from Calgary (except weekend). • Canadian Regional has 5 daily flights from Edmonton (except weekend). • Contact Air has 2 daily flights to Fort Chipewyan (except weekend). • Number of enplaning/deplaning passengers was up by 19% in 1996 and another 16% in the first half of 1997, after a period of marginal decline starting in 1990.
Issues	• The federal government is about to withdraw from operating the airport. The Municipality is evaluating proposals of parties interested in operating the facility. • Most passengers use the service for business purposes. A low cost carrier provided services for some time in 1996, but withdrew from the market. • Morning and evening flights are the busiest. If demand warrants, larger aircraft could be used as opposed to adding new flights.

Issue Area	**Water Transportation**
Description	• Scheduled and unscheduled barge service from Fort McMurray to Fort Chipewyan and points in Northern Saskatchewan and the Northwest Territories.
Resources	• Tug and barges provided by two private operators.
Key Indicator(s)	• Scheduled service: one trip per month.
Issues	• Future road access to Lake Athabasca in Saskatchewan or Alberta will likely affect barge routes and schedules. • Dredging by the Canadian Coast Guard has ceased.

Issue Area	**Land Transportation**
Description	• Scheduled and charter bus service between Fort McMurray and Edmonton. • Freight train service between Lynton Landing to Edmonton. • Intra municipal bus service in the urban services area of Fort McMurray.
Resources	• Highway 63 (paved) from Edmonton to Fort McMurray and Fort McKay and beyond. • Highway 881 (paved) from Fort McMurray to Anzac, Janvier and Conklin. • Winter roads between Fort McMurray and Fort Chipewyan and La Loche (Saskatchewan). The former is operated and maintained by Alberta Transportation, the latter by private individuals. • Railway track from Edmonton to Lynton, just south of the urban services area of Fort McMurray.
Key Indicator(s)	• Four daily scheduled buses by two companies between Fort McMurray and Edmonton. • Commuter bus service to and from Syncrude (75 coaches) and Suncor (25 coaches) plants. • Number of buses in public transit system: 19 • Average Daily Traffic Count on Highway 63 in 1996, south of Suncor turnoff: 4300 north of Suncor turnoff: 3200 south of Ft. McKay turnoff: 190
Issues	• Heavy traffic, especially during rush hours, between urban service area, the Suncor turn-off, and Syncrude's Mildred Lake plant; essentially bumper to bumper traffic slowing down the average speed from 100 km/h to 75-80 km/h. • Turn-off at Suncor improved with new off-ramp; turn-off at Syncrude at times difficult due to south bound traffic. • Reliance on one major highway underlines the vulnerability of the region to possible traffic disruptions as experienced by the fire-related road closures in 1996. • Extension of the Edmonton-Lynton rail track to the Syncrude and Suncor plants is not under active consideration by RaiLink, but could be considered in the future if warranted by freight volumes.

Issue Area	**Telecommunication**
Description	• Radio and television service • Telephone service
Resources	• Fort McMurray has 2 local AM and FM stations, CJOK and CKYX, respectively: Shaw Communications provides additional 16 radio stations and 54 television channels through its cable connections. • Telus is the main telephone service provider.

Issue Area	**Land Use**
Description	• Municipality of Wood Buffalo is the approval authority for all development and building permits. • Applications with regard to energy resources, including pipelines, are within the responsibility of the Alberta Energy and Utilities Board.
Resources	
Key Indicator(s)	
Issues	• Pipeline corridor runs through urban service area of Fort McMurray, sterilizing a swath of land for development. • Approvals by the EUB takes precedent over municipal bylaws; the municipality's role in the approval process for energy projects is limited to that of intervenor in the EUB process.

Issue Area	**Regional Economy**
Description	◦ Regional economy is dominated by the oil sands industry, with two large operations, Syncrude and Suncor, located just north of the urban service area of Fort McMurray. ◦ Oil sands development may increase the oil sands mining operations in the Fort McKay area; commercial *in situ* operations may develop, mainly in the Conklin/Janvier area. ◦ Gas and some conventional oil activity is concentrated mainly in the southern half of the municipality. ◦ Forestry activity is dominated by logging and hauling for the ALPAC pulp mill in Boyle, which is located outside the Municipality of Wood Buffalo; logging of coniferous saw logs is carried out by Northlands Forest Products. ◦ Tourism industry activity is located throughout the municipality, although most of the tourism infrastructure is concentrated in the urban service area of Fort McMurray. The northern part of the municipality is adjacent to the Wood Buffalo National Park.
Issues	◦ Logging operations are seasonal and shift locations, thus contributing little in terms of assessment and hence property tax income for the Municipality, while using provincial, municipal, and private roads to haul logs to the mill. ◦ Oil sands mining activity affects the ability of the area to sustain forestry operations; Land disturbance due to mining reduces the annual allowable cut available to forestry operations. ◦ The status of gas reserves in oil sands mining leases is under review by the Energy Utilities Board. ◦ For issues related to Tourism, see section on the Fort McMurray Visitors' Bureau.

APPENDIX VIII

URBAN POPULATION IMPACT MODEL

VIII.1 INTRODUCTION

VIII.1.1 Background

The oil sands industry is expanding. The Suncor Steepbank Mine project is well underway and the Syncrude Aurora Mine has recently been approved by the regulators. Other projects, including the Shell Muskeg River Mine Project (Lease 13W), Mobil's Kearl Oil Sands Mine, Suncor's Project Millennium, Gulf's Surmount project, and the Syncrude 21 suite of projects have gone through the disclosure process, which starts the regulatory proceedings. Other projects may come forward.

The geographic focus of the oil sands industry development is the Regional Municipality of Wood Buffalo. Most development is expected to take place in the Fort McKay area, just north of the urban service area of Fort McMurray. Some development may take place as well in the southern half of the municipality, closer to the smaller communities of Janvier and Conklin. Although the smaller communities in the municipality will no doubt be influenced by continued oil sands industry expansion, the major socio-economic impacts are expected to occur in the urban service area of Fort McMurray, the administrative and population centre of the region.

The rapidly evolving situation in the region presents challenges to municipal and other service providers. What are the impacts of current and future projects in terms of population? What impact does the population growth have on services? What measures can be undertaken to amplify the positive impacts (such as employment and income growth) and mitigate the negative ones (such as stress on the local housing market)?

To address some of these questions and to give service providers in the region with a comprehensive oil sands industry outlook, the Regional Infrastructure Working Group, a collaboration between oil sands industry firms and the Regional Municipality of Wood Buffalo, commissioned Nichols Applied Management to develop a population impact model for the urban service area. It also commissioned a socio-economic baseline study. Additional baseline and impact assessments with respect to the outlying communities are undertaken by community-based groups on behalf of different project proponents. This document discusses the Urban Population Impact Model part of this study. The baseline information is provided under separate cover.

VIII.1.2 What Is A Population Impact Model?

New oil sands project development or the expansion of existing industrial plants in the region leads to new employment opportunities. If the new employment creation is in excess of the labour force capacity of the local economy, people will migrate into the region to take up jobs, thus leading to

an increase in population. The population will further increase as the new migrants bring along partners and children and as new jobs are created to support and supply the new projects and to provide the service sector infrastructure. These flows of people can be modelled and the resulting population model will provide a forecast of future population levels.

A population impact model is a variant of a population model in that it can accommodate essentially two scenarios: a *base or without development* case, which models the population assuming no new projects and a *with development* case, which estimates future populations assuming additional economic activity. The difference between these two cases is the population impact, hence the name: population impact model.

The *base or without development* case as defined by the model assumes that the Suncor Steepbank and Fixed Plant Expansion projects will go ahead, as well as the Syncrude Aurora Mine and Debottleneck I projects. All of these projects have received regulatory and company approval.

VIII.1.3 What Is Different About This Population Impact Model?

Historically, population impacts have been analyzed as an input to the regulatory approval process of projects. In the oil sands industry context, these analyses were conducted relatively infrequently as new, often very large, projects came forward. Again historically, population impact analyses have been documented in paper-based reports, providing a static snap-shot population forecast.

As the oil sands industry development shifts from stand-alone mega-pattern (such as Suncor and Syncrude) to a regional multi-project, multi-proponent model, the dynamics of the region change as well. Change is occurring as several different proponents come forward with projects of different size and complexity and with different time lines. Thus, the socio-economic conditions, including population numbers, are very much in flux, necessitating frequent updates of the population forecast.

This population impact model is based on an electronic spreadsheet, designed to allow updates as new information comes forward. In addition, the model is designed explicitly from a regional perspective, bringing into focus the cumulative effects of the various projects. The regional perspective notwithstanding, the Urban Population Impact Model can be used as well to assess the impacts on the population of a single oil sands project or a particular set of projects.

VIII.1.4 Scope

The population impact model focuses on the urban service area of Fort

McMurray, which is expected to be the focal point for socio-economic impacts. This scope coincides with that of the companion baseline report.

The outlying communities and, generally, the rural area of the municipality will be the subject of separate baseline and impact work conducted by the communities themselves. This recognizes the uniqueness of the aboriginal communities and the special relationship that oil sands companies have or are establishing with them.

Oil sands projects are the main area of emphasis of the model, although it can be adapted to accommodate other projects as well. In focusing on oil sands projects, the model does not imply that the regional economy does not include other activities. Indeed, the regional economy incorporates forestry, tourism, conventional oil and gas, and other economic activities and these are reflected in base case population numbers. What the model does imply is that the largest changes to the regional economy are likely related to the expansion of the oil sands industry.

VIII.1.5 Methodology

The population impact model was developed by Nichols Applied Management under the direction of a small ad hoc subcommittee of the Regional Infrastructure Working Group. The study team was assisted with respect to the detailed design work by Ms. Kerrie Hale of Robertson Hale Associates and all aspects of the work were reviewed by Golder Associates. A subset of the model – the cohort survival analysis – was discussed with Dr. Lalu of the Population Research Laboratory of the University of Alberta.

The population impact model grew out of earlier work conducted by Nichols Applied Management in the areas of population forecasting and socio-economic impact analysis. The assignment consisted of the following steps:

- the development, review, and amendment of a conceptual model design;
- a critical re-evaluation of all assumptions made in previous work and a further analysis of selected issues, such as the treatment of public sector workers, the timing of project impacts, and the size of the regional multipliers;
- the development, review, and amendment of a detailed design document;
- the implementation of the detailed design parameters and the coding of the model relationships; and
- the testing of model assumptions, implementation, and output.

Participating oil sands developers provided the latest available work force estimates for input in the model, ensuring that the model is based on the best available data. The overall process was subjected to a peer review process by Golder Associates.

VIII.2 MODEL DESCRIPTION

VIII.2.1 Key Drivers

The Urban Population Impact Model has three key drivers. They are:

- new employment in the oil sands industry
- factors -- or multipliers -- that gross-up the direct employment to include as well the employment created by suppliers to the oil sands developers (indirect jobs) and the new jobs required to meet the needs of the direct and indirect workers, such as food, housing, health care, etc. (induced jobs)
- the inescapable fact that every year, everybody is a year older. Each age brings with it a known chance of dying and, in the case of women, a known chance of having children (age cohort survival)

Two of these three main drivers of the model are known with some precision. The project proponents have a good fix on total work force requirements for their projects and the fertility and mortality rates are gathered on a provincial basis by Statistics Canada.

The third driver -- the multipliers -- are known but with less precision. On a provincial level, multipliers are derived from a province-wide input-output model maintained by Alberta Treasury. This organization publishes the resulting industry-level multipliers periodically, the latest publication being *Alberta Economic Multipliers*, dated 1996.

There are two methodological issues related to using the published multipliers for the estimation of the population in a sub-provincial area, such as the Regional Municipality of Wood Buffalo or the urban service area of Fort McMurray. They are:

- the oil sands industry is not recognized as a separate industry in the input-output model, but rather incorporated in the Crude Petroleum and Natural Gas industry (SIC 07)
- no published multipliers for sub-provincial areas are available, thus necessitating their estimation.

These issues notwithstanding, the multiplier methodology is broadly

accepted as an approach to estimate future population levels starting from work force estimates. To enhance the applicability of the methodology, the study disaggregated the oil sands projects into construction, mining, *in situ*, and upgrading projects and derived multipliers for each of these types of projects. With respect to the regional versus provincial multipliers, the study team conducted some research that indicates that the indirect and induced jobs in the region are approximately half of the provincial number.

A subsequent section of this report captures the size of the multipliers used and presents the results of a sensitivity analysis that indicates that the model results are not significantly affected by changes in the multiplier and other assumptions.

VIII.2.2 Assumptions

The model estimates future population levels. Because the future is not known, the model includes a number of variables of unknown size. For example, the age profile and family situation of people who will come to the region to take up project construction and operational jobs is not yet known because most projects are still a number of years into the future.

Table VIII-1 captures the key variables, shows the default setting for each variable, and indicates the sensitivity of the population estimates to changes in these variables. Because the population impact model is computer-based, these assumptions can be adjusted as new information comes forward.

Table VIII-1 shows that the model generally dampens the impact of varying any one assumption. This indicates that the model is not particularly sensitive to any one assumption. Insofar as the chance that all default values are over- or under-stated is small (one would expect that some variables are over- and some under-stated), it follows that the model results are relatively robust within the relevant range of the variables.

Table VIII-1 Key Assumptions and Results of Sensitivity Analysis

	Default Setting	Impact on Population Estimate	
		2001	2021
Ratio of direct jobs to indirect/induced jobs	mine: 1 to 1.26		
	upgrader: 1 to 1.33		
10% higher		+1.4%	+1.0%
10% lower		-1.3%	-1.0%
Total project operations work force:	depending on scenario		
10% higher		+0.1%	+1.3%
10% lower		-0.1%	-1.4%
Percent of retired people leaving:	65%		
60% leaving		-0.2%	-2.2%
40% leaving		+0.2%	+2.2%
Labour Force Participation (ages 18 to 60):	85%		
10% higher		-1.7%	-1.7%
10% lower		+2.1%	+2.1%
Housing Starts Per Year:	350		
10% higher		+0.6%	0.0%
10% lower		-0.6%	0.0%
Regional work force outside urban service area:	5%		
2.5% of work force		+0.2%	+0.1%
7.5% of work force		-0.2%	-0.1%

APPENDIX IX
Key Reference Reports

KEY REFERENCE REPORTS

The following reports are considered Key Reference Reports for the Project Millennium Environmental Impact Assessment

Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region. April 1998. By Golder Associates and Conor Pacific for Suncor Energy Inc., Oil Sands and Syncrude Canada Ltd.

Winter Aquatics Surveys - Steepbank River, Shipyard Lake, and Lease 19, 25 and 29. July 15, 1997. By Golder Associates for Suncor Energy Inc., Oil Sands.

Oil Sands Regional Aquatics Monitoring Program (RAMP) 1997. March 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands, Syncrude Canada Ltd. and Shell Canada Limited.

Project Millennium Conceptual Plan for "No Net Loss" of Fish Habitat. Version 1. March 20, 1998. By Golder Associates for Suncor Energy Inc., Oil Sands.

Suncor Project Millennium - 1997 Fall Fisheries Investigations. March 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

1997 Synthesis of Environmental Information on Consolidated / Composite Tailings (CT). April 1998. By Golder Associates for Suncor Energy Inc., Oil Sands.

Hydrogeology Baseline for Project Millennium. April 1998. By: Klohn-Crippen for Suncor Energy Inc., Oil Sands.

Hydrology Baseline for Project Millennium. April 1998. By Klohn-Crippen for Suncor Energy Inc., Oil Sands.

Soil and Terrain Baseline for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Terrestrial Vegetation Baseline for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Wetlands Baseline for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Forestry Resources (AVI) Baseline for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Ecological Land Classification Baseline for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Winter Wildlife Surveys - Steepbank River Valley, Shipyard Lake and Lease 25 and 29 Uplands. December 1997. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Wildlife Baseline Conditions for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Wildlife Habitat Suitability Index (HSI) Modelling for Project Millennium. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Historical Resources Impact Assessment for Suncor's Project Millennium. Permit #97-123. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.

Traditional Resource Use in Fort McKay and Neighbouring Communities - Archival Sampling Program. April 1998. By: Golder Associates for Suncor Energy Inc., Oil Sands.