Athabasca River Water Releases Impact Assessment

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Prepared for:

Suncor inc.

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This report is one of a series of reports prepared for Suncor Inc. Oil Sands Group for the Environmental Impact Assessment for the development and operation of the Steepbank Mine, north of Fort McMurray, Alberta. These reports provided information and analysis in support of Suncor's application to the Alberta Energy Utilities Board and Alberta Environmental Protection to develop and operate the Steepbank Mine, and associated reclamation of the current mine (Lease 86/17) with Consolidated Tailings technology.

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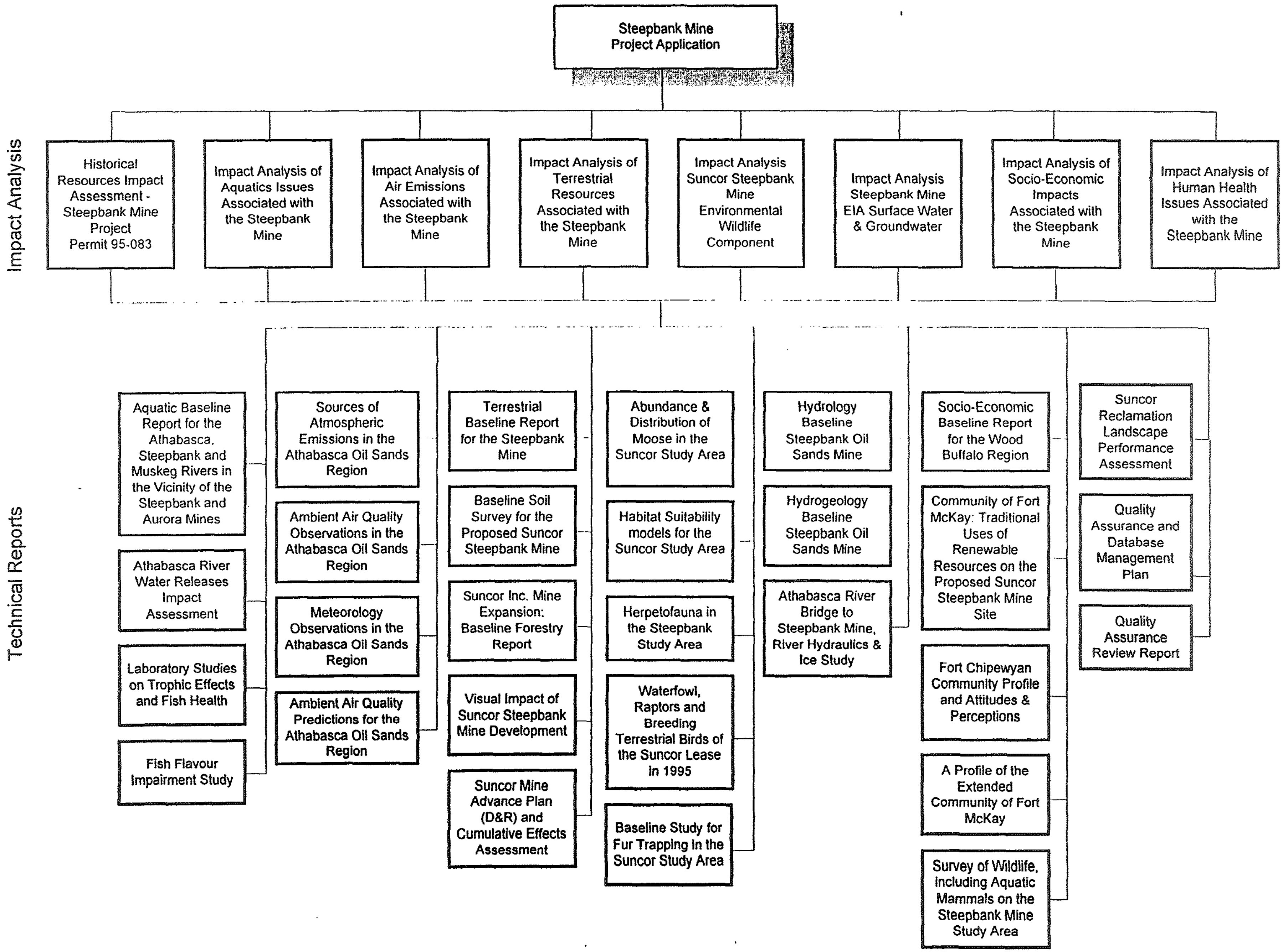

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1.0 INTRODUCTION

Suncor Inc., Oil Sands Group (Suncor) has developed a plan to reclaim its existing Leases 86 and 17 plus the proposed Steepbank Mine. A key component of this reclamation plan involves the use of CT to form trafficable surfaces upon which a diversity of native plants will grow. The reclaimed landscape will provide habitat for a wide variety of wildlife and could be used by people for recreational and traditional activities.

One of the consequences of the use of CT for reclamation is that large volumes of water will be produced as a result of the consolidation process, and that this water must to be managed. Although not yet fully defined, it is expected that most of the CT release water will be recycled, however, a small portion may need to be discharged to the Athabasca River. In addition to the possible discharge of CT water, a variety of other waters are currently released, or might in the future be released, from the existing or proposed mine operations. These releases water include mine drainage waters, seepage from tailings dykes, treated sewage effluent and refinery wastewater and cooling water. This report addresses the potential impacts associated with these water releases on the health of people, wildlife and aquatic biota that either now or in the future might use the Athabasca River, downstream of Suncor's operations. The ecological sustainability of the reclaimed landscape and the potential health impacts from exposure to chemicals by people and wildlife that might use reclaimed site are the subject of a separate report (Golder 1996a).

2.0 FRAMEWORK

The Oil Sands Water Release Technical Working Group (OSWRTWG) was established in 1995 to evaluate the issue of water releases from current and future oil sands operations (OSWRTWG 1996). The group consisted of government and industry representatives and made a number of suggestions as to how to assess potential impacts from water releases. It was recognized that release of water to the environment will occur as part of both the operation and reclamation of oil sands facilities. More specifically, two categories of release waters were recognized - operational and reclamation waters.

The Oil Sands Water Release Technical Working Group (OSWRTWG) classed water releases into two groups: operational and reclamation waters (OSWRTWG 1996). Operational waters are defined as those waters that are:

- discharged from a channel or outfall (i.e., point source),
- discharged over the life of the project, or a shorter time-frame,
- controllable,
- treatable in a managed treatment system,
- amenable to comparing to ambient water quality criteria, and
- potentially of concern with respect to regional off-site impacts.

Sources of operational waters include:

- consolidated tails (CT)
- drainage water collected from dykes and structures,
- mine drainage
- upgrading process,
- cooling water, and
- sewage treatment facility.

Reclamation waters are defined as those waters that are:

- non-point source, diffuse waters that may be directed through wetlands, streams or lakes prior to discharge into the Athabasca or Steepbank Rivers,
- 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 concern and a component of a maintenance-free reclamation landscape.

Sources of reclamation waters include surface runoff and groundwater seepage from:

- sand dumps and dykes,
- CT deposits,
- coke piles, gypsum storage units and other waste dumps,
- overburden dumps and dykes, and
- wetlands treatment systems.

It is important to note that release of operational waters will cease after mine operations are complete, whereas reclamation waters are released during mine operations and will also continue to be released following mine reclamation. Different management strategies are required for each type of release water. In general, for operational waters, the focus needs to be directed towards protection of the receiving environment, whereas for reclamation waters, the focus should be directed towards assessing on-site, ecological sustainability and minimizing impacts to users of the reclaimed landscapes. In addition, assessment of potential impacts related to water releases requires that the cumulative impacts arising from both operational and reclamation water releases be addressed.

The findings of OSWRTWG provide the general framework for assessing potential impacts associated with water releases from Suncor's current and future operations. Specific details of the approach are described below.

2.1 Aquatic Biota

The general approach for assessing potential impact from water releases on aquatic biota is shown schematically in Figure 2.1-1. Three separate components were examined in detail: whole effluent toxicity, chemical-specific effluent quality and ecological assessment of the receiving water body. Examination of all three of these components offers maximum information with respect to assessing potential impacts of water releases on a receiving water body .

This framework followed in this assessment is shown in Figure 2.1-2 and summarized below:

1. A wasteload allocation, following Alberta Environmental Protection (AEP) protocols for screening effluent quality, was applied to identify which chemicals present in release waters are of potential concern with respect to the health of aquatic biota in the receiving water,
2. The wasteload allocation approach was also used to identify potential problems related to acute and chronic toxicity of the release waters,
3. A risk-based approach was used to quantify existing impacts and predict future impacts on aquatic ecosystem health.

The wasteload allocation protocol was developed to assist in setting water quality based effluent limits for a single effluent discharge. This approach was modified to account for the multiple sources of release waters associated with Suncor's existing and future operations. Details of the approach are given in Appendix VI.

The risk-based approach provides specific information on potential impacts of water releases on ecologically-relevant endpoints. Information from laboratory, field and computer modelling studies are integrated to quantify changes in measurable endpoints that could be considered harmful to aquatic biota. These predictions are used to quantify existing impacts and predict future impacts on aquatic ecosystem health. Details of this approach are given in Section 4.0.

2.2 Human and Wildlife Health

A risk assessment framework was followed to assess potential impacts to the health of people and wildlife that might arise as a result of release of operational and/or reclamation waters from Suncor's existing and proposed operations. Risk assessment is a component of the integrated risk management process and its application provides information about estimated health risks associated with exposure to chemicals. The risk assessment framework used in this report is consistent with approaches developed by Environment Canada (1994), Health Canada (1995) and U.S. EPA (1994) and consists of four major components as shown in Figure 2.2-1.

- Problem Formulation
- Exposure Assessment
- Effects Assessment
- Risk Characterization

Risk Analysis

The objective of the first phase, Problem Formulation, is to develop and document a site-specific Conceptual Model to be used in the Exposure and Effects Assessment phases. The results of the exposure and effects assessments are integrated to provide an estimate of risk in the Risk Characterization phase.

Considerable effort is expended during the Problem Formulation phase to thoroughly screen chemicals, exposure pathways and receptors to identify the pertinent ones that need to be included in subsequent phases of the risk assessment. A conservative approach is followed during these screening steps to ensure inclusion of the specific constituents and exposure pathways that may contribute significantly to risk. At the same time, those exposure pathways and chemicals that are insignificant or irrelevant to this specific assessment are removed from further consideration. The ultimate goal of the Problem Formulation phase is to develop a site-specific Conceptual Model, which illustrates how chemicals of potential concern may reach specific receptors, thus potentially creating a health risk.

Risk Analysis involves two discrete components: 1) Exposure Assessment, and 2) Effects Assessment. Exposure Assessment is the process of estimating the daily intake rate (dose) of a chemical that might be received by a person under a given exposure scenario. Effects Assessment is the process of assembling information on chemical intake rates (doses) that cause particular effects and developing reference values. Reference values for people are based upon daily exposure limits developed primarily by regulatory agencies such as Health Canada or the U.S. EPA. For wildlife, reference limits are based on laboratory studies and literature information and are derived according to protocols suggested by Environment Canada and U.S. EPA.

Risk Characterization is the integration of information from the exposure and effects assessments plus other pertinent environmental studies. It involves a quantitative comparison of estimates of predicted doses to the reference value. This information along with findings from other field and laboratory investigations are integrated, using a weight-of-evidence approach, to assess whether the reclaimed landscape poses a significant risk to the health of people or wildlife that might use the site.

3.0 WATER RELEASES

3.1 Water Release Scenarios

A variety of operational and reclamation waters are currently released and will in the future be released from Suncor's existing and proposed operations. Details of the water and wastewater management plans are given in Suncor's Fixed Plant Expansion Application and in the Steepbank Mine Application and details of the existing and future water balance from the existing Leases 86 and 17 and from the Steepbank Mine are given in AGRA (1996) and Klohn-Crippen (1996), respectively. This information is summarized below for five time periods - 1995, 2001, 2009, 2020 and long-term conditions. These time "snapshots" were selected for detailed analysis since each one represents a distinct change in wastewater management, mining and/or reclamation practice that will lead to changes in the reclamation landscape and water release scenarios.

The following discussion lists the primary operational and release waters for each time period that was assessed. The location of discharge points are shown in Figure 3.1-1 and predicted flows are summarized in Table 3.1.1. It is important to recognize that the information presented below is preliminary in nature and may change as mining plans and research into CT consolidation rates advances. In particular, the timing and volumes of these releases might change. Nonetheless, these possible changes are not expected to significantly alter the results of this assessment.

3.1.1 1995 (Baseline Conditions)

Lease 86/17:

Discharge Location	Major Sources
Ruth Lake/ Poplar Creek	natural sources and diversion of run-on water from the Syncrude mine
South Mine Drainage	runoff and seepage from Lot 2 areas south of Lease 86/17
Tar Island Dyke	some seepage discharges directly into the Athabasca River
Wastewater Effluent	cooling water, refinery effluent, coke pile runoff

Discharge Location	Major Sources
Mid-Plant Drainage	treated sewage and run-on water diverted from mine
North Mine Drainage	run-on water diverted from north mine

Steepbank Mine:

No surface discharge other than from natural streams.

3.1.2 2001 (Start-up of Conditions for Steepbank Mine)

Lease 86/17:

Active mining of these leases has been completed and filling and reclamation of several mined-out pits has begun. In 2001, oil sands will be imported from the Steepbank Mine and processed at the existing plant. All tailings will be stored on Lease 86/17. The major changes expected from 1995 conditions will be (1) the establishment of a surface drainage channel (wetlands) along the south end of Ponds 1 and 2/3 to treat low volumes of dyke drainage water prior to release to the environment and (2) decreases in discharge of refinery wastewater and cooling water.

Discharge Location	Source
Ruth Lake/Poplar Creek	diversion of run-off water from the Syncrude mine
South Mine Drainage	possibly small volumes of Pond 2/3 dyke drainage water
Tar Island Dyke	some seepage discharges directly into the Athabasca River
Wastewater Effluent	cooling water, refinery effluent, coke pile runoff
	most CT release water will be recycled into Pond 1A, but some may be released
Mid-Plant Drainage	treated sewage and run-on water diverted from mine
North Mine Drainage	muskeg storage pile and run-on water diverted around north mine

Steepbank Mine:

Key developments at this stage include development of site drainage, major retention basins and initial pre-mine drainage. Mining of Pit 1 will have started. Mine depressurization water will be recycled and mine run-off water will be diverted to the Athabasca River.

3.1.3 2009 (Infilling of Steepbank Mine Pits Begins)

Lease 86/17:

By 2009, CT and sand disposal on these leases will be nearly complete, and most currently-produced CT and sand will be transferred to Steepbank Mine. Fine tails will continue to be stored on site for production of CT, and wastewater will continue to be stored and recycled on site. The major change from 2001 conditions will be the establishment of a surface drainage channel from Basin 1 wetlands on Lot 2.

Lease 86/17:

Discharge Location	Major Sources
Ruth Lake/Poplar Creek	diversion of runoff from the Syncrude mine, small volumes of Pond 2/3 dyke drainage water, surface runoff from Pond 1
South Mine Drainage	surface runoff to Basin 1 wetlands
Tar Island Dyke	some seepage discharges directly into the Athabasca River; surface runoff released to Poplar Creek via wetlands
Wastewater Effluent	cooling water, refinery effluent, coke pile runoff
Mid-Plant Drainage	treated sewage effluent and site runoff
North Mine Drainage	surface runoff from Northeast Sand Storage Area (NESSA)

Steepbank Mine:

Key developments at this stage include infilling of Pond 7 and active mining of Pit 2. Seepage and surface runoff will be recycled and mine drainage water will be diverted to the Athabasca River.

3.1.4 2020 (Partial Reclamation of Lease 86/17 and Steepbank Mine)

Lease 86/17:

Surface reclamation of Pond 1 will be approaching mature cover while Ponds 5 and 6 will just be starting. Fine tailings will continue to be stored on site in Pond 2/3 for production of CT, and wastewater will continue to be stored and recycled on site. The major change from 2009 conditions will be the establishment of surface drainage channels from Ponds 5 and 6 to wetlands along the west side of these ponds and then discharge of this water to Ruth Lake and/or the Athabasca River.

Lease 86/17:

Discharge Location	Major Sources
Ruth Lake/Poplar Creek	diversion of runoff from the Syncrude mine, small volumes of Pond 2/3 dyke drainage water, surface runoff from Pond 1
South Mine Drainage	surface runoff to Basin 1 wetlands
Tar Island Dyke	some seepage discharges directly into the Athabasca River; surface runoff released to Poplar Creek via wetlands
Wastewater Effluent	cooling water, refinery effluent, coke pile runoff
Mid-Plant Drainage	treated sewage effluent and site runoff
North Mine Drainage	surface runoff from Northeast Sand Storage Area (NESSA)
Pond 5/6	CT release water, dyke seepage and surface runoff from Ponds 5/6 will be released to wetlands along north-west toe of the ponds prior to discharge to Ruth Lake and/or the Athabasca River

Steepbank Mine:

Key developments at this stage include the infilling of Pond 7 with CT complete, infilling of Pond 8A with CT begins and active mining of Pit 2B begins. Seepage and surface runoff will be recycled and mine drainage water will be diverted to the Athabasca River.

3.1.5 Long-Term Scenario (Following Reclamation of All Leases)

Lease 86/17:

Discharge Location	Major Sources
Poplar Creek	runoff from Syncrude leases now diverted to Beaver Creek, small volumes of Pond 2/3 dyke drainage water, surface runoff from Pond 1
South Mine Drainage	closed under long-term scenario
Tar Island Dyke	some seepage discharges directly into the Athabasca River; surface runoff released to Poplar Creek via wetlands
Wastewater Effluent	none
Mid-Plant Drainage	wetlands
North Mine Drainage	wetlands
Pond 5/6	dyke seepage and surface runoff from Ponds 5/6 will be released to wetlands along north-west toe of the ponds prior to discharge to Ruth Lake and/or the Athabasca River
Beaver Creek	Releases from Syncrude's reclamation lakes

Steepbank Mine:

Pond 7 has be filled with CT and reclaimed and Pond 8 will be filled with CT and capped with water.

3.2 Water Quality

An extensive set of water quality data has been collected over the last few years. Specifically, data have been collected on specific chemicals that are relevant to oil sands operations, primarily polycyclic aromatic hydrocarbons (PAHs) (including alkylated and sulphur and nitrogen substituted forms), naphthenic acids, metals and conventional water quality parameters such as salts. The rationale for focusing data collection on these parameters is given in Appendix I.

As noted above, two categories of release waters have been defined - operational and reclamation waters. For the purposes of this assessment CT is treated as both an operational and reclamation water. It will represent an operational water if it is discharged to the environment during the operational phase of the mine life cycle. In the longer term, it can be treated a reclamation water as it may continue to be released to the environment as a result of consolidation and/or seepage processes for a considerable time following site reclamation.

The quality of various operational waters is summarized in Table 3.2-1. In general, concentrations of naphthenic acids are high in CT and dyke drainage water and low in other operational waters. Levels of PAHs and other trace organics are high in refinery wastewater, intermediate in dyke drainage waters and low in CT and other operational waters. Levels of nutrients and oxygen demand are low in all waters while salts levels are high in CT and dyke drainage waters. Levels of trace elements and metals are variable. In the future, the quality of the refinery wastewater is expected to improve, as a result of a number of initiatives to investigate and upgrade the wastewater system. There are limited data for CT since this is a new process; over time CT quality will become better defined as additional data become available.

Reclamation landscapes have yet to be constructed, hence it is necessary to use existing waters as surrogates for the quality of water expected to be released from those landscapes. Three processes are present that could potentially contact and mobilize chemicals in an aqueous form within the reclaimed landscape: consolidation and dewatering of CT deposits, groundwater flux and surface runoff. The quality of CT water is shown in Table 3.2-1 and is discussed above. Groundwater moving through the reclaimed landscape could potentially contact five types of reclamation deposits: CT, tailings sand, overburden, gypsum and coke. The quality of groundwater that is expected to be associated with these deposits is summarized in Table 3.2-1 Groundwater that originates from CT deposits is expected to be generally comparable to CT release water collected in various lab and field trials (Table 3.2-1). However, it is likely that the CT groundwater will contain lower concentrations of most chemicals than was measured in the laboratory and field experiments because of physical (e.g., mixing with precipitation, dispersion), chemical (sorption of organics to solids) and biological (microbial decay) processes within the groundwater that will reduce levels of certain chemicals. Hence, the use of CT data from the current laboratory and field experiments is expected to serve as a conservative surrogate for CT seepage water.

Like CT, there are no direct measures of the quality of seepage water expected from gypsum storage units, since the gypsum will only be produced after the Flue Gas Desulphurization Unit is operating (autumn 1996). An indication of the quality of gypsum water is provided in Table 3.2-1.

In contrast to CT and gypsum, direct measures of seepage water originating from tailings sands are available from analysis of water collected from Tar Island Dyke's (TID) seepage collection system and from groundwater wells installed downgradient of the Plant 4 tailing beach (north end of Tar Island Dyke). In addition, direct measures of the quality of shallow groundwater are available from analysis of water collected from wells installed in overburden dumps and dykes within Lease 86/17 and the Steepbank Mine.

Surface runoff water is derived from precipitation and may potentially transport chemicals off of a reclaimed CT pond by (1) mixing with CT exfiltration waters, (2) mobilizing soluble chemicals within the upper layers of the soils as a results of interflow (i.e., percolation through shallow soils) and (3) erosion and transport of particulates. During operational phases of the site, all surface runoff in contact with process-affected soils is collected and contained on site so the potential for off-site transport by surface water is restricted to reclamation conditions. However, the CT ponds will be capped with a layer of sand (at least one metre thick), which in turn will be capped with a layer of muskeg and reclaimed with vegetation. Hence, no direct contact between CT soils and surface runoff water is expected. Further, dewatering of the CT deposits will occur rapidly, so mixing of surface runoff water with exfiltration water will only occur for a few years following filling the ponds with CT. Thus, given this reclamation scenario, it is unlikely that surface runoff from the site will be affected by the processes described above, and runoff water from the existing north and south mine drainages (which drain natural areas and overburden and muskeg storage areas) can serve as surrogates for the quality water that is expected to run off of the reclaimed landscape. This water has been well characterized and the chemical data are presented in Table 3.2-1.

3.3 Receiving Water Quality Predictions

As described in Section 3.1, operational and reclamation waters are currently released and will, in the future, continue to be released to the Athabasca River as a result of Suncor's operations. An assessment of future impacts that might arise from changes in release water flows and/or quality requires that changes in the water quality of receiving water bodies be predicted. Thus, a computer simulation model was developed to predict chemical concentrations in the Athabasca River, alongside and downstream of Suncor's operations.

3.3.1 Chemical -Fate Model Description

Mixing processes in rivers are mainly governed by advection and dispersion. Advection is the transport by the motion of fluid while dispersion is caused by a concentration gradient. To predict the transport of constituents released to the Athabasca River, a vertically-averaged, two-dimensional computer simulation model was developed.

The model is based on analytical solutions to river dispersion equations. The model has the capability of handling both point-source discharges of surface runoff or effluents and non-point source discharges such as groundwater seepage. To account for the difference between these two types of discharges, two separate model equations were used to calculate river concentrations: one for point-sources and the other for line-sources.

The river mixing model was based on the following fundamental assumptions:

- The Athabasca River is relatively shallow so complete vertical mixing occurs rapidly downstream of point-source discharges, hence, a two-dimensional, vertically-averaged model is appropriate.
- The depth of the river is constant and homogeneous across its width, thus, turbulence and dispersion coefficient were set to be constant across the river.

- Mass is conserved in the models by following the standard practice of mathematically reflecting the plume profiles at the river banks which accounts for the finite width of a river.

For point-sources, the following equation was used to estimate river concentrations at any location within the river study reach (Fischer et al. 1979):

$$C\,(x,\eta) = C_{BK} + \frac{Me^{-kx/u}}{udW\xi\sqrt{\pi}} \sum_{j=-Nr}^{j=Nr} \left\{ \exp\left[-\frac{(\eta-2j-\eta_o)^2}{\xi^2}\right] + \exp\left[-\frac{(\eta-2j+\eta_o)^2}{\xi^2}\right] \right\} \quad \textbf{(3.1)}$$

where $C(x,\eta)$ = concentration in Athabasca River [mg/L]

x = longitudinal distance downstream from a reference point [m]

η = the normalized location across the river (normalized by fraction of river flow) [dimensionless]

η_o = the normalized location across the river of the centre of the source (normalized by fraction of river flow) [dimensionless]

ξ = the normalized transverse dispersion parameter, Eq. (3.6) [dimensionless],

C_{BK} = background concentrations in Athabasca River [mg/L]

M = load of constituent from discharge [kg/d]

W = river width, Eq. (3.3) [m]

d = depth of Athabasca River, Eq. (3.2) [m]

u = velocity of Athabasca River [m/s]

j = the j'th reflection.

N_r = the number of river bank reflections depends on the rate of lateral mixing across the river and the distance downstream, x, in the calculation; typically N_r=2 will suffice.

k = decay rate of constituent [s^{-1}]

From Leopold-Maddox relationships developed for the lower Athabasca River, from Fort McMurray to Fort McKay (HydroQual 1989), the velocity and depth of the river can be determined from river flow (Q_{AR} in m^3/s):

$$u = 0.158\, Q_{AR}^{0.25} \tag{3.2}$$

$$d = 0.0996\, Q_{AR}^{0.449} \tag{3.3}$$

Thus, for any given river flow, river depth, velocity as well as dispersion coefficient can be determined, and constituent concentrations at locations downstream of the discharge point can be predicted using the above equations.

A line-source discharge can be treated as an infinite number of point sources along a distance across the river equal to the line source's width. An equation for calculating river concentrations downstream of a line source, such as a zone of influent groundwater seepage, can therefore be derived by integrating the point-source equation over the width of the line source and accounting for the finite width of a river by reflecting the plume at both river bank boundaries:

$$C(x,\eta) = C_{BK} + \sum_{i=1}^{N_s} \frac{C_{o_i}}{2}\, e^{-kx/u} \sum_{j=-N_r}^{N_r} \left[\begin{array}{l} \operatorname{erf}\left(\dfrac{r+(\eta-(2j+\eta_i))}{\xi}\right) + \operatorname{erf}\left(\dfrac{r-(\eta-(2j+\eta_i))}{\xi}\right) \\ + \operatorname{erf}\left(\dfrac{r+(\eta-(2j-\eta_i))}{\xi}\right) + \operatorname{erf}\left(\dfrac{r-(\eta-(2j-\eta_i))}{\xi}\right) \end{array} \right] \tag{3.4}$$

where: C_{oi} = initial concentration of constituent fully vertically mixed over the line source segment river flow fraction (see below) [mg/L]

i = the i'th source in a series of line sources

j = the j'th reflection.

N_s = number of line sources in a series of adjacent line sources

η = the normalized location across the river (normalized by fraction of river flow) [dimensionless]

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$$C(x,\eta) = C_{BK} + \sum_{i=1}^{N_s} \frac{C_{o_i}}{2}\, e^{-kx/u} \sum_{j=-N_r}^{N_r} \left[\begin{array}{l} \operatorname{erf}\left(\frac{r+(\eta-(2j+\eta_i))}{\xi}\right) + \operatorname{erf}\left(\frac{r-(\eta-(2j+\eta_i))}{\xi}\right) \\ + \operatorname{erf}\left(\frac{r+(\eta-(2j-\eta_i))}{\xi}\right) + \operatorname{erf}\left(\frac{r-(\eta-(2j-\eta_i))}{\xi}\right) \end{array} \right] \tag{3.4}$$

where: C_{oi} = initial concentration of constituent fully vertically mixed over the line source segment river flow fraction (see below) [mg/L]

i = the i'th source in a series of line sources

j = the j'th reflection.

N_s = number of line sources in a series of adjacent line sources

η = the normalized location across the river (normalized by fraction of river flow) [dimensionless]

η_i = the normalized location across the river of the centre of the i'th source [dimensionless]

ξ = the normalized transverse dispersion parameter. Eq. (3.6) [dimensionless]

r = half width of the line source normalized by fraction of river flow [dimensionless]

The above line source equation has been normalized by the fraction of river flow (i.e., the lateral distance is represented by the fraction of total river flow). The initial concentration for a line source is calculated by mixing the line source flow with the river flow over the width of the line source:

$$C_{o_i} = \frac{q_{s_i} C_s}{q_{s_i} + 2rQ_{AR}} \tag{3.5}$$

where: q_{si} = the line source flow rate [m^3/s] (see next section)

C_s = the line source concentration which is assumed to be the same for each line source segment, although it need not be [mg/L]

The normalized transverse dispersion parameter is given by:

$$\xi = \frac{2d\sqrt{E_t x u}}{Q_{AR}} \tag{3.6}$$

where ξ = the normalized transverse dispersion parameter [dimensionless]

d = depth of Athabasca River [m]

u = velocity of Athabasca River [m/s]

E_t = transverse dispersion coefficient [0.07 m^2/s; Golder 1994a]

The value of d, and u are determined from Q_{AR} as outlined above. The transverse dispersion coefficient, E_t, was determined from a river mixing study (Golder 1994a).

To account for changes in seepage rate with distance from shore, a series of line sources are used with varying initial concentrations. The initial concentrations are determined by an exponential function and are distributed in such a way that the total seepage mass of constituent is conserved. The seepage rate from the bank to the centre of the river was, therefore, assumed to follow the following form of decay (Shaw and Prepas 1990):

$$q_s' = Q_s K_1 e^{-k_Q \eta} \tag{3.7}$$

where: q_s' = line source element seepage per unit η [m^3/s]
K_1 = a scaling constant [dimensionless]
k_Q = exponential decay constant [η^{-1}]

Integrating this functional form for the seepage rate over the half width of the river and normalizing by the total seepage, the seepage flow fractions between η_1 and η_2 can be expressed as:

$$\frac{q_s}{Q_s} = \frac{e^{-k_Q \eta_1} - e^{-k_Q \eta_2}}{1 - e^{-0.5 k_Q}} \tag{3.8}$$

where: q_s = line source segment seepage between river flow fraction η_1 and η_2 [m^3/s]
Q_s = total seepage to river [m^3/s]

The seepage may also be expressed in terms of the line source segment centre, η_i and its half width, *r*:

$$\frac{q_s}{Q_s} = \frac{e^{-k_Q(\eta_i - r)} - e^{-k_Q(\eta_i + r)}}{1 - e^{-0.5 k_Q}} \tag{3.9}$$

The following steps are required to solve the river mixing equations:

- Obtain appropriate background data for Athabasca River (flows and concentrations). Background concentrations of constituents in the Athabasca River are available from Alberta Environment's NAQUADAT database and water quality data collected during the 1995 baseline study (Golder 1996b).
- Discharge locations along the river also need to be specified (Figure 3.1-1). Figures 3.3-1 to 3.3-5 are schematics of drainage patterns for all the sources at various stages of the mine life-cycle and also indicate the flow rates and effluent quality for each of discharge source. The flow scenarios are described in Section 3.1 and flow rates are from AGRA (1996) . Water quality data were based on the data presented in Section 3.2. A total of 11 different water quality categories were used in model simulations. As indicated in Figures 3.3-1 to 3.3-5, some outfalls receive more than one source of discharge from the mine site. For such cases, the discharges were grouped together as one lumped loading source into the Athabasca River at that outfall location, and flow-weighted concentrations and the total flow of the discharges were input to the model.
- Estimate the velocity and depth of the river from Eq. (3.2) and Eq. (3.3).
- Compute dispersion coefficient using Eq. (3.6).
- Estimate the exponential decay constant, k_Q, in Eq. (3.9) which describes the distribution of groundwater seepage flow to the river. The exponential distribution of flow is described in Shaw and Prepas (1990). Values for k_Q are site specific, but a value of $k_Q = 0.1$ provides a reasonable estimate.
- Specify locations in the river for which modelled concentrations are desired. The river models described by Eq. (3.1) and Eq. (3.4) provide estimates of river concentrations at specific locations downstream of the specified source. Therefore, both a distance downstream from the source, x, and a lateral location across the river width (which is expressed as a fraction of the total river flow), η, are specified. The calculation is generally performed using a matrix of x and η values so that river concentrations are plotted or contour-plotted.

These input data provide sufficient information to apply the river dispersion models in Eq. (3.1) and Eq. (3.4) to a single discharge. However, as noted in Section 3.1, there are numerous sources of release water associated with Suncor's existing and future operations that discharge to the

Athabasca River. To accommodate these multiple sources, the model was set-up so that each discharge was simulated separately, and the total river concentration downstream of the sources was obtained by an additive approach. This was accomplished by applying a grid to the study reach (from Poplar Creek to the confluence of Mackay River) with 1340 nodes (20 in the lateral direction and 67 in the longitudinal direction).

For each discharge, river concentration was calculated at each of the nodes. The chemical concentration at each node was then determined by summing all the concentrations attributed to each discharge source at that node. Using this summation procedure, all types of discharges into the Athabasca River are accounted for and their cumulative effects on the distribution of constituent concentrations in the river are considered in the model.

To quantify the variability in the predicted concentrations downstream of the sources, the river dispersion model is applied in a probabilistic manner. Distributions for flow and water quality must be determined for each discharge and for the Athabasca River. Distributions in the following steps include:

- Select from each distribution, randomly, a single value for flow and concentration for each release water source and for background concentrations in the Athabasca River.
- Apply the river dispersion model, as explained above, using the randomly selected input quality and flow. The result is the chemical concentration in the river downstream of all the sources at a specific location.
- This process is then repeated to produce a second estimate of the concentration in the river downstream of all the sources. This second iteration will produce a different river concentration because all of the inputs will be different as a result of the random sample of each input.
- 500 iterations are performed to produce a distribution of the river concentrations at a specific location.

The river dispersion model was integrated into a C++ program, which was linked dynamically to an Excel spreadsheet to facilitate data input and result presentation. The probabilistic assessment of was performed by assigning distributions to input parameters in the spreadsheet using Crystal Ball® add-in for Excel.

4.0 ASSESSMENT OF IMPACTS ON AQUATIC BIOTA

As noted in Section 2.1, chemical-specific, toxicity-based, and risk-based approaches were utilized to assess potential impacts from Suncor's water releases on aquatic biota in the receiving water body. Each of these approaches are described, in detail, below.

4.1 Chemical-Specific Wasteload Allocation

In late 1995, AEP established procedures to help derive limits for wastewater effluents based on the assimilative capacity of the receiving water body (AEP 1995a). This protocol is shown schematically in Figure 4.1-1, and details of the approach are given in Appendix VI. Effectively, this approach is based on estimating, on a chemical-by-chemical basis, the maximum load or effluent concentration that could be discharged to the Athabasca River without exceeding AEP's in-stream water quality guidelines. If the in-stream guidelines are predicted to be exceeded, based on a protective, low-flow river condition, then the reasons for the exceedance are investigated. Ultimately, the risk associated with exceeding the guidelines are evaluated.

The wasteload allocation protocol was developed to assist in setting water quality based effluent limits for a single effluent discharge. That protocol was followed initially to examine Suncor's wastewater and cooling water effluent with respect to changes associated with plant expansion. The results of that assessment are given in Appendix VI and presented as part of Suncor's Fixed Plant Expansion Project Application dated March 1996. The protocol was then modified to account for the cumulative effects from the multiple sources of release waters associated with all of Suncor's existing and future reclamation and operational release waters operations, including the wastewater and cooling water effluent.

4.1.1 Methods

The approach followed for this assessment was to first calculate, on a chemical-specific basis, the total load that might be discharged to the Athabasca River from all of Suncor's release waters. These total loads were calculated based on the maximum effluent concentration and average flows for each time snapshot under investigation: 1995, 2001, 2010, 2020, and post-reclamation. The predicted chemical concentrations within the mixing zone of the river were then compared to chronic aquatic life guidelines. In addition, to evaluating in-stream concentrations, "end-of-pipe" concentrations associated with the various releases waters were also investigated by comparing to acute aquatic life guidelines. Chemicals that do not exceed either the acute of chronic guidelines clearly pose no risk to aquatic biota in the Athabasca River and can be safely eliminated from further investigation. Chemicals that exceed either the acute of chronic guideline do not necessarily pose a risk but require further investigation.

The following assumptions were made in accordance with AEP's (1995a) methodology:

- **Background Water Quality** - Chemical concentrations upstream of the discharge point were defined based on median winter concentrations from historical data obtained from AEP's NAQUADAT database (Table 4.1-1).

- **River Flow** - River flow was set at 115 m^3/s (7Q10; the lowest flows that occur over seven consecutive days, on average, once every 10 years).

- **Water Quality Guidelines** - A database was complied that consisted of Alberta, Ontario, Canada and United States water quality guidelines. An emphasis was placed on U.S. guidelines as they were developed in conjunction with the assessment procedures similar to that adopted by AEP. Canadian, Ontario and Alberta guidelines were used when U.S. guidelines were not available. Some modifications (removal of uncertainty factors) were made when using some of these guidelines to make them consistent with the approach used in deriving the U.S. guidelines (Table 4.1-1).

- **Mixing Zones** - Acute aquatic life water quality guidelines were evaluated against concentrations at "end-of-pipe", i.e., at a point immediately prior to discharge into the Athabasca River. These guidelines are set at levels to protect sensitive aquatic biota from lethal short-term exposure. Chronic aquatic life guidelines were evaluated after complete mixing with 10% of the river flow, downstream of the cumulative loading from all of

Suncor's release waters. These guidelines are set at levels to protect sensitive aquatic biota from measurable, non-lethal impacts associated with long-term exposure.

- **Effluent** - Historical maximum loads were calculated from historical maximum concentrations and long-term, average flows reported for each existing release water. Chemicals included in this analysis were ones that were both detectable (in one or more release waters) and for which an established guideline exists (Table 4.1-1). The quality of future CT release waters were based on a combination of laboratory and field data. Flows were based on current monitoring records plus future projections (Table 4.1-2).

4.1.1 Results

Four chemicals were identified for which maximum concentrations in one or more release waters are greater than acute aquatic life guidelines - ammonia, copper, chromium, and cyanide (Table 4.1-3):

Ammonia - The refinery wastewater is the only release water for which the maximum concentration exceeded the acute guideline of 8 mg/L. This exceedance is an artifact of the use of the historical maximum value rather than more recent values. For instance, during 1980 and 1981 ammonia concentrations ranged from 20 to 25 mg/L. However, the maximum ammonia concentration have been reduced substantially as a result of improvements in the wastewater system; since 1983 the maximum concentration recorded is only 3 mg/L. Thus, this chemical is no longer a concern with respect to acute toxicity.

Chromium - The refinery wastewater is the only operational water for which the maximum concentration exceeded the acute guideline for Cr^{+6} of 0.016 mg/L. Historically, this guideline has been exceeded at a frequency of only 1% of all samples analyzed. Given this low frequency of exceedance, the assumption that all chromium in wastewater would be present as Cr^{+6}, plus the nearly instantaneous dilution with Athabasca River water immediately below the outfall, the resulting chromium concentrations within the Athabasca River pose no risk of acute toxicity to aquatic biota in the river.

Copper - The refinery wastewater is the only release water for which the maximum concentration exceeded the acute guideline of 0.03 mg/L. Historically, this guideline has been exceeded at a frequency of less than 4 % of all samples analyzed. Given this low frequency of exceedance coupled with the nearly instantaneous dilution with Athabasca River water immediately below the outfall, the resulting copper concentrations within the Athabasca River pose no risk of acute toxicity to aquatic biota in the river.

Cyanide - Elevated cyanide levels (maximum 0.055 mg/L) have been measured in CT water, although most concentrations are less than 0.002 mg/L. Additional data are necessary to confirm whether untreated CT release waters will in fact exceed the 0.022 mg/L criterion.

Four chemicals were identified for which the predicted river concentrations might exceed chronic aquatic life guidelines - aluminum, mercury, phenols, and strontium (Table VI-10):

Aluminum - Aluminum was identified only because concentrations in the Athabasca River (<0.1 to 8.64 mg/L) naturally exceed the chronic guideline of 0.1 mg/L. Concentrations in Suncor's release waters are within the range of that reported for the Athabasca River and, thus, will not results in any further increase of aluminum concentrations in the river. In any case, these concentrations of aluminum are not toxic under the conditions prevalent in the river since virtually all of the aluminum would be associated with particulate material and would not be bioavailable.

Mercury - The cumulative loads of mercury associated with Suncor's water releases might result in mercury concentrations in the Athabasca River to slightly exceed the chronic guideline, under the low flow conditions examine here (Table VI-10). The largest single source of mercury is from the wastewater/cooling pond discharge, which represents about 75% of the total mercury loadings from all release waters (2020 scenario). However, the expected frequency at which mercury in-stream levels might exceed the chronic guideline is only 10%. Hence, given the conservative nature of the assessment and the low frequency of exceedance, it is unlikely that mercury associated with Suncor's water releases will affect aquatic biota in the Athabasca River.

Phenols - Phenol concentrations above the 0.001 mg/L chronic guideline have been recorded in most of Suncor's release waters, and the background concentration in the Athabasca River is equal to the 0.001 mg/L guideline. This guideline is also regularly exceeded in many natural surface water bodies. The total contribution from Suncor's release waters, under worst-case conditions of maximum effluent concentration and low river flows would only contribute to an increase of phenols of 0.0005 mg/L beyond the 10% river mixing zone. Hence, under worst-case conditions, river concentrations would only increase from 0.001 to 0.0015 mg/L. The guideline for phenols is for a group of chemicals but is based upon effects due to specific chlorinated forms, none of which have not been measured in any of Suncor's release waters. Hence, it is exceedingly unlikely that the phenols in Suncor's release water would affect aquatic biota in the Athabasca River.

Strontium - Like aluminum, strontium was identified only because concentrations in the Athabasca River (0.18-0.36 mg/L) naturally exceed the chronic guideline of 0.16 mg/L. Concentrations of strontium in most of the release waters are comparable or less than those in the Athabasca River levels. One exception to this is the CT water, where concentrations have ranged from 0.75 to 2.12 mg/L. Even so, under worst-case conditions of maximum effluent concentration and low river flows, river concentrations would only increase by 0.02 mg/L beyond the 10% mixing zone. Hence, it is exceedingly unlikely that strontium concentrations would affect aquatic biota in the Athabasca River.

In conclusion, it is unlikely based on the results presented above that Suncor's release waters either are currently affecting or will in the future affect aquatic biota in the Athabasca River.

4.2 Whole-Effluent Toxicity

A sustainable aquatic ecosystem requires that all major components of the ecosystem (bacteria, plants, animals) are viable. Alberta Environment Protection (1995a) suggests using a battery of toxicity tests to help evaluate aquatic ecosystem health. The toxicity tests done for this assessment include acute tests for mortality to rainbow trout (*Oncorynchus mykiss)* and zooplankton (*Daphnia magna)* and inhibition of light production by bacteria (*Photobacterium phosphoreum* or *Vibrio* *fischeri*), plus chronic tests for reproduction and survival of a zooplankton (*Ceriodaphnia*) and growth of an aquatic plant (the algae, *Selenastrum*).

Toxicity data are summarized in Table 4.2-1. With the exception of TID or CT release water, there is little evidence of acute toxicity in either reclamation or operational waters, and no evidence of acute or chronic toxicity in either the Athabasca or Steepbank Rivers. *Ceriodaphnia* reproduction is the most sensitive chronic endpoint, and the highest levels of response were noted for CT water (IC25 14%).

The potential impacts associated with release of these waters to the Athabasca River can be assessed using the river mixing model described in Section 3.3. Figure 4.2-1 shows predicted levels of toxicity units (inverse of No-Observed-Effect-Concentration (NOEC) for *Ceriodaphnia*, expressed as a fraction) in the Athabasca River, alongside and downstream of Suncor. Toxic units are useful for modelling purposes because they can be used to compute a toxic unit loading rate, so that potential toxicity in receiving waters can be predicted. AEP suggest an in-stream guideline for TU_c (toxic units for chronic endpoints) of 1.0, which is equivalent to the NOEC of the most sensitive test organism. It is evident from Figures 4.2-1 to 4.2-5 that for all time periods examined, in-stream concentrations are expected to be considerably lower than the 1.0 TU_c guideline, even directly adjacent to Suncor's existing facility under 7Q10 flows (the lowest flows that occur over seven consecutive days, on average, once every ten years). Hence, no toxicity is expected in the Athabasca River as a result of the cumulative discharge of operational and reclamation waters.

Similarly for the Steepbank River, the maximum TU_c level is estimated at only 0.02 TU_c (based on *Ceriodaphnia* NOEC of 12.5% for CT water from Table 4.2-2, which gives a TU_c of 8, CT seepage to river of 0.0014 m^3/s and mean winter river flows and TU_c of 0.48 m^3/s and 0, respectively. Hence, a simple dilution calculation gives:

$$(8TU_c \times 0.0014 m^3/s + 0TU_c \times 0.48\ m^3/s) \div (0.0014 m^3/s + 0.48 m^3/s) = 0.023\ TU_c$$

Thus, as for the Athabasca River, no toxicity is expected in the Steepbank River as a result of the inflow of CT reclamation waters, even under low-flow, winter conditions.

In summary, there is no evidence from the battery of laboratory toxicity tests used that the cumulative impact from operational and reclamation waters will adversely affect ecosystem health in either the Athabasca or Steepbank Rivers.

4.3 Risk-Based Approach

The risk-based approach provides specific information on potential impacts of water releases for ecologically-relevant endpoints. Information from laboratory, field and computer modelling studies are integrated to quantify changes in measurable endpoints that could be considered harmful to aquatic biota. These predictions are used to quantify existing impacts and predict future impacts on aquatic ecosystem health. In particular, the focus of this assessment was on whether or not Suncor's existing and proposed water releases might affect the health and sustainability of fish populations in the Athabasca River. The maintenance of health fish populations also requires that other organisms, such as benthic invertebrates, which are an important food source for some fish, also remain healthy.

The following method was used to predict whether Suncor's water releases might adversely affect the health of fish populations:

1. Examine historical data and collect additional data to establish the current status of ecosystem health in the Athabasca and Steepbank River, near Suncor's operations.
2. Define assessment and measurement endpoints.
3. Assemble experimental data to test measurement endpoints.
4. Derive no-observed-effect-levels (NOELs) and lowest-observed-effect-levels (LOELs) for the suite of fish health parameters used in laboratory experiments (primarily the biochemical/ physiological measurement endpoints).
5. Compare LOELs and NOELs to the modelled concentrations in the river for the years 1995, 2001, 2010, 2020 and long-term (post reclamation).
6. Predict impacts on the biochemical/physiological measurement endpoints.
7. Predict impacts on the whole-organism and population-level measurement endpoints.
8. Draw a conclusion regarding the health and sustainability of fish populations (i.e., assessment endpoint).

4.3.1 Current Status of Ecosystem Health

The current status of ecosystem health was evaluated through field and laboratory investigations. Benthic invertebrate and fish communities upstream and downstream of Suncor in both the Athabasca River and in the Steepbank River. These data are presented and interpreted in Golder (1996b) and summarized below.

4.3.1.1 Benthic Invertebrates

Benthic invertebrate communities were surveyed during the autumn of 1995 in the Athabasca and Steepbank Rivers (Figures 4.3-1 and 4.3-2). Various sampling techniques were used (artificial substrates, Ekman grab, Neill cylinder), depending on habitat characteristics at the sampling sites. Both artificial and natural substrates were sampled in the Athabasca River. The Athabasca River is a relatively unproductive system compared to other large rivers in Alberta, and consequently invertebrate density is low.

The abundance of benthic invertebrates colonizing artificial substrates in the Athabasca River varied moderately among sites, but was similar at sites above and below Suncor discharge locations (Figure 4.3-3A). There was a trend of lower numbers of invertebrates on both banks downstream from the Steepbank River. Taxonomic richness (total number of taxa) and the composition of the benthic fauna were generally similar at all sampling sites on the Athabasca River (Figures 4.3-4A and 4.3-5A). Benthic invertebrates colonizing artificial substrates were dominated by stonefly nymphs and Plecoptera midge larvae (chironimidae). Chironomid dominance was most pronounced at the mouth of Poplar Creek and 5 km below the Steepbank River on the east bank, most likely due to greater amounts of organic detritus deposited from Poplar Creek and reduced current velocity relative to other sites, respectively. The benthic community colonizing artificial substrates was dominated by collector-gatherers and predators at all sampling sites in the Athabasca River.

Community composition and total abundance of benthic invertebrates were more variable on natural substrates in the Athabasca River than on artificial substrates, most likely as a result of greater variation in habitat characteristics. Taxonomic richness varied little among sites. On natural substrates, the relative proportions of major functional feeding groups were similar to those on artificial substrates, but varied more among sites.

Results of the benthic invertebrate survey of the Athabasca River suggest biological effects were absent at sites exposed to discharges from Suncor. Although not directly comparable to historical data due to differences in sampling locations and, potentially, habitat characteristics, results of this study are generally consistent with those of previous benthic surveys of the Athabasca River (McCart et al. 1977, Noton 1979, Barton and Wallace 1980, Noton and Anderson 1982).

Benthic communities in the Steepbank River varied moderately among sites, most likely as a result of differences in habitat characteristics. There was a trend of decreasing abundance and taxonomic richness from upstream to downstream stations, as well as a gradual decline in the proportion of chironomid larvae (Figures 4.3-3B, 4.3-4B and 4.3-5B). The relative proportions of different functional feeding groups were similar at all sites. The changes in benthic communities with distance downstream appeared to parallel the variation in current velocity and substratum composition.

Results of the bioaccumulation assessment at reference sites in the Athabasca and Steepbank Rivers indicated that concentrations of most metals analyzed were detectable in benthic invertebrates tissues, and were similar at all sites (Table 4.3-1). Concentrations of PAHs and PANHs were non-detectable or near the detection limit at the sites sampled in the Athabasca River. In the Steepbank River, concentrations of several organic compounds, particularly substituted phenanthrenes/anthracenes and dibenzothiophenes, were elevated relative to the other sites sampled, but levels were relatively low. These results probably reflect differences in the amount of oil sands present in the substratum in the rivers sampled. No marked differences in tissue concentrations of metals and organics were noted between samples taken in August 1994 and October 1995 in the Athabasca River.

4.3.1.2 Fish Health

The current (1995) status of the Athabasca River watershed aquatic ecosystem in the vicinity of Suncor's current operation is reviewed by Golder (1996b). Since the baseline represents conditions prior to the development of the Steepbank Mine, it is indicative of potential impacts associated with Suncor's existing operations.

The 1995 fish health collected a suite of indicator data, representing several levels of biological organization (i.e., biochemical, physiological, whole-organism, population and community). This suite of indicators produced baseline information about various levels of biological response to stress in the Suncor area. The suite of indicators was necessary because stress effects on fish cannot be adequately evaluated by measurement of either a single response or several responses displayed at only one level of biological organization (Adams and Ryon 1994).

Biochemical and physiological measurements are short-term indicators of the response to stress (where stress can include exposure to chemicals, unfavourable temperatures, water velocity, sediment loads, reduced food availability, variations in dissolved oxygen and exposure to natural pathogens or parasites). Such short-term indicators are highly sensitive, but may not predict effects at either the whole-organism or population level. The biochemical and physiological indicators measured in 1995 included mixed function oxidase (MFO) activity (measured as ethoxyresorufin-o-deethylase (EROD) and aryl hydrocarbon hydroxylase (AHH)), PAH metabolites in bile, PAH and metal concentrations in fillets, lactate, protein and glucose in blood serum, retinol in liver and circulating sex steroids.

Whole-organism measurements are longer-term indicators of the overall response of an individual organism to stress. These measurements integrate the whole-organism response that may follow from a combination of biochemical and physiological responses; thus, they are somewhat more ecologically relevant than biochemical and physiological measurements. The whole-organism indicators measured in 1995 included condition factor, liver size, gonad size, fecundity, fat content, gross pathology and histopathology.

Population and community parameters are indicators of long-term responses that integrate the exposure to stressors over both time and space. Population and community-level indicators can demonstrate a pattern in health responses that are quite different from those indicated by physiological parameters (Adams and Ryon 1994). Population and community-level parameters are generally more ecologically relevant than those measured at lower levels (e.g., physiological parameters), since they are directly related to survival, growth and reproduction of fish species (Adams et al. 1989). The population and community parameters assembled from the 1995 data included age-frequency; size-at-age, community species composition (presence/absence) and, habitat utilization.

Although a suite of fish health indicators was examined during the 1995 baseline study, most of the inferences regarding the impact of the existing Suncor operation are based upon whole-organism, population and community-level parameters. This approach was used because of the greater ecological relevance of whole-organism, population and community-level measures, the availability of a considerable amount of historical data on fish communities and populations and the lack of 1995 reference data for physiological parameters (reference data were available, however, from other sources such as Northern River Basin Studies (NRBS) and Environmental Effect Monitoring (EEM) for pulp and paper mills and these data were used where appropriate). Historical (pre-development) data for physiological parameters were not available for fish in the Athabasca River. Therefore, analysis of physiological parameters is largely limited to a summary presentation of baseline information, which is now available for comparison with future monitoring data. The exception is the data for two exposure indicators: the MFO and PAH metabolites in bile.

The focus of the fish health studies were directed to surrogate species, denoted as Valued Ecosystem Components (VECs). The VECs selected for the detailed fish health studies are walleye, goldeye and longnose sucker and the rationale for selecting these species is given in Golder (1996b).

Community Indicators - Presence/Absence Data

Athabasca River - Tables 4.3-2 and 4.3-3 depict presence/absence data for fish species captured in the current study compared to the fish community documented in the Alberta Oil Sands

Environmental Research Program (AOSERP) studies. In the 1970s, the presence of 27 fish species was documented in the Athabasca River downstream of Suncor and Syncrude (Bond 1980). Wallace and McCart (1984) reported that the most abundant large fish species in the vicinity of Suncor and Syncrude are: longnose sucker, goldeye, lake whitefish and walleye. The results of the 1995 inventory confirm that these species are indeed still the most common (Golder 1996b). Other large fish species include: northern pike, burbot, mountain whitefish, white sucker and yellow perch. The major small fish species in the Athabasca River portion of the study area in 1995 were: trout-perch, flathead chub, lake chub, emerald shiner, spottail shiner and slimy sculpin. These results agree with the findings of McCart et al. (1977) from the late 1970s. Brassy minnow, longnose dace, slimy sculpin and spoonhead sculpin which were captured in 1995 have previously been documented to occur in the area but in limited abundance (McCart et al. 1977).

Non-game species that were not captured in 1995 but have been documented to occur in the area include: northern redbelly dace, finescale dace, pearl dace, ninespine stickleback, brook stickleback, fathead minnow and Iowa darter. All of these species are uncommon in the Athabasca River within the study area (Bond 1980), so their absence in the fish inventory is not surprising. The only game species that have previously been documented but were not collected in 1995 are bull trout and Arctic grayling. While bull trout have been documented in this area of the Athabasca River, this species is at the eastern geographical extent of its range (Nelson and Paetz 1992). Arctic grayling are known to use the tributaries extensively for spawning and summer feeding, and consequently their numbers are low in the Athabasca River during the open water season.

Steepbank River - Thirteen species of fish were captured in the 1995 fish inventory on the Steepbank River. Arctic grayling, lake chub, longnose dace, longnose sucker, mountain whitefish, spoonhead sculpin, trout-perch, walleye and white sucker were found in all three reaches. In contrast, burbot, goldeye, lake whitefish and northern pike were only found in the lower reach of the river, near the mouth.

In the past, twenty-five species of fish have been recorded from the Steepbank River, of which 10 (Arctic grayling, northern pike, longnose sucker, white sucker, lake chub, pearl dace, longnose dace, trout-perch, brook stickleback and slimy sculpin) are common and widespread (Sekerak and Walder 1980). In 1995 all of these species were captured except for brook stickleback and slimy sculpin (both of which are not easily susceptible to capture by boat electrofisher).

Several additional species are confined to the lowermost portion of the river near the confluence with the Athabasca River. In 1995, goldeye, lake whitefish, longnose dace, mountain whitefish, spoonhead sculpin and walleye were captured near the mouth of the Steepbank. Other species that have previously been documented in the lower reaches of the Steepbank River but were not captured in 1995 include bull trout, lake cisco, flathead chub, redbelly dace, spottail shiner, brassy minnow and flathead minnow. Since these species are only occasional visitors to the Steepbank River their absence from the 1995 fish inventory is not surprising and does not necessarily indicate a disappearance of a species.

Community Indicators - Habitat Utilization

One indicator of fish community health is the use of available habitats by various life stages of individual fish species. Typically, fish have different habitat requirements for spawning, rearing, feeding and overwintering. This section presents habitat availability/use information from 1995 for VEC species (walleye, goldeye, longnose sucker) in historical context.

Walleye - Walleye that are found in the vicinity in the Athabasca River near Suncor and Syncrude are thought to be part of the population that overwinters in Lake Athabasca (McCart et al. 1977). Walleye are known to spawn near the Delta in Richardson Lake (Bond 1980). As well, upstream spawning migrations have been documented in both past and present studies (McCart et al. 1977, Tripp and Tsui 1980, Bond 1980). Spawning areas have still not been documented with certainty, although there is evidence of spawning upstream of the present study area at Cascade rapids (Tripp and McCart 1979). Walleye spawning has not been documented in the vicinity of Suncor historically or in 1995.

The Athabasca River near Suncor provides important feeding and rearing habitat for walleye. Backwaters and tributary mouths are important feeding areas. Habitat utilization patterns for walleye, as documented in the 1970s, were similar in 1995.

Goldeye - Warm, turbid lakes and rivers are typical goldeye habitat (Scott and Crossman 1973). In the Athabasca River system, goldeye overwinter in Lake Athabasca and spawn in the Delta (McCart et al. 1977). Large numbers of immature goldeye are known to migrate into the Athabasca River from the Delta (McCart et al. 1977). The Cascade Rapids upstream of Fort McMurray appear to be at least a partial barrier to goldeye movement (Tripp and Tsui 1980). Thus, the lower reaches of the Athabasca River are important feeding habitat. Goldeye enter the Suncor study area in April and May to feed, and migrate back to the Delta by the end of October. This species is mainly confined to the turbid waters of the Athabasca River mainstem and rarely enters the smaller tributaries such as the Steepbank River. Both past and present studies show this pattern of habitat utilization.

While previous studies have not documented goldeye spawning in the vicinity of Suncor and Syncrude, spent individuals of both sexes were documented in the spring of 1995, indicating that this species is possibly spawning in the vicinity of Suncor.

Longnose Sucker - Longnose sucker migrate widely in the Athabasca River system. Most longnose sucker overwinter in Lake Athabasca and migrate into Athabasca River tributaries to spawn. The gravel/cobble substrate and moderate current velocities on the Steepbank River provide ideal sucker spawning habitat (Scott and Crossman 1973). In the spring of 1977, Machniak and Bond (1979) documented an upstream spawning migration of 3811 longnose sucker. Data from the spring of 1995 confirm that the Steepbank River remains an important spawning area for longnose sucker. Longnose sucker spawning sites were found throughout the study reach on the Steepbank River but were most common in the top half of the study area. At a number of sites, longnose sucker spawning activity was observed and at others, eggs were collected. Also, the Steepbank River provides important rearing habitat for young-of-the-year and juvenile longnose sucker. Riffles with large boulders and pool tails provide good cover for juvenile longnose sucker. Most adult longnose sucker vacate the Steepbank River shortly after spawning and spend the summer feeding in the Athabasca River. Longnose sucker were abundant in the Athabasca River near Suncor throughout the summer and fall, particularly in backwater areas. Findings of the present study are similar to those of the AOSERP studies from the 1970s.

Population-Level Indicators

Age-Frequency Distributions - To assess the potential baseline impact of refinery activities on the age-specific survival of VECs, age-frequency plots for Athabasca River longnose sucker, walleye and goldeye collected in the vicinity of the Suncor facility were compared to historical data for fish collected upstream of Grand Rapids during the Alberta-Pacific (Al-Pac) pulp mill baseline study (SENTAR 1994). Figures 4.3-6, 4.3-7 and 4.3-7, show age-frequency plots for longnose sucker, walleye and goldeye, respectively. Data shown in these figures are from a subsample of all fish caught by all sampling methods in the two studies, and therefore are representative of the fish population as a whole. The age-frequency distributions of longnose sucker and walleye collected in spring 1995 within the oil sands reach of the Athabasca River appear very similar to data for fish collected upstream of Grand Rapids during spring 1991 and 1992 (Figure 4.3-6 and 4.3-7). These data suggest that the population structure and age-dependent survival for these species are not affected by natural leachates from the oil sands area, or by refinery activities. For goldeye, no fish older than nine years were collected in the vicinity of the Suncor operations. In contrast, goldeye as old as 17 years were collected further upstream (Figure 4.3-8). Moreover, the age-distribution of goldeye in the vicinity of the oil sands refineries is shifted towards younger fish. This is consistent with the findings of Tripp and McCart (1979), and Tripp and Tsui (1980) suggesting that the goldeye population in the oil sands reach of the Athabasca River consists mainly of highly mobile, younger aged cohorts of this species that utilize this stretch of the river for feeding. The presence of juvenile fish of various ages in samples collected near the Suncor plant is an indicator of successful reproduction and subsequent survival of larval-juvenile stages of these fish.

Length-at-Age Relationships - Information on fish growth rates can be obtained from the size (length) of fish at each age class. Age-length plots for longnose sucker, walleye and goldeye are presented in Figures 4.3-9, 4.3-10 and 4.3-11, respectively. These figures compare data collected during 1995 to those collected during historical studies on the Athabasca River system. It is apparent from these figures that longnose sucker, walleye and goldeye collected in the vicinity of the oil sands have faster growth rates that fish collected upstream of the oil sands area in previous studies. Increased growth rates could be related to higher food availability in the oil sands reach of the Athabasca River.

Whole-Organism Indicators (Energy Use and Reproduction)

Length-Weight Relationships and Condition Factor - Condition factor can yield information on energy reserves in fish (Mayer et al. 1992) and can be calculated from the relationship between fish length and weight. Figures 4.3-12 and 4.3-13 show the relationship between length and weight for longnose sucker and walleye collected in the present and in past studies. Data for goldeye length versus weight were not available for the Al-Pac baseline study. Walleye collected in the vicinity of the oil sands operations in the present study appear to be lighter at a given length (i.e., lower in condition) than other members of this species collected upstream. Similarly, longnose sucker of the smaller, younger size classes collected from the oil sands study area in 1995 weigh less than those from other sites. These data do not support the hypothesis that higher growth rates in the study reach may be due to increased food availability, since increased food should result in increased growth rate and increased condition (Munkittrick et al. 1992). However, data for fish weight and length reported in Figures 4.3-12 and 4.3-13 were collected non-destructively, and therefore sex, reproductive status and other factors affecting fish weight could not be recorded. In contrast, the length-weight relationships for longnose sucker and walleye shown in Figures 4.3-14 and 4.3-15 are from smaller data sets consisting of fish that were sacrificed for biomarker analysis and sorted by sex and reproductive status. In this case, male and female longnose sucker and walleye from the study area are consistently heavier at a given length than are fish from further upstream. Data for condition factor support this conclusion (Table 4.3-4).

Liver Size - Changes in liver size measured in fish may be largely due to variations in fat and glycogen content, and therefore liver size functions as an indicator of nutritional status. Increases in liver size are common in fish exposed to organic chemicals such as petroleum hydrocarbons (see review in Heath 1995). An increase in liver size can be caused by hyperplasia (increased cell number) and/or hypertrophy (increase in cell size); and, consequently increased liver size may be associated with an increased capacity to metabolize xenobiotics, and therefore could be considered an adaptation to pollutant stress rather than a dysfunction caused by it (Heath 1995). Figures 4.3-16 and 4.3-16 show the relationship of liver size to total body weight for female and male longnose sucker and walleye from the present study, and for fish collected during the 1992 baseline survey of these species at the Al-Pac site; liver somatic index (LSI) data are summarized in Table 4.3-4. Except for female longnose sucker, LSI for both sexes of these two species were lower in fish collected at the Suncor site than in fish collected during the Al-Pac study. Histopathological analysis of liver tissue from fish collected near the Suncor facility during the 1995 survey did not detect anomalies attributable to refinery activities (GlobalTox 1995). Data for goldeye are not presented because of small samples sizes (n<5) captured for the Al-Pac baseline study.

Gonad Size - Gonad size is an important indicator of reproductive fitness in fish. Reductions in relative gonad size (expressed as gonad-somatic index (GSI)) have been noted in fish exposed to industrial effluents (Payne et al. 1978, cited in Heath 1995). Total fish weight versus gonad weight relationships for pre-spawning male and female longnose sucker collected from the vicinity of Suncor in 1995 and from the Al-Pac baseline study in 1992 are shown in Figure 4.1-18. Mean GSI and associated statistics are given in Table 4.3-4. Male and female longnose sucker collected from the site adjacent to Suncor's operations in 1995 had larger relative gonad sizes than their counterparts collected upstream during the 1992 baseline survey at the Al-Pac site. Gonad size in walleye or goldeye was not examined because these species were sampled post-spawning.

Fecundity - Fecundity is a measure of the number of eggs produced by a female fish, and is therefore an indicator of reproductive fitness. Fecundity for longnose sucker collected during the present study are compared to historical data collected in previous studies in Table 4.3-5. From these data, it appears that fecundity measured during the present study is within the range for female longnose sucker noted in other studies.

Fat Content - Gross mesenteric fat is a measure of fat storage and nutrition in fish. Lipid and mesenteric fat content decrease in fish exposed to some chemicals (Rao and Rao 1984) and increases in response to others (Swanson et al. 1993). Mesenteric fat for Al-Pac was reported differently than in the present study. In the present study mesenteric fat is reported in percent coverage (none, 50%, < 50% and 100%) whereas the Al-Pac report cites fat content as normal, none or excessive. Therefore, no statistical analyses were done on these data. Comparison of Suncor and Al-Pac data does, however, indicate that mesenteric fat content is within the same range at both sites.

Pathology - External and internal pathology was recorded for all fish species captured during the course of the 1995 baseline study (see Golder 1996b). The incidence of gross external and internal pathologies was similar to that observed further upstream at the Al-Pac site (SENTAR 1994). A report on the histological examination of fish collected during the Suncor study concluded that "The findings ranged from incidental changes that could be attributed to the method of capture and sampling to chronic parasitism. There were no changes consistent with toxicity, nor were there any neoplasia" (GlobalTox 1995).

Biochemical and Physiological Indicators

Reproductive Hormones - Sex steroid levels are important for determining reproductive development, maturation and behaviour in fish. Chemical exposure may affect sex steroid metabolism, thereby adversely affecting reproduction; for example, levels of circulating sex steroids and gonad size were reduced in white sucker exposed to pulp mill effluents (Munkittrick et al. 1991, 1994). In the 1995 baseline study, circulating sex steroids (testosterone in males, 17 -estradiol in females) were measured in longnose sucker, walleye and goldeye (Tables 4.5-16, 17, 18 from Golder 1996b). Levels in longnose sucker were similar to those found in prespawning fish from the Wapiti-Smoky River system and the North Saskatchewan River (Schryer et al. 1995). Sex steroid levels in walleye and goldeye measured in the 1995 survey were within the normal range expected during the mid-summer post-spawning season.

Blood Chemistry - Concentrations of lactate, glucose and total protein in plasma may be used as general indicators of stress in fish. Levels of lactate, total protein and glucose in walleye and goldeye collected during the 1995 survey at the Suncor site are presented in Table 4.5-15 of Golder (1996b). It is difficult to draw conclusions regarding these data because of the lack of comparable data for reference fish. Glucose appears to be somewhat elevated in the fish from the Suncor site (Folmar 1993); however, it is difficult to say whether these changes are a response to exposure to chemicals, or simply due to environmental factors such as pH, temperature, or water velocity (Hille 1980 cited in Folmar 1993).

Retinol - Retinol (Vitamin A) stores have been shown to decline in fish exposed to organic chemicals that interact with the Ah receptor (PCBs, PAHs, dioxins) (Palace et al. 1995). Retinol was measured in liver tissues of goldeye and walleye to provide baseline data for later comparisons; there are no comparable retinol data for either upstream fish or from the pre-development period. Retinol data from the Suncor study are presented in Table 4.5-15 of Golder (1996b).

Mixed Function Oxidases - Table 4.3-6 shows levels of MFO activity in the livers of longnose sucker, walleye and goldeye from the present study, compared to data from previous studies focusing on the same species at a number of reference sites and sites on and near the Athabasca River system. Generally, data for fish collected during the 1995 survey in the vicinity of Suncor show induction of MFOs (as EROD) activity in males and females of all three species, relative to reference sites on the North Saskatchewan River, Peace River and Beaver-Cowan River, and relative to upstream sites on the Athabasca River. Data from Brownlee et al. (1993) show similar relative induction for goldeye. Induced activity of MFO is a physiological response consistently noted in fish exposed to various natural and anthropogenic compounds, including: pulp mill effluents (McMaster et al. 1991; and Munkittrick et al. 1991), dioxin and dioxin-like compounds (Stegeman et al. 1992) and PAHs; (Parrott et al. 1996a, 1996b). As a result of natural leaching processes, river water travelling through the area of the oil sands deposits carries high background levels of PAH capable of inducing MFO activity in fish. For example, data from the Northern River Basin Study show that goldeye collected from the Athabasca River upstream of Fort McMurray have elevated EROD levels; this is evidence that there are naturally occurring levels of inducing compounds well outside of the zone of any possible influence of the refinery activities (Brownlee et al. 1993, Brownlee person. comm.). Other unpublished data from the NRBS study include the results of a basin-wide survey of burbot health indicators - this survey found that relative to other sites in northern Canada, MFO activity in burbot liver was elevated at only two sites: Fort McMurray and the Wabasca oils sands area (*Brownlee person. comm.*). The Wabasca oil sands area is hydrologically separated from the Athabasca River (and therefore outside the area of exposure to effluents from the oil sands refineries), but geographically within the area of the oil sands deposits.

PAH Metabolites in Bile - PAH and other xenobiotics that enter the body can be metabolized by the MFO and other components of the detoxification system. These metabolites can collect in tissues, sub-cellular macromolecules and bodily fluids, especially bile - which serves as a route for excretion out of the body. PAH metabolites can be more toxic than the original parent compound, and have been correlated with the occurrence of hepatic and other lesions (Thakker et al. 1985; Krahn et al. 1986 as cited in Melancon et al. 1992).

In Table 4.3-7, data on levels of benzo(a)pyrene (BaP) in bile samples from fish collected during the present survey and the baseline Al-Pac survey (SENTAR 1994) are shown. Although bile residues of other PAH were analyzed in both studies, BaP was the only PAH common to both. Relative to fish collected upstream at the Al-Pac site, fish, particularly walleye and goldeye collected within the oil sands reach, had markedly higher levels of BaP residues in the bile, particularly walleye and goldeye. However, without further study, it is difficult to say what proportion of the residues were due to exposure to refinery effluents, and what proportion was due to exposure to naturally occurring levels of BaP in the river water.

Fish Tissue Concentrations - Levels of xenobiotics such as PAHs and metals in fish tissue (body burden) are related to levels of these compounds in the environment, pathways and time-frames of exposure and the ability of the liver to detoxify and excrete these compounds. Body burdens were examined in composite (by sex and species) samples of fish tissue (fillets). Walleye and goldeye had non-detectable levels of PAH/PANH and alkylated PAH/PANH compounds. Longnose sucker composite samples showed detectable naphthalene levels of 0.09 µg/g (ppm) for males and 0.04 µg/g for females; however, other PAH/PANH parameters were not detected (detection limits range from 0.02 to 0.04 µg/g). Metals were not detectable in composite walleye, goldeye and longnose sucker fillets (Tables 4.5-21 to 4.5-23 in Golder 1996b).

The low body burdens of PAHs and metals in walleye, goldeye and longnose sucker indicate that bioaccumulation of these compounds is low. Since previous analyses indicate that the MFO system is induced and PAH metabolites are present in bile it is likely that the fish in the Suncor area are either successfully metabolizing and excreting PAHs.

Summary

To assess the current state of health of the fish community in the Suncor study area, a suite of indicators was examined at several levels of biological organization. This approach was necessary because stress effects on fish cannot be adequately evaluated by measuring a single indicator at a single level of organization. The following points summarize the major findings of the baseline fish health study:

- Presence/absence data indicate a fish community in the vicinity of the Suncor operations that is similar in diversity to what was found historically in other parts of the Athabasca drainage basin, indicating no discernible effect of present refinery activities on the structure of the fish community.

- Habitat utilization surveys conducted during the Suncor survey indicate that various fish species continue to use different areas of the Athabasca River and its tributaries for spawning, feeding and other activities. Habitat utilization does not appear to be affected by Suncor's existing operations.

- Age-frequency distributions for the three VECs show no unusual patterns, with no mortality of sensitive juvenile life stages indicated. Goldeye did show a downwards shift in age distribution, however this is more likely due to the behaviour and movements of this species than a result of Suncor's existing operation.

- Growth rates of all three VEC species are higher in the vicinity of the Suncor operations, relative to growth rates further upstream. This may be due to higher food availability of food in the Suncor area, although the exact cause of the higher growth rate is not known.

- The condition in longnose sucker and walleye collected for biomarker analysis near the Suncor operations is higher than comparable fish collected upstream. This agrees with the observation of higher growth rates in this area, and supports the hypothesis of greater food availability in the area.

- Liver size of fish collected near the Suncor plant was generally smaller than that of fish collected upstream, and there was no pathological evidence of liver disease in fish collected at the Suncor site.

- Gonad size in male and female longnose sucker collected near Suncor was larger than that of comparable fish collected upstream, and circulating sex steroid levels in the Suncor fish were considered within the normal range. These data, coupled with the presence of juvenile life stages of all three VECs in the Suncor area, suggest that Suncor's current operations do not affect fish reproduction.

- Activity of the liver MFO system and levels of PAH metabolites in the bile of fish collected near the Suncor site are elevated relative to fish collected at reference sites. This is to be expected, because fish collected at other sites upstream of the Suncor plant, but still within the area of the oil sands deposits have naturally high levels of MFO activity.

- Body burdens of PAHs and metals are low to non-detectable in fish collected in the vicinity of Suncor.

4.3.2 Assessment and Measurement Endpoints

Endpoints are characteristics of ecological components that may be affected by exposure to a stressor (e.g., chemical). Assessment endpoints are explicit expressions of the actual ecological value that is to be protected. For this investigation, the assessment endpoints include protection of the viability of populations of the fish VECs: walleye, goldeye and longnose sucker.

However, assessment endpoints tend to be qualitative or semi-qualitative, and are rarely directly measurable. As a result, measurement endpoints are usually defined as surrogates for assessment endpoints. Measurement endpoints are the quantitative response of the ecosystem component or receptor to the stressor, which is related to the characteristics of the assessment endpoint. In other words, it is the response to which exposure to the chemicals of potential concern is related so that one can identify whether a specific exposure scenario might adversely affect ecosystem components. For this study, he measurement endpoints used to evaluate the assessment endpoint are at three levels of organization: (1) population; (2) whole-organism; and, (3) biochemical/physiological. The population-level endpoints include age distribution (an indicator of age-specific survival), size-at-age (an indicator of growth), GSI and fecundity (two indicators of reproductive capability). Data for these endpoints are from the field component of the study are summarized in Golder (1996b). Whole organism endpoints include condition, short-term growth, pathology, disease resistance and swimming stamina. Data for these endpoints are from the 1995 field study (Golder 1996b) and/or laboratory experiments (HydroQual unpublished data). Biochemical and physiological endpoints include relative liver size, blood chemistry, blood cell counts, MFO and chemical concentrations in tissue. Data for these endpoints are from the 1995 baseline field study (Golder 1996b) and/or laboratory experiments (HydroQual unpublished data).

The measurement endpoints provide quantitative information from which ecological risks can be characterized. For this assessment. ecological risks were classified as follows:

Negligible risk	No change in measurement endpoints.
Low risk	Less than or equal to 10% change in measurement endpoints that relate to survival, reproduction or growth, or a measurable change in other endpoints.
Moderate risk	Greater than 10% but less than or equal to 20% change in measurement endpoints that relate to survival, reproduction or growth.
High risk	Greater than 20% change in measurement endpoints that relate to fish survival, reproduction or growth.

These definitions are more protective that those proposed by Suter et al. (1995), who suggests that changes of less than 20% in endpoints that relate to survival, reproduction or growth *are de minimus* with respect to sustainability of most ecological populations or communities.

4.3.3 Summary of Experimental Data

There are three sources of experimental information about the effects on fish health from exposure to operational and reclamation release waters from oil sands operations:

1. Northern River Basins Study (NRBS),
2. short-term (4- day) exposure study in which fish were exposed to CT water, dyke seepage water, Athabasca River water and Suncor's refinery wastewater, and
3. 7-day and 28-day laboratory data for exposure of fish to water from TID and the Athabasca River.

The NRBS data include those obtained during a study that used semi-permeable membrane devices (SPMDs). SPMDs are polyethylene dialysis bags filled with triolein (a purified fish lipid). They act as accumulators of lipophilic (fat-soluble) compounds that are present in the water column. The SPMDs in the NRBS study were suspended in the water column for two weeks at several locations throughout the Athabasca River Basin (Parrott et al. 1996a, 1996b). The contents of the SPMDs were then extracted with hexane, concentrated and then applied to fish liver cell cultures. Induction of the MFO detoxification system (measured as EROD activity) in the liver cell cultures was then measured and the potencies of the various SPMD extracts compared.

The short-term laboratory experiments involved 4-day exposures of rainbow trout fingerlings to CT release water, dyke seepage water, Athabasca River water from downstream of Suncor's wastewater (J. Parrott, 1996, person. commun.). The primary measurement endpoint for these short-term experiments was induction of the MFO system, measured as EROD activity

The 7-day and 28-day, flow-through experiments involved exposures of juvenile walleye and rainbow trout as well as larval rainbow trout to a series of dilutions of TID water, plus Athabasca River water and a 1% naphthenic acid solution. (HydroQual 1996). Endpoints included survival, growth (weight gain over the 28-day period), condition factor, relative liver size (Liver Somatic Index), blood chemistry, blood cell counts, EROD induction, gross external and internal pathology, histopathology, swimming stamina and resistance to a bacterial challenge.

4.3.4 Experimental Results

The SPMD data collected by Parrott et al. (1996a, 1996b) showed that the Suncor refinery effluent contained EROD inducers; however, the levels of EROD induction were similar to that from exposure to water from the Steepbank and Clearwater Rivers.

The results of the 4-day fish exposure study showed that dyke seepage water and Athabasca River water (upstream and downstream of the oil sands operational area) do not cause a significant increase in EROD induction (Table 4.2-1). CT water and Suncor refinery wastewater caused a significant increase in EROD induction at dilutions of $\geq 32\%$ and $\geq 10\%$, respectively (Table 4.2-1).

The results of the 7-day and 28-day experiments showed very little evidence for effects on fish health except at the highest concentrations tested. The only significant reduction in survival occurred in 50% TID water during the 7-day exposures. There was no significant effect on growth in either juvenile walleye or rainbow trout. Larval rainbow trout grew more quickly in Athabasca River water than in other treatments. The only change in condition factor occurred in juvenile trout exposed to 1% naphthenic acid (where the condition factor averaged 0.8 compared to 1.4 in controls). Enlarged livers occurred in juvenile trout exposed to 1% naphthenic acid. There were no differences in the incidence of gross external and internal pathology. Significant histopathological change (hepatic lipidosis) was noted in fish from the 10% TID and naphthenic acid treatments. The fish in the 10% TID treatment also exhibited some kidney degeneration and regeneration. Hematocrit was reduced in the 50% TID treatment during the 7-day experiment and in the 10% TID and 1% naphthenic acid treatments during the 28-day exposure experiment. Lactic acid levels were elevated in the severely stressed fish exposed to 50% TID water in the 7-day experiment. The longer-term, 28-day test produced lower lactic acid levels in the highest exposure (10% TID) as well as in the 1% naphthenic acid treatment. This result was attributed to the relative inactivity of fish in these treatments compared to lower concentrations and the controls. Plasma glucose levels were decreased in the 50% TID treatment of the 7-day test and in the 10% TID and 1% naphthenic acid treatments of the 28-day test. There were no differences in white blood cell ratios among treatments. The induction of EROD activity was significantly higher in the 10% TID treatment. There was no reduction in the ability to resist bacterial infection among fish exposed to TID water; the highest mortality in the bacterial challenge tests was observed in the Athabasca River water treatment. There was no relationship between exposure to TID water treatments and swimming stamina; fish exposed to Athabasca River water had less endurance than fish from other treatments.

The walleye and rainbow trout responses were very similar during the 28-day exposure test. Therefore, results from one species appear to be applicable to the other. This is important because it provides some reassurance that predictions based on rainbow trout and walleye also apply to longnose sucker and goldeye (the other VECs) and to other fish in the Athabasca River.

4.3.5 NOEL and LOEL

Since toxicity testing is often done with a series of dilutions of a toxic substance (e.g., 0.1%, 0.32% and 1% percent concentrations of TID water) a useful way to rank effects is by classifying the concentrations that cause an effect. Concentrations are typically classified as NOELs or LOELs. The NOEL is the highest concentration at which no effects on the measurement endpoint are observed and the LOEL is the lowest concentration at which effects are observed.

Based upon the short-term laboratory results, the LOEL for EROD induction by exposure to CT water and refinery wastewater is 10% and the NOEL is 1%. (The actual NOEL will lie between 1% and 10%.)

The results of the 28-day exposure experiment were consistent among all of the measurement endpoints. The LOEL for the sensitive physiological endpoints and for histopathology was 10% (Table 4.2-2). Other "higher-order" whole-organism endpoints such as (growth and swimming stamina) that integrate the effects of all stress (including that caused by laboratory handling) showed no effect at any of the treatment concentrations (Table 4.2-2). There were no effects on the sensitive physiological endpoints at 1% or less. Therefore, the estimated NOEL is 1%. The actual NOEL is unknown, but would lie between 1% and 10%.

The 1% naphthenic acid treatment produced effects at both the physiological and higher-order levels (Table 4.2-2). The naphthenic acid used in the treatment is a laboratory standard and is not analogous to the types of naphthenates that may be present in Suncor operational or reclamation water releases. Therefore, the naphthenic acid data from the 28-day exposure cannot be used to derive effect thresholds or LOEL/NOEL information for concentrations in the Athabasca River.

There is evidence to suggest that naphthenic acids are the primary source of acute toxicity to biota from oil sands water releases (OSWRTWG 1996). However, at present there are several factors that preclude the determination of LOEL and NOEL levels for naphthenic acids. Naphthenic acids are a complex group of compounds (number of carbon atoms, number of ring structures) and the ability to characterize and isolate individual compounds is currently limited. Moreover, toxic responses appear to be complex. For example, the same concentration of naphthenic acids in different samples or waste streams can produce varying degrees of toxicity. This variation in toxicity is believed to be due to varying levels of individual naphthenic acids. Given the present uncertainties in establishing guidelines for naphthenic acids, OSWRTWG (1996) recommends the use of the whole-effluent toxicity approach. This approach is based on toxicity testing of whole effluent and not only eliminates the need to isolate individual fractions of the effluent but also incorporates interactions and synergistic effects of the numerous chemicals in effluent.

4.3.6 Predicted Concentrations Versus LOEL and NOEL

The available data indicate an LOEL of 10% for operational and reclamation waters affected by either the extraction process (i.e., dyke and pond seepage water, CT release water) or upgrading process (i.e., refinery wastewater). This LOEL applies to all endpoints, including the most sensitive biochemical/physiological parameters. The NOEL for all endpoints is assumed to be 1%. The actual NOEL for all endpoints may be greater than 1%, but it is not less than 1%.

These effect levels are almost entirely based upon exposure to TID water. Operational and reclamation water releases will include other types of water, notably refinery wastewater, mine drainage water and runoff and drainage water from reclamation units (including CT water). The limited information on other types of water (CT water, refinery wastewater and other dyke seepages) also indicates a LOEL of 10% and a NOEL of 1% (one endpoint only - EROD). Induction of EROD is a very sensitive endpoint; therefore, although it was the only endpoint used in tests on other types of water releases, it is unlikely that any other endpoint would yield lower LOELs or NOELs. Based on this reasoning, it was assumed that the LOEL and NOEL derived from the existing information could be also applied to Suncor's refinery wastewater, CT release water and seepage waters derived from other existing or future recycle or reclamation ponds and dykes. A comparable study to the 28-day TID exposure experiment is currently underway to test the applicability of this assumption for Suncor refinery wastewater.

The following assessment includes evaluating potential impacts for the current (1995) condition and four future scenarios (2001, 2010, 2020 and long-term). For each of these time periods, the river mixing model, which was described in Section 3.3, was used to predict levels of dilution within the Athabasca River associated with release of pertinent operational and reclamation waters. In particular, the model was set up assuming the same potency for dyke and pond seepage water, CT release water and refinery wastewater. Those release waters were examined under two flow conditions: 7Q10 and mean annual flows. The model results were then plotted to show the dilution zones in the river alongside and downstream of the water release points (Figures 4.3-19 to 4.3-28). For example, Figure 4.3-19 shows a small zone of 1% effluent adjacent to Suncor as a result of the existing cumulative loads from TID seepage and the wastewater effluent. That zone indicates that in that zone, the river water is made up of 1% operational and reclamation waters derived from Suncor's operations and 99% water from the Athabasca River. Mixing processes act to disperse the release waters within the river, so that the 1% zone is restricted to only a small area.

4.3.6.1 1995

Mean Annual Flow - The concentrations of operational and reclamation water releases in the Athabasca River under mean annual flow conditions are all much lower than the LOEL of 10% (Figure 4.3-19). There is a small area (1/20th of the river width and about 2 km long) with a 1% concentration and a very small area immediately adjacent to the refinery wastewater discharge point with a 2% concentration. The only area where some effects on sensitive endpoints could potentially occur would be the small area with a 2% concentration (assuming a NOEL of 1%). This area is so small that the total number of fish potentially responding to exposure would be negligible relative to populations of fish in the region.

7Q10 Low-Flow - 7Q10 flows represent the lowest flows that occur over a 7-day consecutive time period, once every 10 years. These flows, thus, represent a worst-case condition for dilution potential in the Athabasca River. Even so, the predicted concentrations are all less than the LOEL of 10% under 7Q10 conditions (Figure 4.3-20). There is a very small area immediately adjacent to the refinery wastewater discharge point with a 5% concentration and a somewhat larger area (about 5 km long and 1/20th of the river width) with a 2% concentration. The baseline study showed that several species of fish (including goldeye and longnose sucker) frequent the area adjacent to and downstream of the discharge because of the presence of backwater habitat (Golder 1996b). Therefore, the 7Q10 scenario presents the highest likelihood of a significant number of fish being exposed to water releases. However, since low-flow periods occur in late autumn and winter, and since overwintering habitat is not plentiful in the 2% zone, the overall exposure of fish to this concentration may be minimal (Golder 1996b). Therefore, effects on sensitive biochemical or physiological endpoints could occur within these two areas, assuming a NOEL of 1%, but the number of fish and the duration of exposure would be exceedingly small because of the time of year and infrequency that such concentrations occur.

4.3.6.2 2001 Through 2020

Mean Annual Flow - The highest modelled concentrations for all scenarios from 2001 through 2020 occur immediately adjacent to the refinery wastewater discharge point in 2001 (2%) (Figures 4.3-21 to 4.2-23). All other modelled concentrations are less than or equal to the NOEL. Thus, no effects (including those on the most sensitive endpoints) are likely.

7Q10 Low-Flow - A zone of 2% concentration along the west bank exists for all three model-years, ranging in size from about 4 to 9 km in length and occupying about 1/20th of the river width (Figures 4.3-24 to 4.3-26). A very small area of 5% concentration occurs immediately adjacent to the refinery wastewater discharge for all three model-years. All other modelled concentrations are less than equal to the NOEL. The area occupied by the 2% zone is used by several fish species during the open-water seasons, as noted above. However, since low-flow periods occur in late autumn and winter, and since overwintering habitat is not plentiful in the 2% zone, the overall exposure of fish to this concentration will be minimal.

4.3.6.3 Post-Reclamation

Mean Annual Flow - All concentrations are well below the NOEL of 1% (Figure 4.3-27); therefore, no detrimental effects on fish health are expected.

7Q10 Low-Flow - Concentrations are all below the 1% NOEL (Figure 4.3-28); therefore, no detrimental effect on fish health are expected.

4.3.7 Predicted Impacts on Biochemical and Physiological Endpoints

The threshold-effect concentrations used for comparison with modelled river concentrations are largely based upon biochemical and physiological endpoints for fish health (e.g., EROD). These endpoints are very sensitive and are indicative of exposure to a stressor or stressors and the fish's response to that stressor. A response by one of the biochemical or physiological systems does not necessarily predict adverse effects on the whole organism; in fact, early responses to stressors are often detoxification or adaptive responses that are designed to prevent whole organism effects. Therefore, threshold-effect concentrations based upon biochemical or physiological endpoints are conservative with respect to protecting fish from effects on individuals (whole organism) and even more conservative with respect to protecting fish populations.

The modelled concentrations for both the current (1995) case and future cases were all well below the observed LOEL for biochemical and physiological responses in fish. This was true even for 7Q10 extreme low-flow conditions. Thus, it is very unlikely that exposure to operational and reclamation water releases will cause biochemical or physiological responses in fish in the Athabasca River. However, the presence of areas of concentration below the LOEL but above the NOEL indicate that there may still be a potential for effects on these endpoints.

The inference regarding the current situation in the Athabasca River can be tested by comparing the predicted lack of biochemical and physiological responses with observed responses in fish collected in the field during the summer of 1995. These field-collected fish spend some of their time in the immediate vicinity of the Suncor operations (see Section 4.1.1 for description of habitat use in the study area). Data for EROD and AHH activity show that the wild fish have an activated liver detoxification system; both EROD and AHH activity levels are high relative to fish from farther upstream. Blood chemistry data do not indicate any differences from normal ranges reported in the literature (although reference data are limited or lacking). The elevated EROD activity in field fish indicates either that: (1) the laboratory exposures did not sufficiently represent the exposure conditions in the field (such as prolonged exposure well beyond 28 days even though concentrations are very low); or, (2) the EROD activity in the field is in response to stressors that were not represented in the laboratory experiments (such as naturally-occurring compounds related to the bitumen deposits). The blood chemistry results from the field corresponded with predictions based upon laboratory data.

4.3.8 Predicted Impacts on Whole-Organism and Fish Population Endpoints

4.3.8.1 Effects on Whole Organism Responses

Some of the laboratory endpoints are indicative of the health of the whole organism, including growth, condition, pathology, disease resistance and swimming stamina. None of these whole-organism endpoints showed a response in the laboratory exposures (including in the highest concentration of 10%). Therefore, effects from the current Suncor operations and from future operations are not expected. The prediction of no effect on whole-organism endpoints can be compared to field data for wild fish captured in the Suncor study area in the summer of 1995. All three VEC species had higher growth rates than fish caught further upstream. The condition of walleye and longnose sucker was also higher in fish collected near Suncor than comparable fish collected upstream. Incidence of internal and external pathology was similar to fish from upstream, and there was no evidence of toxic effects. These findings show that although there are some differences in whole-organism parameters, these differences are not what would be expected from a response to chemicals. Rather, they are indicative of higher productivity (reflected in higher growth rates).

4.3.8.2 Effects on Fish Populations

The laboratory-derived endpoints and modelled river concentrations predict no effects at the physiological or whole-organism level. Therefore, effects on fish populations are also not expected. This prediction can be compared to observed fish population parameters (age-frequency distributions, fecundity, gonad size) from the summer of 1995 in the Suncor study area. Age-frequency distributions for walleye, goldeye and longnose sucker showed no unusual patterns, with no mortality of sensitive juvenile life stages indicated. Goldeye did show a downwards shift in age distribution, however this is most likely due to the behaviour and movement of this species than as a result of Suncor's operation. Similarly, reproductive parameters did not indicate any changes in fish reproduction that would affect fish populations. Gonad size in male and female pre-spawning longnose sucker was larger than comparable fish collected upstream and circulating sex steroid levels in all three fish species were considered in the normal range. As well, fecundity in longnose sucker female fish was similar to that of other studies. In summary, the field data show that there have been no discernible effects on survival (since there are no missing or severely-depleted age classes) or reproduction (gonad sizes and fecundity are, if anything, somewhat larger in the study area). The higher growth rates may be indicative of a more productive system, as discussed above.

4.3.9 Conclusions Regarding Fish Health

The assessment endpoint for fish health is to maintain healthy and sustainable populations of walleye, goldeye and longnose sucker. The only potential effect identified, which would not likely be measurable since it would only occur only under extremely low flow conditions and within a small zone in the river immediately below Suncor's wastewater discharge, is for slight changes in levels of some biochemical indicators. The lack of predicted effects on survival, growth and reproduction suggest that fish health will not be adversely affected by the proposed water releases scenarios. These predictions are supported by observations of current fish populations, which have been exposed to water releases from Suncor operations for the past three decades years. These populations continue to successfully utilize habitat in the Suncor study area, and exhibit normal growth and reproduction. Since future volumes of water releases to the Athabasca River are predicted to be lower than current conditions, future populations of fish should continue to be healthy. Thus, this information suggests that risks to fish populations from Suncor's operations are negligible.

4.4 Summary

Three separate approaches, chemical-specific, toxicity-based, and risk-based, were utilized to assess potential impacts from Suncor's water releases on aquatic biota in the Athabasca River. The findings from these three approach are consistent, that is there is no evidence that discharge of Suncor's operational or reclamation waters, either now or in the future, will adversely affect populations of aquatic organisms, including fish, that live downstream of Suncor's operations. The only potential impact that might occur is that under extremely low flow conditions, transient, non-lethal impacts might be evident for sensitive aquatic organisms that live within a small zone immediately below Suncor's wastewater effluent. However, it is not expected that these impacts would result in any measurable change in population attributes of fish or other aquatic organisms.

5.0 ASSESSMENT OF IMPACTS ON PEOPLE AND WILDLIFE

5.1 Problem Formulation

The objective of the Problem Formulation phase of a risk assessment is to develop a focused understanding of how chemical releases from the site might contribute to health risks for people and wildlife that might use the Athabasca or Steepbank Rivers. This is achieved by characterizing the setting, both physically and from a regulatory perspective, by identifying the wildlife and human activity that is expected to occur, by focusing on the chemicals that are present at concentrations that may be hazardous and identifying the important chemical exposure pathways. The outcome of the Problem Formulation phase is a list of chemicals of potential concern and a qualitative Conceptual Model of the important exposure pathways to be considered in the quantitative risk analysis portion of the risk assessment. In the case of ecological health, the Conceptual Model also includes statements about the ecosystem under consideration and the relationship between assessment and measurement endpoints (U.S. EPA 1994).

As discussed above, the Problem Formulation is the critical initial phase of the risk assessment and is conducted by completing three major steps as illustrated in Figure 5.1-1:

1) Preliminary Considerations
2) Screening Process
3) Development of the Conceptual Model

The geographical location, the scope of the problem, regulatory context, and remediation plans are outlined in the Preliminary Consideration step. Next, the chemicals, exposure pathways and receptor sub-populations of concern are identified and screened to focus the remainder of the assessment. This is a critical step since the existence of risk at any site is based on three components, as illustrated in Figure 5.1-2: i) chemicals must be present at hazardous concentrations, ii) human or animal receptors must be present and iii) pathways must exist for the chemicals to migrate from the source to the receptor. In the absence of any of the three components outlined in Figure 5.1-2, health risks cannot occur.

As discussed above, the product of Problem Formulation is the development of a site-specific Conceptual Model, which is qualitative in nature, and provides both the basis for and guidance to conduct the quantitative risk analysis phase.

5.1.1 Preliminary Considerations

Suncor's development is located on the Athabasca River near Fort McMurray in northeastern Alberta. Oil sands, which are a mixture of sand, clay, water and hydrocarbons in the form of bitumen, occur naturally in the area in seams of varying thickness. The oil-rich sand is excavated to produce high-quality, synthetic crude oil. However, the extraction process generates large volume of tailings, consisting of water, sand and fine clay particles, along with small quantities of unextracted bitumen. The tailings are hydraulically transported and deposited in tailings ponds, where the sand particles settle out and form a beach. The fine particles (<22 µm), on the other hand, remain in suspension in the water and accumulate in the ponds, eventually forming mature fine tails (MFT) with an average solids content of 30% by weight.

As of December 1995, MFT has been stored in ponds on Lease 86/17. Reclamation of these ponds will involve dewatering MFT using a mixture of sand and gypsum and incorporating the CT into various mined-out pits. This chemical treatment results in rapid dewatering such that a trafficable surface can be established within several years of treatment, as opposed to the hundreds of years (or more) required for natural consolidation of MFT.

The ultimate reclamation of the Suncor mine site is governed by AEP and Alberta Energy and Utility Board (AEUB). These regulatory authorities require that the reclaimed mine site achieves a level of biological capability approximating the original undisturbed condition (AEP 1995b). In addition, the reclaimed site must, over a reasonable period of time, develop into a normal, healthy ecosystem that can maintain itself without further human intervention. The health of organisms supported by the ecosystem must not be impaired by tailings chemicals, and movement and/or cycling of water and nutrients must eliminate the need for further additions or interventions. In addition, any potential for both short-term and long-term off-site impacts must be mitigated in the reclamation design.

Details of Suncor's current operations and proposed reclamation plan are given in Golder (1996a).

5.1.2 Chemical Screening

Two different approaches were used to identify which chemicals present in Suncor's operational and reclamation waters might pose a risk to people:

- A wasteload allocation study was completed in accordance with Alberta Environment Protection (1995a) guidelines, and
- A risk-based approach was completed in accordance with Health Canada (1995) guidelines.

5.1.2.1 Wasteload Allocation

Details of the wasteload allocation approach are given in Section 4.1 and Appendix VI. The general approach involves estimating chemical concentrations within the Athabasca River, based on the cumulative load from all of Suncor's current and future operational and reclamation water releases. These predicted concentrations are then compared to health-based drinking water criteria. Chemicals identified as potential health issues using this approach are ones that require further investigation as to the reason why they were flagged as an issue.

The primary differences between the approach explained in Section 4.1 for aquatic biota and that followed for human health are that:

- Human health guidelines are used that are based on protecting sensitive individuals from any adverse health effect that might occur from drinking untreated river water over a lifetime, and
- Human health guidelines are evaluated after complete mixing with 100% of the 30Q5 flows or harmonic mean river flows

The wasteload allocation study identified three parameters as potential health issues: arsenic, benzo(a)anthracene, and total PAHs. The PAH benzo(a)anthracene was also identified as a chemical of potential concern using a risk-based screening approach and is thus addressed in detail in Section 5.4.1. Arsenic was identified as a result of the extremely low criteria (0.000018 mg/L) set forth by the U.S. EPA, because of its potential for bioaccumulation in fish. The criterion for arsenic is naturally exceeded in the Athabasca River at sites upstream of Suncor. For example, the median winter value at Fort McMurray is 0.00052 mg/L. However, there is no evidence of arsenic accumulating in tissues of any of the fish from the Athabasca River analyzed during the 1995 field studies (Golder 1996a), nor any evidence that exposure to process-affected waters results in elevated arsenic levels in fish tissues (HydroQual 1996). Further, if the drinking water criterion was used (0.05 mg/L), arsenic would not have been identified as a chemical of concern. A comprehensive laboratory study has been initiated to confirm that arsenic from Suncor's refinery wastewater does not significantly bioaccumulate in fish tissues.

5.1.2.2 Risk-Based Screening

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

The screening process used for both the human health and ecological risk assessments followed a methodical, step-wise process, as shown schematically in Figure 5.1-3, and outlined in detail below. Detailed screening tables are presented in Tables 5.1-1 to 5.1-13.

Human Health

Step 1: Compile Validated Data of Chemical Concentrations from Site Investigations

Site-specific data were collected, evaluated and appropriate concentrations were selected for the screening process. For this assessment, the maximum concentrations measured were selected as a conservative estimate of the chemical concentrations. This step is identical for both human and wildlife health assessments.

Water - Six types of operational and reclamation waters were screened: refinery wastewater, cooling pond E water, mine drainage water, groundwater from TID seepage collector system, groundwater wells downgradient of Plant 4 tailings and CT release water.

Suncor refinery wastewater samples were collected from the wastewater system at the duck pond (ID: RW 254) and Cooling Pond E samples were collected from Cooling Pond E at the duck pond (ID: RW 256). Samples of mine drainage water were obtained from mine drainage systems at the north mine, mid-plant and south mine (ID: RW 250, RW 251 and RW 252). These samples are considered to be representative of natural surface waters diverted around the mine so they have not been in contact with oil sands or mining wastes. In addition, one area of particular concern with respect to tailings sand is the quality of seepage water associated with Plant 4 tailings. This tailings is beached in Pond 1 resulting in a large area of exposed tailings. Raw tailings from Plant 4 (Sample ID# Beach #2) contain a wider range of PAHs, and generally higher concentrations than those present in most other TID water and, thus, represents worst case concentrations for dyke seepage water. Quality of Plant 4 tailings seepage waters are based on groundwater samples (ID: RG 088 and RG 089) and Plant 4 Beach #2 tailings water (ID: E504203-02).

Dyke drainage water consists of process-affected water that is entrained in the coarse sand tailings that are used to form the dykes surrounding tailings ponds 1/1A, 2/3 and 4. Dyke drainage water quality data are available from composite samples collected from the TID collection system (ID: RW 127). These samples are assumed to be representative of water that will seep from sand dykes structures associated with the reclaimed landscape.

Samples of CT release waters were obtained from laboratory and field experiments conducted by Suncor and Syncrude in 1995:

- Suncor's 1995 CT field trial experiments - Pit 1 without nutrients, static pit (RW 163);
- Suncor's 1995 CT field trial experiments - Pit 2 without nutrients (RW 164).

- Suncor's 1995 CT field trial experiments - Pit 3 with nutrients (RW 162);
- Suncor's 1996 pilot CT study (1219 and PD 5)
- Syncrude's 1995 CT laboratory flume test experiment (CT 900; CT 1400).

Background water quality data used in this assessment included water samples that were collected in the Athabasca River upstream of Lease 19 and water samples collected in the tributaries of the Athabasca River within or adjacent to Lease 86, 17, 97 and 19 (*i.e.*, Steepbank River, Leggett Creek, McLean Creek and Wood Creek).

Fish Tissues - Fish tissue data were obtained from walleye, goldeye and longnose sucker collected during spring and summer of 1995 and were analyzed for PAH/PANH, alkylated PAH/PANH and trace ICP metals (Golder 1996b). These data were considered to be representative of baseline conditions. In addition, tissue analyses were performed on trout held in 10% TID water in the laboratory and these data were considered to represent a worst-case scenario (HydroQual 1996). 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 1996). The fish tissue samples were analyzed for PAH/PANH, alkylated PAH/PANH and trace ICP metals.

Step 2: 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. Chemicals for which SLCs were lacking were grouped according to their structure, physiochemical and toxicological properties. Groupings and rationale are presented in Appendix II.

Water - Drinking water criteria included:

- Health and Welfare Canada (HWC) Guidelines for Canadian Drinking Water Quality. Maximum Acceptable Concentration (HWC 1993);
- U.S. EPA's (U.S. Environmental Protection Agency) Maximum Contaminant Level for Drinking Water for Humans (U.S. EPA 1993); and
- BC Environment (BCE) Water Quality Criteria. Ambient Criteria. Drinking Water (BCE 1994).

The lowest value of the three above criteria was used as the SLC for chemical in drinking water for people (Table 5.1-1).

Fish Tissues - No pertinent criteria were located for screening chemicals levels in fish tissue.

Step 3: Comparison of Observed Background Concentrations to SLC

The Suncor site is located in a unique environment, having near-surface pools of naturally occurring petroleum hydrocarbons. Therefore, background concentrations of some petroleum-derived chemicals would be naturally high in this region in comparison to other areas of Alberta. Site-specific background concentrations of chemicals are important in defining those chemicals in which exposure-point concentrations may increase as a result of site reclamation.

Observed background concentrations were compared to SLC (as defined in Step 2) to determine the relevance of regulatory criteria for this unique site. If the observed background concentrations fell below the SLC, then the criteria were considered to be appropriate for the site. If an observed background concentration was greater than the SLC, then the applicability of the criterion was further discussed as part of the risk characterization (for those chemicals retained for Risk Analysis). Chemical detection limits were also reviewed at this stage. If a chemical detection limit exceeded the SLC, then the chemical was identified and the implications were further discussed as part of the risk characterization (for those chemicals retained for the Risk Analysis).

Concentrations of aluminum, iron, manganese and phosphorus in Athabasca River and reference tributaries exceeded the SLC for drinking water (Table 5.1-2).

Step 4: Comparison of Maximum Observed Concentration to SLC

If the concentration of a chemical exceeded the SLC or if there was no SLC for a particular chemical (Table 5.1-3), then the chemical was retained for further analysis and carried forward to Step 5 (Table 5.1-4). If the concentration of a chemical did not exceed the SLC, then the chemical was eliminated from further consideration.

The following chemicals exceeded SLCs drinking water and were carried forward to the next screening step:

benzo(a)anthracene group
benzo(a)pyrene group
aluminum
arsenic
cadmium
chloride
iron
manganese
molybdenum
nickel
phosphorus
sodium
sulphate
vanadium

The following chemicals did not have any relevant criteria to determine a SLC for drinking water and were carried forward to the next screening step:

acenaphthylene
acenaphthene group
benzo(ghi)perylene
biphenyl
dibenzothiophene group
fluoranthene group
fluorene group
naphthalene group
phenanthrene group
pyrene
acridine group
quinoline group
naphthenic acids
2,4-dimethyphenol
m-cresol
ammonia
calcium
cobalt
lithium
potassium
silicon
strontium
tin
zirconium

Detection limits for chemicals that were excluded at this step were all below health-based criteria.

Step 5: Comparison of Observed Chemical Concentrations to Background Values

The maximum chemical concentrations observed for each environmental medium (*i.e.,* water, fish) were compared to background levels (Table 5.1-4 and 5.1-5). If the maximum chemical concentrations measured at the site were less than or equal to maximum concentrations measured in background samples, then these chemical concentrations were assumed to be natural in origin and typical of the area and were removed from any further chemical screening.

Water - The maximum concentrations of the following chemicals exceeded background concentrations and were carried forward to the next screening step:

acenaphthylene
acenaphthene group
benzo(a)anthracene group
benzo(a)pyrene group
benzo(ghi)perylene
biphenyl
dibenzothiophene group
fluoranthene group
fluorene group
naphthalene group
phenanthrene group
pyrene
acridine group
quinoline group
naphthenic acids
2,4-dimethylphenol
m-cresol
ammonia
arsenic
cadmium
calcium
chloride
cobalt
iron
lithium
manganese
molybdenum
nickel
phosphorus
potassium
silicon
sodium
sulphate
strontium
vanadium

The following chemicals did not have any relevant background data for surface water and were, thus, carried forward to the next screening step:

tin
zirconium

Fish Tissue - The maximum concentrations of the following chemicals exceeded background concentrations and were carried forward to the next screening step:

naphthalene group
calcium
copper
magnesium
manganese
nickel
potassium
silicon
sodium
zinc

Step 6: Comparison of Maximum Observed Concentration to Risk-Based Concentration

Risk-Based Concentrations (RBCs) for the ingestion of tap water and fish are available from U.S. EPA's Region III Risk-Based Concentration Table (Smith 1995). This list of chemicals in which RBCs are defined is more complete than that for which SLCs have been derived. In this step, the maximum chemical concentrations measured in release waters and fish were compared to the RBCs (Tables 5.1-6 and 5.1-7). If the maximum concentration of a chemical exceeded the RBC or if a RBC was not available, then the chemical was retained for further analysis. If the RBC was not exceeded, then the chemical was eliminated from further consideration. The RBCs used here are based on the assumption that people will drink the source water and eat fish on a daily basis, 350 days per year for 30 years.

Water - Concentrations of the following chemicals exceeded RBCs for drinking water and were carried forward to the next screening step:

benzo(a)anthracene group
benzo(a)pyrene group
ammonia
arsenic
chloride
manganese
molybdenum
vanadium

The following chemicals were retained because RBCs were not available:

naphthenic acids
calcium
iron
phosphorus
potassium
silicon
sodium
sulphate
zirconium

Fish Tissue - None of the chemicals exceeded RBCs for fish ingestion.

The following chemicals were retained because RBCs were not available:

calcium
silicon
magnesium
sodium
potassium

Step 7: Substance is Essentially Non-Toxic Under Environmental Exposure Scenarios

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 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).

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

Arsenic exceeded both SLC and RBC because a concentration of 0.17 mg/L was recorded in a single sample of refinery wastewater. Concentrations in all other refinery wastewater samples (n=66) ranged from less than the detection limit of 0.000001 mg/L to a maximum of 0.01 mg/L. Values reported for all other types of water including CT release water (0.0007-0.0058 mg/L), TID seepage water (0.0026-0.003 mg/L), plant 4 seepage water (0.0036 mg/L), mine drainage water (<0.0002-0.002 mg/L) and cooling Pond E water (0.0002-0.004 mg/L) were well below this value and did not exceed the health-based drinking water criteria of 0.025 mg/L. Given that the maximum value of 0.17 mg/L was reported only for a single sample, that no similar values have been reported in any other samples, and that all other water concentrations were well below the drinking water criteria, it is assumed that this maximum value detected in March 1992 is an outlier and is not representative of typical conditions. Therefore, arsenic was eliminated from further consideration.

Chloride is an essential nutrient for people functioning to ensure the proper fluid-electrolyte balance and 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 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 (HWC 1993). 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. Furthermore, concentrations in limestone groundwater (background) ranged from 0.009 to 8.7 mg/L compared to a maximum concentration of 1.76 mg/L measured in any of Suncor's operational or reclamation waters (Plant 4 tailing sand groundwater). Therefore, given that there is no anthropogenic source for manganese, that absorption of manganese into the body is low and that concentrations fell within the range reported for background groundwater concentrations, manganese was eliminated from further consideration.

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 (NAQUADAT 1985). Concentrations in waters at the site ranged from 0.046 to 0.43 mg/L (Table 5.1-3). Given that phosphorus occurs naturally and that concentrations at the site fall within concentrations reported for surface waters in western Canada, phosphorus was eliminated from further consideration.

Silicon is insufficiently bioavailable to be absorbed following intake and is also considered biologically inert (HSDB 1995), therefore, it is considered non-hazardous for the purpose of this assessment and eliminated from further evaluation.

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 is considered non-hazardous for the purpose of this assessment.

Most zirconium compounds in common use are insoluble and considered inert (Sax 1975). The limited toxicity data available suggest that zirconium is considered toxic via inhalation, however; it does not appear to be a human health concern via the ingestion pathway (Gough et al. 1978). Therefore, zirconium was eliminated from further consideration.

Step 8: List of Chemicals of Potential Concern following Chemical Screening

The chemical screening process incorporated several protective assumptions to ensure that chemicals of potential concern would not fall through the screening process:

- The maximum recorded concentration of each chemical was used.
- No chemical-fate processes were incorporated into this screening. These processes would substantially reduce chemical concentrations prior to exposure (e.g., dilution by Athabasca River).
- SLCs were based on published criteria that are designed to prevent any adverse health effects.
- If no SLC were available for a chemical, it was retained and carried forward to the next chemical screening step.
- RBCs were based on extremely exposure conservative scenarios, e.g., assuming that people drink untreated operational and reclamation waters 350 days of every year for 30 years.

Considering all of the above protective assumptions, chemicals that are retained for further analysis after this screening are ones that require further investigation and do not necessarily pose a risk to people's health. Based on this screening, the following chemicals were identified as ones that required more detailed investigation with respect to people who might drink water from the Athabasca River downstream of Suncor's operations:

benzo(a)anthracene group
molybdenum
benzo(a)pyrene group
vanadium
naphthenic acids

It is important to emphasize that this screening process was restricted to chemicals related to Suncor's operations. Other chemicals, such as chlorinated organics derived from pulp mills, were not investigated here because Suncor is not a source for those chemicals. In addition, there are natural hazards, such as bacteria and viruses, associated with the river water that pose a health hazard to people who drink untreated river water.

No chemicals of potential concern were identified from the fish tissue screening. However, it should be noted that 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).

Wildlife Health

A similar, methodical step-wise screening process was applied to identify chemicals of potential concern that might affect the health of wildlife drinking water from the Athabasca River downstream of Suncor's operations.

Step 1: Compile Validated Data of Chemical Concentrations from Site Investigations

This is identical to that described above for screening chemicals against human health criteria.

Step 2: Compile Relevant Environmental Criteria and Select SLC

Water - Pertinent 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) Water Quality Criteria. Ambient Criteria. Wildlife and/or Livestock (BCE 1994).

The lowest available value of the two criteria was chosen as the SLC for drinking water (Table 5.1-8).

Fish Tissue - No criteria were located.

Step 3: Comparison of Observed Background Concentrations to SLC

The chemical concentration of aluminum in Athabasca River water exceeded the SLC; chemical concentrations in the reference tributaries did not exceed any SLCs (Table 5.1-9).

Step 4: Comparison of Maximum Observed Concentration to SLC

The following chemicals exceeded the SLC for drinking water supplies and were carried forward to the next screening step:

aluminum
vanadium
molybdenum
sulphate

The following chemicals did not have SLCs so were carried forward to the next screening step:

acenaphthene group
benzo(a)pyrene group
dibenzothiophene group
acenaphthylene
benzo(ghi)perylene group
fluoranthene group
benzo(a)anthracene group
biphenyl
fluorene group

- naphthalene group
- phenanthrene group
- pyrene
- acridine group
- quinoline group
- naphthenic acids
- chloroform
- ethylbenzene
- toluene
- xylenes
- 2,4-dimethylphenol
- m-cresol
- ammonia
- antimony
- barium
- chloride
- cyanide
- iron
- magnesium
- manganese
- phosphorus
- potassium
- silicon
- silver
- sodium
- strontium
- tin
- titanium
- zirconium

Step 5: Comparison of Observed Chemical Concentrations to Background Values

Water - The maximum concentrations of the following chemicals exceeded background concentrations and were carried forward to the next screening step:

- acenaphthene group
- acenaphthylene
- benzo(a)anthracene group
- benzo(a)pyrene group
- benzo(ghi)perylene
- biphenyl
- dibenzothiophene group
- fluorene group
- fluoranthene group
- naphthalene group
- phenanthrene group
- pyrene
- acridine group
- quinoline group
- naphthenic acids
- chloroform
- ethylbenzene
- toluene
- xylenes
- 2,4-dimethylphenol
- m-cresol
- ammonia
- antimony
- barium
- chloride
- cyanide
- iron
- magnesium
- manganese
- molybdenum
- phosphorus
- potassium
- silicon
- silver
- sodium
- strontium
- sulphate
- vanadium

The following chemicals did not have any background water data available so were carried forward to the next screening step:

tin

zirconium

Fish Tissue - The maximum concentrations of the following chemicals exceeded background concentrations (Table 5.1-5):

naphthalene group
magnesium
potassium
zinc
calcium
manganese
silicon
copper
nickel
sodium

Step 6: Comparison of Maximum Observed Concentration to Risk-Based Concentration

RBCs were calculated for water and fish were based on the method by Opresko et al. (1994) and chronic No-Observed-Adverse-Effect Levels (NOAEL) derived from the toxicological literature (Appendix III). 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 (Opresko et al. 1994).

Water - Concentrations of the following chemicals exceeded RBCs for drinking water and were carried forward to the next screening step:

vanadium

The following chemicals were retained for further analysis because no RBC was available (Table 5.1-12):

ammonia
magnesium
silicon
chloride
phosphorus
sodium
iron
potassium
sulphate

naphthenic acids

Fish Tissue - None of the chemicals exceeded RBCs for fish ingestion for wildlife.

The following chemicals were retained for further analysis because no RBC was available (Table 5.1-13):

calcium
silicon
magnesium
sodium
potassium

Step 7: Substance is Essentially Non-Toxic Under Environmental Exposure Scenarios

A number of chemicals did not have RBCs for wildlife (see Step 6). 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.

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 is an essential nutrient for the growth of plants (CCREM 1987) and is an essential nutrient for animals functioning to ensure the 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 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 (NAQUADAT 1985). Concentrations in waters at the site ranged from 0.046 to 0.43 mg/L (Table 5.1-3). Given that phosphorus occurs naturally and that concentrations at the site fall within concentrations reported for surface waters in western Canada, phosphorus was eliminated from further consideration.

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 for the purpose of this assessment and was eliminated from further consideration.

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. Concentrations of sulphate in TID and CT water ranged from 29.1 to 1290 mg/L falling well within the reported range of environmental concentrations of sulphate for western Canadian surface waters (i.e., 1 to 3,149 mg/L) (NAQUADAT 1985). 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.

Vanadium exceeded the RBC for river otter (0.84 mg/L) because a maximum concentration of 1.61 mg/L was recorded in a sample of refinery wastewater in September 1993. Only one other sample exceeded the 0.84 mg/L criterion, it was also recorded in September 1993. However, concentrations in all other refinery wastewater samples (n=78) ranged from less than the detection limit of 0.005 mg/L to a maximum of 0.775 mg/L. Values reported for all other types of water including CT release water (<0.002-0.17 mg/L; 1995; n=31), TID seepage water (0.003-0.01 mg/L; 1995; n=20), plant 4 seepage water (<0.002-0.05 mg/L; 1995; n=4), mine drainage water (<0.002-0.005 mg/L; 1995; n=21) and cooling Pond E water (<0.002-0.013 mg/L; 1984-1986; n=45) were well below the RBC value for river otter. Given that the only two out of 78 samples exceeded the RBC, that no similar values have been reported in the other 76 samples, and that all other water concentrations were well below the RBC, it is assumed that the values detected in September 1993 are outliers and are not representative of typical conditions. In any case, dilution with Athabasca River water would immediately reduce concentrations in the river below the RBC, even directly downstream of the refinery effluent. Therefore, vanadium poses no risk to wildlife and was eliminated from further consideration.

Step 8: List of Chemicals of Potential Concern following Chemical Screening

Water - Based on this screening, the only chemical of potential concern identified was naphthenic acids.

Fish Tissue - No chemicals of potential concern were identified for wildlife that might ingest fish from the Athabasca River downstream of Suncor's operations.

5.1.3 Receptor Screening

5.1.3.1 People

Suncor's oil sands operations are located in north-eastern Alberta approximately 46 kilometres from Fort McMurray and 20 kilometres from Fort McKay. It is reasonable to assume that the Athabasca River could be used by members of the Fort McKay First Nations and others for activities such as fishing and boating. Hence, the assessment of potential impacts on the health of people focused on two scenarios: recreational use and swimming in the river at the two locations shown in Figure 3.1-1. The recreational scenario addresses occasional use of river water as a drinking water source, such as might occur during recreational activities. The swimming scenario addresses intakes via dermal exposure and incidental ingestion that would occur while swimming (or using the water for washing and/or bathing).

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). Children are defined as between the ages of 7 months and 4 years (i.e., "pre-school children" as defined in guidance).

The scenarios are the same as those used by Syncrude (1993) to evaluate human health implications of exposures to surface waters affected by oil sands operations. A residential drinking water scenario was not included in the assessment because people in the area do not use untreated water from the Athabasca River as a primary drinking water source (Ft. McKay

Environmental Services Ltd. 1996). Since water releases from Suncor's operations do not appear to affect chemical concentrations in tissues of fish in the Athabasca River, eating fish caught downstream of Suncor poses no incremental risk above background; hence, this exposure pathway was not included as part of the exposure scenario.

5.1.3.2 Wildlife

Suncor's 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 screening wildlife receptors during the Problem Formulation phase is to: i) identify wildlife that might use the Athabasca River and ii) 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 VECs for the Steepbank Mine EIA were also given extra weight in the evaluation. An attempt was also made to represent various trophic levels (i.e., mammalian predators, mammalian insectivore, avian insectivore, avian predator). Insectivores were considered important as PAHs may accumulate in some invertebrate prey. Predators were included to assess potential for food chain effects. Water shrew (insectivore) and river otter (predator) were selected as mammalian receptors. Avian receptors included the killdeer (insectivore) and the great blue heron (predator).

5.1.4 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. As noted above, a chemical represents a 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. The characterization and quantification of exposure is conducted in the Exposure Assessment phase of the study.

All source of operational and reclamation waters that are and will be released to the Athabasca and Steepbank Rivers are summarized in Section 3.0. In addition to these sources, off-site exposure could occur through wind erosion and volatilization, which might release chemicals into the air, and surface runoff, which might release particulate material from the site. Thus, potential environmental residency and exposure media could include:

- surface water
- river sediment
- biota
- air

Exposure pathways were identified for the two major classes of chemicals: water soluble (hydrophilic) compounds, such as naphthenic acids, volatile organic chemicals and some trace metals (depending on pH of solution); and non-water soluble (hydrophobic) compounds, such as most PAHs and most metals at higher pH values. Potential transport and exposure pathways associated with the current operations and reclamation of Suncor's leases are outlined below and shown diagramatically in Figure 5.1-4. Critical pathways to be modelled are shown in Figures 5.1-5 and 5.1-6, respectively.

5.1.4.1 Exposure Pathways for People

Inhalation

Volatile Chemicals - Volatilization of volatile organic compounds (VOCs) from surface water and soils into 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, this pathway is not likely a contributor to off-site health impacts. Off-site chemical speciation data for VOCs are not available. However, there are limited VOC data from the vicinity of Suncor's tailings ponds, API (wastewater treatment systems) and north tank farm that provide a worst-case condition for evaluation of potential off-site health impacts. Even at these locations, concentrations of most VOCs are well below RBCs for a residential scenario, in which people are assumed to be exposed 24 hours per day, 350 days per year, for 30 years (Table 5.1-14). The only exceptions are for hexane, benzene, toluene and trimethyl benzene, although concentrations of these chemicals are well below guidelines for worker safety. Given that off-site concentrations will be considerably lower because of dispersion, mixing and decay processes, it is unlikely that off-site concentrations pose a health hazard. Thus, these limited data suggest that health risks pertaining to VOCs are low or negligible for people who live, work or recreate near Suncor's operations. Data collected near Suncor's plant are required to validate the predictions of low VOC levels at off-site locations.

There are no direct measurements of ambient concentrations of PAHs and metals associated with airborne particulates, thus, it is not possible to explicitly quantify off-site health risks associated with this exposure pathway. There is, however, indirect evidence that suggests that exposures to particulates from dust derived on site poses no health hazard to people who might live, work or recreate near the mine. For instance, a screening-level assessment of the potential hazard associated with particulates was completed as follows:

- Syncrude maintains two high volume samplers, one located near Fort McMurray and the other on Syncrude's existing site (Tailings North). (Suncor has no comparable samplers). These samplers collect air samples for a 24-hour period, once every six days (~61 samples per year) and typically collect particles that are less than 30 μm in diameter. From 1990 to

1994, the annual, maximum recorded concentrations ranged from 34 to 79 $\mu g/m^3$ at Fort McMurray and 88 to 273 $\mu g/m^3$ at Tailings North; and geometric means ranged from 9.4 to 14.9 $\mu g/m^3$ at Fort McMurray and from 10.5 to 19.0 $\mu g/m^3$ at Tailings North. The particles sampled are presumably derived from natural sources (forest fires, off-site dust), dust generated on site and from air emissions from Suncor's and Syncrude's plants.

- Assume that all of the particulates measured at the Tailings North monitoring site are derived solely from dust derived from the active mines and tailings sand structures (e.g., wind-based erosion of tailings dykes, dust generated by vehicular traffic). Further assume that 100% of the particulates measured at the site are of respirable size (generally considered to be less than 10 μm in diameter). These are both highly protective assumptions for assessing potential off-site health hazards.

- Assume that the relative amounts of PAHs and metals measured in tailings sand are representative of relative concentrations in particulates collected at Tailings North and at off-site locations. Further assume that the worst-case particulate level of 273 $\mu g/m^3$ (i.e., maximum concentrations recorded from 1990 to 1994 at Tailings North) was representative of typical off-site particulate levels that might occur adjacent to existing or future operations. Then, worst-case concentrations of PAHs and metals associated with respirable particulates can be estimated as shown in Table 5.1-15.

- Compare predicted, worst-case exposure concentrations to RBCs for air, where the RBCs are set at levels to protect the health of sensitive individuals who are exposed for 24 hours per day, 350 days per year for 30 years (Table 5.1-15). As evident from Table 5.1-15, predicted concentrations are considerably lower than RBCs. Considering the multiple protective assumption built into this analysis, it is reasonable to conclude that dust generated from Suncor's operations does not pose an off-site health hazard.

Although it appears unlikely that dust generated from Suncor's operations is a health hazard, there are other sources of PAHs and metals for which no information is available. For instance, PAHs are associated with combustion and pyrolysis of fossil fuels, and metals are also released into the atmosphere in both gaseous and particulate forms as a result of combustion. Hence, Suncor's stack emissions from heating and power generation and the upgrading process plus exhaust from internal combustion engines are potential sources of PAHs and metals.

Dermal Exposure

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, as noted above off-site VOC levels are likely to be low near the plant and it is exceedingly unlikely that this pathways significantly to off-site chemical exposure. Data collected near Suncor's plant are required to validate the predictions of low VOC levels at off-site locations

Direct contact with surface water - As noted above, people can be exposed to chemicals released from the site directly contacting surface water. Although the contribution of dermal exposure to chemicals in surface water is expected to be small relative to ingestion exposure (discussed below), this pathway has been retained for further analysis to confirm this assumption.

Ingestion

Ingestion of surface water - As identified during the chemical screening, several chemicals that are of potential concern are and will be released from both operational and reclamation waters. 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 Suncor's operational or reclamation waters results in accumulation of chemicals to levels above background. Thus, eating fish exposed to Suncor's release waters poses no incremental risk above background; and this path has been eliminated as a contributor to health risks.

5.1.4.2 Exposure Pathways for Wildlife

The previous discussion of exposure pathways for people also applies to wildlife, with the exception of drinking water. As noted above in Section 5.1.3, no chemicals of potential concern were identified following chemical screening for wildlife drinking water supplies. Thus, exposure via the drinking water pathway is not expected to contribute to health risks in wildlife.

5.1.5 Assessment and Measurement Endpoints

Explicit definitions of assessment and measurement endpoints are not necessary for assessing risks to people, since protection of sensitive individuals from adverse effects is the accepted endpoint for all human health risk assessments. However, there is no general agreement on endpoints for ecological risk assessments, so explicit definition of the endpoints are required.

Information compiled in the first stage of problem formulation is used to help select ecologically-based endpoints that are relevant to decisions about protecting the environment (U.S. EPA 1992a). Endpoints are characteristics of ecological components that may be affected by exposure to a stressor (e.g., chemical). Assessment endpoints are explicit expressions of the actual ecological value that is to be protected and are the ultimate focus in risk characterization. For this investigation, the assessment endpoints include protection of the viability of populations of wildlife previously selected as outlying in Section 5.1.1.3. Since these receptors encompass different taxa and trophic levels, it is assumed that these receptors also serve as surrogates to other levels of organization and/or receptors not directly included in this evaluation.

However, assessment endpoints tend to be qualitative or semi-qualitative, and are rarely directly measurable. As a result, measurement endpoints are usually defined as surrogates for assessment endpoints. Measurement endpoints are the quantitative response of the ecosystem component or receptor to the stressor, which is related to the characteristics of the assessment endpoint. In other words, it is the response to which exposure to the chemicals of potential concern is related so that one can identify whether a specific exposure scenario might adversely affect ecosystem component. For this study, measurement endpoints are based on laboratory, field and modelling studies of adverse effects (e.g., mortality, reproduction, growth) on surrogate species that may ultimately result in adverse effects on populations, communities or hierarchical structures or wildlife species (Table 5.1-16).

5.1.6 Conceptual Model

5.1.6.1 People

The Conceptual Model outlines how the chemical stressors might affect people. This involves clearly defining the chemicals and important exposure pathways that are to be pursued in the quantitative risk analysis portion of the assessment. The Conceptual Model provides information of the types of chemicals of concern since the physical/chemical properties of the chemicals dictate their distribution in the environment and the pathways for exposure to people. The Conceptual Model for exposure of people is outlined in Figure 5.1-5.

5.1.6.2 Wildlife

As noted above, no chemicals of concern were identified during the chemical screening phase of the study. As such, risks to wildlife from drinking river water or eating biota are negligible and a quantitative risk assessment is not necessary.

5.2 Exposure Assessment

Exposure assessment is the process of estimating the daily intake rate (dose) of a chemical by a person under a given exposure scenario. As noted above in Section 5.1.6.1, the only operational exposure pathways for this investigation relate to ingestion of water or dermal absorption by people using the Athabasca River immediately below Suncor's site. Thus, the only chemical concentration data required are for Athabasca River water. Concentrations of the chemicals of potential concern were predicted for two locations in the Athabasca River, using the river mixing model described in Section 3.3 (Table 5.2-1). The chemical concentrations given in Table 5.2-1 are upperbound estimates of current (1995) and future conditions (2001, 2010, 2020 and post-reclamation).

While in contact with water, e.g., while swimming, people might absorb chemicals across the skin and into the bloodstream. For swimming exposures, it is assumed that the whole body is exposed to water. The dermal uptake of a chemical was calculated as follows (U.S. EPA 1992b).

$$\text{Intake} = (SA \times C_{water} \times K_p \times ET \times EF \times ED \times 10^3\ L/m^3)\ /\ BW \times AT$$

where:

Intake = dermal intake while swimming (mg chemical/kg body weight/day)

SA = surface area available for contact while swimming (adult = 1.82 m^2, child = 0.94 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 (2.6 h/event)

EF = frequency of exposure events (7 events/year)

ED = duration of exposure (adult = 50 years, child = 3.5 years) (Health Canada 1994)

BW = receptor body weight (adult = 70 kg, child = 13 kg)

AT = averaging time (ED x 365 days/year for noncarcinogens, 70 year x 365 days/year for carcinogens)

Swimming may also result in incidental water ingestion. Exposure to chemicals through incidental ingestion of water while swimming is calculated based on the following equation (U.S. EPA 1992b):

$$\text{Intake} = (IR \times BA \times C_{water} \times ET \times EF \times ED)\ /\ BW \times AT$$

where:

Intake = incidental water consumption while swimming (mg chemical/kg body weight/day)

IR = ingestion rate (0.05 L/hour for both adults and children)

BA = oral bioavailability of compound (chemical-specific, unitless)

C_{water} = chemical concentration in water (mg/L)

ET = time of exposure (2.6 hr/event)

EF = frequency of exposure (7 events/year)
ED = duration of exposure (adult = 50 years, child = 3.5 years) (Health Canada 1994)
BW = receptor body weight (adult = 70 kg, child = 13 kg)
AT = averaging time (ED x 365 days/year for noncarcinogens; 70 year x 365 days/year for carcinogens)

The major route of exposure for a recreational user is assumed to be occasional consumption of river water during recreational activities. The person is assumed to drink from the river two days a week, year round. Chemical exposure via ingestion of water is calculated using the following equation:

$$\text{Intake} = (\text{IR} \times \text{BA} \times C_{water} \times \text{EF} \times \text{ED}) / \text{BW} \times \text{AT}$$

where:

Intake = intake from water consumption (mg chemical/kg body weight/day)
IR = ingestion rate (child = 0.8 L/day, adults = 1.5 L/day) (Health Canada 1994)
BA = oral bioavailability of compound (chemical-specific, unitless)
C_{water} = chemical concentration in water (mg/L)
EF = frequency of exposure (104 days/year)
ED = duration of exposure (adult = 50 years, child = 3.5 years) (Health Canada 1994)
BW = receptor body weight (adult = 70 kg, child = 13 kg)
AT = averaging time (ED x 365 days/year for noncarcinogens; 70 year x 365/year days for carcinogens).

As indicated in the above equations, two of the input parameters (bioavailability and dermal permeability) are characteristics of the chemicals being evaluated. For this assessment, these chemicals are benzo(a)anthracene, benzo(a)pyrene, naphthenic acids, molybdenum and vanadium.

Oral bioavailability is used to estimate the amount of chemical that will enter the bloodstream following ingestion of the chemical. This is an important issue because many chemicals exert their toxic effects only following absorption. For the human health risk assessment, the oral bioavailability of each chemical via ingestion is assumed to be 100%. This is a conservative assumption since this implies that all of a chemical that is ingested is also absorbed into the blood. A more accurate assessment of bioavailability may indicate that absorption is significantly less than 100%.

For dermal exposures, it is necessary to determine how much chemical would be absorbed by the body following exposure to chemicals in the water (i.e., while swimming). The parameter that describes the extent of absorption is the dermal permeability constant, K_p. Consistent with the U.S. EPA (1992b) approach, dermal permeability constants for inorganic chemicals, such as molybdenum and vanadium, are set equal to $1x10^{-5}$ m/hr. The permeability constants for the organic chemicals (benzo(a)anthracene, benzo(a)pyrene) are also provided by U.S. EPA (1992b). A permeability constant has not been developed for naphthenic acids, and a surrogate that adequately represents the physical characteristics of naphthenic acids has not been identified. Therefore, dermal intakes associated with naphthenic acids are not calculated.

Table 5.2-2 summarizes the chemical-specific parameter values use to characterize oral bioavailability, dermal permeability and exposure-point concentrations. Table 5.2-3 summarizes the exposure parameters for people (e.g., body weight, ingestion rates, etc.). These values along with the equations presented above were used to calculate the intake values. Intake values for swimming and recreational scenarios are presented in Table 5.2-4.

5.3 Effects Assessment

Effects Assessment is the process of determining the reference value or intake rate at which the health of sensitive individuals is protected. This section presents toxicity information used to provide qualitative and quantitative estimates of health effects associated with exposure to site chemicals.

Reference values are daily exposure rates that could occur over a lifetime of a sensitive person without causing any measurable, adverse effect. These values are based on information on concentrations or doses of chemicals that cause particular effects. This information is usually available through toxicological databases such as IRIS (*Integrated Risk Information System*);

RTECS (*Registry of Toxic Effects of Chemical Substances*); TOXLINE (*Toxicology information on-line*); MEDLINE (*Medlars on-line*); HSDB (*Hazardous Substances Databank*) and OHMTADS (*Oil and Hazardous Materials/Technical Assistance Data System*.

Carcinogens are assumed not to exhibit a dose-response threshold since mutations in the DNA are passed on from one cell generation to the next generation (assuming no repair); therefore, effects are assumed even at doses approaching zero. For such chemicals, an exposure limit is derived from mathematical models that estimate a unit risk carcinogenic slope factor (depending on potency) from which a Risk Specific Dose (RsD) is developed. The RsD is calculated from the carcinogenic slope factor by dividing the lifetime risk of cancer development by the slope factor value (i.e., RsD = $1 \text{ x}10^{-5}$/slope factor).

Benzo(a)pyrene has been classified as a B2 carcinogen indicating that benzo(a)pyrene is a probable human carcinogen based on 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-day was developed based on stomach tumours (U.S. EPA 1996); hence the RsD is $1.4\text{x}10^{-6}$ mg/kg-day.

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 1996). However, the carcinogenic potency of certain PAHs, such as benzo(a)anthracene, can be estimated by using toxicity equivalency factors (TEFs). TEFs are unitless factors used to estimate the carcinogenicity of carcinogenic PAHs. The approach simplifies the evaluation of PAHs by relating their carcinogenic potential to that of benzo(a)pyrene. The TEF for benzo(a)anthracene used in this report (0.1) was provided by the U.S. EPA (1992c) memo "Risk Assessment for Polyaromatic Hydrocarbons". An oral slope factor for a particular PAH is calculated by multiplying the oral slope factor of benzo(a)pyrene by the associated TEF for that PAH. For example, the slope factor for benzo(a)anthracene is 7.3 mg/kg-day x 0.1 = 0.73 mg/kg-day, hence the RsD is $1.4\text{x}10^{-5}$ mg/kg-day.

There are insufficient data with which to classify naphthenic acids with respect to carcinogenic potential. Molybdenum and vanadium are classified as noncarcinogens.

For noncarcinogens, the exposure limit used in this assessment is a chemical's reference dose (RfD). An RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound.

To date, there are insufficient mammalian toxicological data to calculate a defensible RfD for naphthenic acids (Appendix V). RfDs are normally calculated based on chronic or subchronic studies in laboratory animals. Currently, there are only acute toxicity mammalian data available for naphthenic acids. Methylcyclohexane has been used as a surrogate for determining the RfD for naphthenates (Syncrude 1993). If methylcyclohexane had been used to derive an RfD for naphthenates, then we would have concluded that naphthenates pose no risk to human health under the exposure scenarios discussed above. However, upon further review, we have concluded that methylcyclohexane was not an adequate surrogate because of the differences in ring chemistry (e.g., planarity, number of rings), substituted side chains (methyl versus carboxylic acid, alkyl, allyl, aryl and functional-substituted chains), polarity (nonpolar versus polar/bipolar), surfactant properties (hydrophobic versus bipolar with high degree of surfactant action), molecular weight (low versus medium to high) and salt formation capacity (none versus high probability). In addition, the toxicity information available for methylcyclohexane is limited to short-term toxicity determinations with high concentrations. The toxicity of naphthenic acids is, therefore, identified as a data gap. Intakes of naphthenic acids are presented (as shown in Section 5.2.2), but these intakes are not interpreted with respect to impacts on human health.

RfD values have not been developed for benzo(a)pyrene and benzo(a)anthracene. However, if RfDs for these chemicals were to be identified, it is likely that their carcinogenic potential would be of greater concern.

The RfDs for molybdenum and vanadium are 0.005 and 0.007 mg/kg-BW/day, respectively (U.S. EPA 1996; HEAST 1995). Table 5.3-1 provides additional information regarding the RfD for molybdenum and vanadium. A summary of the RfDs and RsDs for the chemicals under consideration is also provided in Table 5.3-1.

5.4 Risk Characterization

5.4.1 Human Health Impacts

Information from the exposure assessment and effects assessment is integrated to form the basis for the characterization of risks and health hazards. In particular, Exposure Ratios (ER) are calculated as the ratio of the predicted dose to the reference value. For non-carcinogenic chemicals, an ER value of less than one represents exposure scenarios that do not pose a significant health risk to exposed individuals (Health Canada 1995). For carcinogenic chemicals, an ER value that is less than one indicates that the rate of intake for a chemical or group of chemicals is less than that attributed to an incremental lifetime risk of cancer of one per 100,000 individuals ($1x10^{-5}$), which does not pose a significant health risk to exposed individuals (Health Canada 1995). It is important to note that ER values greater than one do not necessarily indicate that adverse health effects will occur. However, when the ER is greater than one, the scenarios pose a potential concern and require further investigation.

Exposure ratios for each scenario and for each time period are shown in Table 5.4-1. Exposure ratios for both benzo(a)anthracene and benzo(a)pyrene groups, molybdenum and vanadium are well below 1.0 for all conditions tested. Therefore, these chemicals does not pose a significant health risk to exposed individuals (Health Canada 1995). As noted previously, a scientifically defensible reference value could not be derived for naphthenic acids. Notwithstanding this lack of information, it is unlikely that exposure to this group of chemicals is a health concern at the concentrations measured in 1995 (0.1-0.3 mg/L; Syncrude Research, person. commun.) or predicted within the mixing zone (0.5-1.0 mg/L) poses an incremental health hazard. Firstly, the concentrations projected within Suncor's mixing zone are within the range that naturally occur in other water bodies such as the Steepbank or Clearwater Rivers (0.5-1.0 mg/L; Syncrude Research, person. commun.). Secondly, naphthenates are a heterogeneous group of saturated higher fatty acids and salts derived from naturally occurring petroleum. Little is known about the specific long-term effects of naphthenic acids or salts on mammalian species, but similarly structured compounds appear to have little or no long-term deleterious effects at low concentrations. This suggests that the naphthenates may also have little or no long-term deleterious effects at low concentrations. Additional information is required, however, to confirm this assumption.

In reporting the results of a risk assessment, it is necessary to consider the uncertainty associated with cancer risk and ER estimates. A series of protective assumptions was incorporated into the assessment to ensure that the final risk estimates would not underestimate health. An examination of each of the input parameter values indicates that they are biased in a way that tends to overestimate the computed ER value. For example, the concentrations used for the current scenario (1995) were based on the upper 95% percentile of concentrations measured in water samples collected from lower Athabasca River, from 1985-1995 (Table 5.4-2). Future exposure concentrations were based on the upper 95 percentile of modelled levels. Exposures were assumed to occur within the mixing zone, immediately downstream of Suncor's current and future water releases as well as, in the future below the discharge point from water draining from Syncrude's reclaimed landscape. Exposures at other locations in the river would be considerably lower, or even nil. Other exposure parameter values represented reasonable maximum exposure values; that is, reasonable upper bounds and not average values. Bioavailability was set to a maximum value (100%). Exposure limits for noncarcinogens are designed to be protective of sensitive subpopulations under chronic exposure conditions.

As indicated in Section 5.3.1, benzo(a)pyrene and benzo(a)anthracene are classified as B2 (probable human) carcinogens (U.S. EPA 1996). Human data specifically linking these chemicals to a carcinogenic effect are lacking. There are, however, multiple animal studies in many species demonstrating benzo(a)pyrene to be carcinogenic following administration by numerous routes. Benzo(a)anthracene is a component of mixtures (e.g., coal tar, soots, cigarette smoke) that have been associated with human cancer. It is not possible, however, to conclude from this information that benzo(a)anthracene is the responsible agent. In spite of this lack of direct evidence of human carcinogenicity, cancer risks are calculated as if the slope factor represent carcinogenic potential to people.

In addition to these conservative biases of the individual input parameters, the use of multiple protective assumptions itself mathematically compounds the conservative bias in the ER values. Consequently, the actual ER values are likely to be considerably lower than those reported here.

5.4.2 Wildlife

No chemicals of potential concern were identified with respect to off-site exposure by wildlife. Hence, such exposures will not result in adverse impacts on wildlife. Notwithstanding the lack of chemicals of concern, it is necessary to consider the uncertainty associated with this conclusion.

Multiple, protective assumptions were incorporated into the screening process to ensure that chemicals of concern would not fall through the screening process. These assumptions included:

- The maximum recorded concentration of each chemical was used in the screening process to ensure that any chemicals of potential concern would not fall through the screening process;
- No chemical-fate processes were incorporated into this screening to reduce chemical concentrations prior to exposure;
- The SLC were based on published criteria that are designed to prevent adverse effects in wildlife;
- If no SLC were available for a chemical, the chemical was retained and carried forward to the next chemical screening step;
- RBCs were based on extremely exposure conservative scenarios (e.g., wildlife were assumed to spend all of their time in the area); and,
- Although wildlife are unlikely to restrict their exposures to contaminated media, it was assumed that sampled media (e.g., fish and water) are representative of media to which receptors may be exposed under nearly continuous conditions.

Given the conservative nature of these assumptions, it is unlikely that chemicals that pose a potential health concern for wildlife would have been inadvertently excluded during the screening process.

6.0 CONCLUSIONS

6.1 Aquatic Ecosystem Health

Three separate approaches were used to investigate potential impacts on aquatic biota: chemical-specific wasteload allocation, toxicity testing and a risk-based assessment.

The chemical-specific wasteload allocation approach indicates that it is unlikely that Suncor's release waters either are currently affecting or will in the future affect aquatic biota in the Athabasca River.

There is no evidence from the battery of laboratory toxicity tests used that the cumulative impact from operational and reclamation waters will adversely affect ecosystem health in either the Athabasca or Steepbank Rivers.

Similarly, the risk-based assessment of fish health suggest that it is extremely unlikely that fish populations either are currently being affected or will, in the future be affected by the cumulative releases of operational and reclamation waters associated with oil sands operations. These predictions are supported by observations of current fish populations, which have been exposed to water releases from Suncor operations for the past three decades. These populations continue to successfully utilize habitat in the Suncor study area, and exhibit normal growth and reproduction. Since future concentrations of water releases to the Athabasca River are predicted to be lower than current conditions, future populations of fish should continue to be healthy.

6.2 Human Health

A quantitative, human health risk assessment was conducted to examine potential health associated with the release of operational and reclamation waters from oil sands operations. The potential for exposure to these chemicals was investigated by estimating the chemical dose that people might receive who occasionally drink water or swim in the Athabasca River, downstream of Suncor's operations. The results of the risk assessment indicated that the use of the Athabasca River, downstream of Suncor's operations, does not currently or will not in the future pose a risk to people's health.

6.3 Wildlife Health

No chemicals of concern were identified with respect to off-site exposure to wildlife. Hence, no adverse effects on terrestrial wildlife from current or proposed water releases are expected.

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8.0 GLOSSARY

Acute	Having a sudden onset lasting a short time. Of a stimulus, severe enough to induce a response rapidly. Can be used to define either the exposure or the response of an exposure (effect). The duration of an acute aquatic toxicity test is generally 4 days or less and mortality is the response usually measured.
Acute Tests	A toxicity test of short duration, typically 4 days or less, and usually of a short duration relative to the lifespan of the test organism.
Acute Toxicity	Toxicity expressed over a short period of time relative to the lifespan of the organism, usually minutes to days.
Advection	Physical transport of materials (e.g., dust) by the bulk movement of an environmental medium (e.g., air).
Adverse Effect	An undesirable or harmful effect to an organism (human, animal or plant) indicated by some result such as mortality, altered food consumption, altered body and organ weights, altered enzyme concentrations or visible pathological changes.
Ambient	The conditions surrounding an organism or area.
AEP	Alberta Environmental Protection
AOSERP	Alberta Oil Sands Environmental Research Program
AEUB	Alberta Energy and Utilites Board
Assessment Endpoint	An explicit expression of the environmental value that is to be protected.

Background Concentration (environmental)	The concentration of a chemical in a defined control area during a fixed period of time before, during, or after a data-gathering operation.
Benthic Community (Benthos)	The community of organisms dwelling at the bottom of a river, lake or ocean.
Benthic Invertebrates	Invertebrate organisms living at, in or associated with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include several aquatic insect species (such as caddisfly larvae) which spend at least part of their life stages dwelling on bottom sediments in the river. These organisms are involved in mineralization and recycling of organic matter produced in the open water above or brought in from external sources, and they are important second and their links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for small fish.
Bile	An alkaline secretion of the vertebrate liver. Bile which is temporarily stored in the gall bladder, is composed of organic salts, excretion products, and bile pigment. It primarily functions in emulsifying fats in the small intestine.
Bioaccumulation	A general term, meaning that an organism stores within its body, a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate salt in order to survive in intertidal waters. Many chemicals, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.

Bioassay	Test used to evaluate the relative potency of a chemical by comparing it's effect on living organisms with the effect of a standard preparation on the same type of organism. Bioassay and toxicity tests are not the same - see toxicity test.
Bioavailability	The degree to which a material in environmental media is assimilable by organism.
Bioconcentration	A process by which there is a net accumulation of a chemical directly from an exposure medium into an organism.
BCF	Bioconcentration Factor.
Biodegradation	Decomposition into more elementary compounds by the action of microorganisms such as bacteria.
Biological Indicators	Any biological parameter that is used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomagnification	Result of the process of bioaccumulation by which tissue concentrations of chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of the chemical from food to consumer.
Biomarker	Biomarker refers to a chemical, physiological or pathological measurement of exposure or effect in an individual organism from the laboratory or field. Examples include: chemicals in liver enzymes, bile and sex steroids.
BOD	Biological Oxygen Demand

Cancer	A disease characterized by the rapid and uncontrolled growth of aberrant cells into malignant tumours.
Carcinogen	An agent that is reactive or toxic enough to act directly to cause cancer.
Chronic	Involving stimulus that is lingering or continues for a long time; often signifies periods from several weeks to years, depending on the reproductive life cycle of the species. Can be used to define either the exposure or the response to an exposure (effect). Chronic exposures typically induce a biological response of relatively slow progress and long duration.
Chronic Exposure	A relatively long duration of time (Health Canada considers periods of human exposure greater than three months to be chronic while the U.S. EPA only considers human exposure that are greater than seven years to be chronic).
Chronic Tests	A toxicity test used to study the effects of continuous, long-term exposure of a chemical or the potentially toxic material on an organism.
Chronic Toxicity	The development of adverse effects after an extended exposure of time relative to the life span of the organism, usually from several weeks to years depending on the reproductive cycle of the organism.
Community	An assemblage of populations of different species within a specified location and time.
Computer Model	Equations that represent a mathematical interpretation of a natural phenomenon.
Concentration	Quantifiable amount of a chemical in environmental media.

Conceptual Model	A model developed at an early stage of the risk assessment process that describes a series of working hypotheses of how the chemicals of concern may affect potentially exposed populations. The model identifies and describes the populations potentially at risk and exposure pathways and scenarios.
Condition Factor	A measure of the relative "fitness" of an individual or population of fish by examining the mathematical relationship between length and weight. The values calculated show the relationship between growth in length relative to growth in weight. In populations where increases in length are matched by increases in weight, the growth is said to be isometric. Allometric growth, the most common situation in wild populations, occurs when increases in either length or weight are disproportionate.
Conductivity	A measure of water's capacity to conduct an electrical current. It is reciprocal of resistance. This measurement provides the limnologist with an estimation of the total concentration of dissolved ionic matter in the water. It allows for a quick check of the alteration of total water quality due to the addition of pollutants to the water.
Conservative Approach	Approach taken to incorporate protective assumptions to ensure that risks will not be underestimated.
Consolidated Tailings (CT)	Consolidated tailings (CT) is a non-segregating mixture of plant tailings which consolidates relatively quickly in tailings deposits. At Suncor, consolidated tailings will be prepared by combining mature fine tails with thickened (cycloned) fresh sand tailings. This mixture is chemically stabilized to prevent segregation of the fine and coarse mineral solids using gypsum ($CaSO_4$).

Control	A treatment in a toxicity test that duplicates all the conditions of the exposure treatments but contains no test material. The control is used to determine basic test conditions in the absence of toxicity (e.g. health of test organisms, quality of dilution water).
Critical Exposure Pathway	The exposure pathway which either maximizes the dose or is the primary pathway of exposure to an identified receptor of concern.
CT Release Water	Water derived from consolidated tailings deposits.
CV	Coefficient of Variation, a statistical measure of the standard deviation expressed as a percentage of the mean.
CWQG	Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.
Degradation	Conversion of an organic compound to one containing a smaller number of carbon atoms.
Detection Limit (DL)	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Deterministic	Risk approach using a single number from each parameter set in the risk calculation and producing a single value of risk.
Dispersion	Physical processes of mixing.

Dose	A measure of integral exposure. Examples include (1) the amount of a chemical ingested, (2) the amount of a chemical taken up, (3) the product of ambient exposure concentration and the duration of exposure.
Dose Rate	Dose per unit time, for example in mg/day, sometimes also called dosage. Dose rates are often expressed on a per-unit body-weight basis, yielding units such as mg/kg body weight/day expressed as averages over some time period, for example a lifetime.
Dose-Response	The quantitative relationship between exposure of an organism to a chemical and the extent of the adverse effect resulting from that exposure.
EC50 or EC_{50}	Where the measured endpoint is some effect other than death, the concentration of a chemical which causes an endpoint effect in 50% of the test organisms (effective concentration).
Ecological Risk Assessment	The process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors.
Ecosystem	An integrated and stable association of living and nonliving resources functioning with a defined physical location.
Ecotoxicology	A subfield of toxicology, specifically dealing with the effects of chemicals and other stressors on natural systems, as opposed to human health effects.
Effects Assessment	Review of literature regarding the toxicity of any given material to an appropriate receptor. Also known as Toxicity Assessment.

Effluent	Stream of water discharging from a source.
EIA	Environmental Impact Assessment
ELC	Ecological Land Classification
Environmental Media	One of the major categories of material found in the physical environment that surrounds or contacts organisms (e.g., surface water, groundwater, soil, food or air) and through which chemicals can move and reach the organism.
EROD	Ethoxyresorufin-O-deethylase (EROD) are enzymes which can increase in concentration and activity following exposure of some organisms to chemicals such as PAHs. EROD measurement indirectly measures the presence of catalytical proteins that remove a CH_3CH_2-group from the ethoxyresorufin. This substrate was chosen because the fluorescent product formed is very easy to monitor in the laboratory. In animals, various compounds can be biotransformed by this enzyme to more polar products, which prepare them for eventual elimination from the body. Thus, this is a "detoxification" or defence system that reduces the amounts of potentially harmful foreign substances in the body. Cytochrome P4501A is the scientific designation of the dominant protein which carries out this catalytic function in mammals and fish. EROD activity refers to the rate of the deethylation and indirectly reflects the amount of enzyme present.
Exposure	The contact reaction between a chemical and a biological system, or organism.
Exposure Assessment	The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.

Exposure Concentration	The concentration of a chemical in its transport or carrier medium at the point of contact.
Exposure Limit	The maximum acceptable dose (per unit-body-weight and unit of time) of a chemical to which a specified receptor can be exposed to, assuming a specified risk (e.g., one in a hundred thousand). May be expressed as a Reference Dose (RfD) for threshold-response chemicals (i.e., noncarcinogens) or as a Risk Specific Dose (RsD) for non-threshold response chemicals (i.e., carcinogens).
Exposure Pathway	The path a chemical or physical agent takes from a source to exposed organism. Each exposure pathway includes a source or release from a source exposure point, and an exposure route. Examples of exposure pathways include the ingestion of water, food and soil, the inhalation of air and dust, and dermal absorption.
Exposure Pathway Model	A model in which potential pathways of exposure are identified for the selected receptor species.
Exposure Ratio (ER)	A comparison between total exposure from all predicted routes of exposure and exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit.
Exposure Route	The way a chemical or physical agent comes in contact with an organism (e.g. by ingestion, inhalation, or dermal contact).
Exposure Scenario	A set of facts, assumptions and inferences about how exposure takes place that aid the risk assessor in evaluating, estimating and quantifying exposures

Fate	In the context of the study of contaminants, fate refers to the chemical form of a contaminant when it enters the environment and the compartment of the ecosystem in which that chemical is primarily concentrated (e.g., water or sediments). Fate also includes transport of the chemical within the ecosystem (via water, air or mobile biota) and the potential for food chain accumulation.
Fecundity	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
FGD	Flue Gas Desulphurization
Fish Health Parameters	Parameters used to indicate the health of individual fish. May include, for example, short-term response indicators such as changes in liver mixed function oxidase activity, and the levels of plasma glucose, protein and lactic acid. Longer-term indicators include internal and external examination of exposed fish, changes in organ characteristics, hematocrit and hemoglobin levels. May also include challenge tests such as disease resistance and swimming stamina.
Food Chain Transfer	A process by which materials accumulate in the tissues of lower trophic level organisms and are passed on to higher trophic level organisms by dietary intake.
Forage (Feeding) Area	The area utilized by an organism for hunting or gathering food.
Golder	Golder Associates Ltd.
Gonads	Organs which are responsible for producing haploid reproductive cells in multi-cellular animals. In the male, these are the testees and in the

female, these are the ovaries.

GSI	Gonad-Somatic Index. The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total gonad weight by the total body weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
Habitat	The place where a plant or animal naturally or normally lives and grows, for example, a stream habitat or a forest habitat.
Hazard	Likelihood that a chemical will cause an injury or adverse effect under specified conditions.
Histology/Histological	The microscopic study of tissues.
Home Range	The area to which an animal confines its activities.
Hydrophilic	A characteristic of charged molecules in which they tend to interact with water molecules.
Hydrophobic	With regard to a molecule or side group, tending to dissolve readily in organic solvents, but not in water, resisting wetting, not containing polar groups.
ICP (Metals)	Inductively Couple Plasma (Atomic Emission Spectroscopy). This analytical method is a U.S. EPA designated method (Method 6010). The method determines elements within samples of groundwater, aqueous samples, leachates, industrial wastes, soil sludges, sediments and other solid wastes. Sample require chemicals digestion prior to analysis.

Induction	Response to a biologically-active compound that involves new or increased gene expression resulting in enhanced synthesis of a protein. Such induction is commonly determined by measuring increases in protein levels and/or increases in the corresponding enzyme activity. For example, induction of EROD would be determined by measuring increases in cytochrome P4501A protein levels and/or increases in EROD activity.
Ingestion Rate	The rate at which an organism consumes food, water, or other material (e.g. soil, sediment). Ingestion rate is usually expressed in terms of unit of mass or volume per unit of time (e.g. kg/day, L/day).
LC50 or LC_{50}	Where death of the organism is the measured endpoint, the concentration of a chemical which is lethal to 50% of the exposed organisms (lethal concentration).
Lesions	Pathological change in a body tissue.
Lethal	Causing death by direct action.
Lowest Observable Adverse Effect Level (LOAEL)	The lowest concentration of a material used in a toxicity test that has a statistically significant adverse effect on the exposed population of test organisms as compared with the controls. Same as LOEL (lowest observed effects level).
LOEC	Lowest observed effect concentration of a toxic compound.
LSI	Liver Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight.
Measurement Endpoint	A measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint. Measurement

endpoints are often expressed as the statistical or arithmetic summaries of the observations that make up the measurement.

Medium	The physical form of environmental sample under study (e.g. soil, water, air); plural form media.
Metabolism	Metabolism is the total of all enzymatic reactions occurring in the cell; a highly coordinated activity of interrelated enzyme systems exchanging matter and energy between the cell and the environment. Metabolism involves both the synthesis and breakdown (catabolism) of individual compounds.
Metabolites	Organisms alter or change compounds in many various ways like removing parts of the original or parent compound or in other cases adding new parts. Then, the parent compound has been metabolized and the newly converted compound is called a metabolite.
MFO	Mixed Function Oxidase. A term for reactions catalyzed by the cytochrome P450 family of enzymes, occurring primarily in the liver. These reactions transform organic chemicals, often altering toxicity of the chemicals.
MFT	Mature Fine Tails
Mine Drainage Water	Water derived from drainage from mine site areas which are not undergoing active oil sands removal.
Mortality	Death
NESSA	Northeast Sand Storage Area
NOAEL	No-Observed-Adverse-Effect-Level. The highest dose of a stressor to

	an organism evaluated in a toxicity test that causes no statistically significant difference in effect as compared with the controls.
NOEC	No-Observed-Effect-Concentration. The highest concentration in a medium that does not cause a statistically significant difference in effect as compared to controls.
Noncarcinogen	A chemical that does not cause cancer and has a threshold concentration.
Nutrients	Environmental substances (elements or compounds), such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Operational Waters	Waters that 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 to ambient water quality criteria and potentially of concern with respect to regional off-site impacts. Sources of operational waters include CT, drainage waters collected from dykes and structures, mine drainage, upgrading process, cooling water and sewage treatment facility.
OSRPAF	Oil Sands Reclamation Performance Assessment Framework
OSWRTWG	Oil Sands Water Release Technical Working Group
Overwintering Habitat	Habitat used during the winter as a refuge and for feeding.
PAH(s)	Polycyclic aromatic hydrocarbon(s). A chemical by-product of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs are composed of at least two fused benzene rings, many of which are potential

carcinogens. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.

PANH	Polycyclic aromatic nitrogen heterocycles.
PASH	Polycyclic aromatic sulphur heterocycles.
Pathology	The science which deals with the cause and nature of disease or diseased tissues.
Physiological	Related to function in the cells, organs or entire organisms, in accordance with the nature processes of life.
Population	An aggregate of individuals of a species within a specified location in space and time.
Problem Formulation	The first phase in a risk assessment where the geographical location, scope fo the project and future plans are outlined. In addition, receptors, chemical and exposure pathways of concern are identified and screened to focus the remainder of the assessment. A focused understanding of the site is developed and brought together in a Conceptual Model that illustrates how chemicals may reach specific receptors, thus potentially creating risk to the receptor, and how risk is to be evaluated.
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control refers to a set of practices that ensure the quality of a product or a result. For example, "Good Laboratory Practice" is part of QA/QC in analytical laboratories and involves such things as proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.

RBC	Risk-Based Concentration. Concentration in environmental media below which health risk are not expected to occur.
Rearing Habitat	Habitat used by young fish for feeding and/or as a refuge from predators.
Receptor	The person or plant or animal subjected to exposure to chemical or physical agents.
Reclaimed Landscape	Dry landscape created following the reclamation of tailings generated in the mining process where the tailings are chemically treated and dewatered to form a trafficable surface.
Reclamation Waters	Waters derived from a non-point source, released at slow rates over large areas for extended periods of time, non-controllable, nontreatable, not amenable to conventional end-of-pipe approval requirements and primarily an on-site water management concern and a component of a maintenance-free reclamation landscape. Sources of reclamation waters include surface runoff and groundwater seepage from sand dumps and dykes, CT deposits, coke piles, gypsum storage units and other waste dumps, overburden dumps and dykes and wetlands treatment system.
Reference Site	A relatively unpolluted site used for comparison to polluted sites in environmental monitoring studies, often incorrectly referred to as a control.
RfD (Reference Dose)	The maximum recommended daily exposure for a chemical exhibiting a threshold (highly nonlinear) dose-response (i.e., noncarcinogen) based upon the NOAEL determined for the chemical from human and/or animals studies and the use of an appropriate uncertainty factor.

Refinery Wastewater	Water derived from the refining process.
Relative Abundance	The proportional representation of a species in a sample or a community.
Replicate	Duplicate analyses of an individual sample. Replicate analyses are used for quality control.
Riffle Habitat	Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.
Risk	The likelihood or probability, that the toxic effects associated with a chemical will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect at a given time and the total number of individuals exposed to the factor. Risk is expressed as a fraction without units and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.
Risk Assessment	The process that evaluates the probability of adverse effects that may occur, or are occurring on target organism(s) as a result of exposure to one or more stressors.
Risk Characterization	A phase of ecological risk assessment that integrates the results of the exposure and ecological effects analyses to evaluate the likelihood of adverse ecological effects associated with exposure to the stressor. The ecological significance of the adverse effects is discussed, including consideration of the types and magnitudes of the effects, their spatial and temporal patterns, and the likelihood of recovery.

RsD (Risk Specific Dose)	The exposure limit determined for chemicals assumed to act as genotoxic, non-threshold carcinogens. An RsD is a function of carcinogenic potency (q_1^*)and defined acceptable risk (i.e., RsD = target level of risk ÷ q_1^*).
Run Habitat	Areas of swift flowing water, without surface waves, which approximates uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Sample	Representative fraction of a material tested or analysed; a selection or collection from a larger collection.
Screening	The process of filtering and removal of implausible or unlikely exposure pathways, chemical or substances, or populations from the risk assessment process to focus the analysis on the chemicals, pathways and populations of greatest concern.
Screening Test	Toxicity tests applied to undiluted field samples to determine the initial positive or negative toxicity response. A positive toxic response may be subject to further definitive tests.
Seepage	The act of trickling from a substrate.
Site	The area determined to be significantly impacted after the iterative evaluations of the risk assessment. Also can be applied to political or legal boundaries.
SLC	Screening Level Criteria. The lowest of available published criteria used for screening for chemicals of concern.
Species	A group of organism's that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic

	grouping of morphologically similar individuals; the category below genus.
Species Composition	A term that refers to the species found in the sampling area.
Species Distribution	Where the various species in an ecosystem are found at any given time. Species distribution varies with season.
Statistic	A computed or estimated statistical quantity such as the mean, the standard deviation, or the correlation coefficient.
Stressor	Any physical, chemical, or biological entity that can induce an adverse effect on an organism.
Subchronic Toxicity	The adverse effects occurring as a result of the repeated daily exposure to a chemical for a short time.
Sublethal	Below the concentration that directly causes death. Exposure to sublethal concentrations or material may produce less obvious effects on behaviour, biochemical and/or physiological functions, and histology of organisms.
Suncor	Suncor Inc., Oil Sands Group
Syncrude	Syncrude Canada Ltd.
TDS	Total dissolved solids.
TEF	Toxicity Equivalent Factor.
Threshold Concentration	A concentration above which some effect (or response) will be produced and below which it will not.

TID	Tar Island Dyke
TOC	Total organic carbon. TOC is composed of both dissolved and particulate forms. TOC is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). TOC has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
TIRA	Tar Island Reclamation Area
Toxic	A substance, dose or concentration that is harmful to a living organism.
Toxic Threshold	Almost all compounds become toxic at some level with no evident harm or adverse effect below that level. Scientists refer to the level or concentrations where they first see evidence for an adverse effect on an organism as the toxic threshold.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Toxicity Assessment	Review of literature regarding the toxicity of any given material to an appropriate receptor. Also known as Effects Assessment.
Toxicity Test	The means by which the toxicity of a chemical or other test material is determined. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).
Trafficable	A solid material capable of supporting weight.

Trophic Level	A functional classification of taxa within a community that is based on feeding relationships (e.g., aquatic and terrestrial plants make up the first trophic level and herbivores make up the second).
TSS	Total suspended solids.
Uncertainty	Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.
Uncertainty Factor	A unitless numerical value that is applied to a reference toxicological value (i.e., NOAEL) to account for uncertainties in the experimental data used to derive the toxicological value (e.g., short testing period, lack of species diversity, small test group, etc.) And to increase confidence in the safety of the exposure dose as it applies to species other than the test species (e.g., sensitive individuals in the human population). RfD equals the NOAEL divided by the uncertainty factor.
Uptake	The process by which a chemical crosses an absorption barrier and is absorbed in the body.
U.S. EPA	U.S. Environmental Protection Agency

Valued Ecosystem Component (VEC)	Components of an ecosystem (either plant, animal, or abiotic feature) considered valuable by various sectors of the public.
VOC(s)	Volatile Organic Compound(s).
Volatilization	The conversion of a chemical substance from a liquid or solid state to a gaseous vapour state.
Wasteload Allocation	The amount of a stream's total permissible substance load that is allocated to one or more existing or future point source discharges. The total allowable substance load is determined by calculating the amount of substance that can be discharged while maintaining instream guidelines under worst-case conditions
Worst-Case	A semi-quantitative term referring to the maximum possible exposure, dose or risk, that can conceivably occur, whether or not this exposure, dose or risk actually occurs is observed in a specific population. It should refer to a hypothetical situation in which everything that can plausibly happen to maximize exposure, dose, or risk does happen. The worst-case may occur in a given population, but since it is usually a very unlikely set of circumstances in most cases, a worst-case estimate will be somewhat higher than what occurs for a specific population.

TABLES

TABLE 3.1-1

FLOW RATES - EXISTING AND FUTURE (L/s)

Outfall ID	Outfall Description	1995	2001	2010	2020	Equilibrium
S1	Shipyard Lake Groundwater	0.00	0.00	2.50	6.20	6.80
S2	South Mine Discharge Point	15.29	28.26	30.81	103.16	65.91
S3	TID Seepage	19.00	19.00	19.00	15.00	5.70
S4	Wastewater/Cooling Pond E	950.88	613.88	443.88	458.45	35.01[1]
S5	Steepbank Mine Groundwater	0.00	0.00	1.10	1.40	1.40
S6	Mid-Plant Discharge Point	12.54	12.54	12.54	12.54	0.00
S7	Pond 4 Seepage	1.00	1.00	1.00	1.00	1.00
S8	Pond 5 Seepage	0.00	0.00	3.50	3.50	4.70
S9	North Mine	14.65	3.51	3.51	59.09	32.83
S10	Pond 6 Drainage Outlet	0.00	0.00	0.00	137.90	31.18
S11	Pond 6 Seepage	0.00	0.00	6.80	6.80	3.60
S12	Syncrude Lakes	n/a	n/a	n/a	n/a	154.00
Total		1013.36	678.19	524.64	805.04	307.12

[1] Natural runoff from reclaimed plant site.

Note:
- Flows from AGRA (1996), except for S12 (W.E.R. 1992); based on an average year.
- For outfall locations, please refer to Figure D1.0-2.
- Concentrations to be added at a later date.

TABLE 3.2-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

Page 1 of 5

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
ORGANICS									
Total Petroleum Hydrocarbons (mg/L)									
Total Petroleum Hydrocarbons	-	-	-	-	-	-	99-113	-	-
Hydrocarbons, Recoverable	<1-1	<1-9	<1-22	<1-19	-	<1	<1	<1	-
Total Extractable Hydrocarbons (mg/L)									
Total Extractable Hydrocarbons	-	-	38.9-59.8	-	-	-	<1	<1	-
Naphthenic Acids (mg/L)									
Naphthenic acids	<1	<1	62-94	47-55	-	<2-5	<1-4	<1-5	-
Polycyclic Aromatic Hydrocarbons (µg/L)									
1-Methyl-7-isopropylphenanthrene (Retene)	<0.04	<0.04	<0.04	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
Acenaphthene	<0.02	<0.02	<0.02-<0.08	<0.02	<0.02-0.12	<0.02	<0.02	<0.02	-
Acenaphthylene	<0.02	<0.02	<0.02-0.16	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Anthracene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Benzo(a)anthracene/chrysene	<0.02	<0.02	<0.02-0.27	<0.02	<0.02-0.1	<0.02	<0.02-1	<0.02	-
Benzo(a)pyrene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.02	<0.02	<0.02	<0.02	-
Benzo(b&k)fluoranthene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Benzo(ghi)perylene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.03	<0.02	0.02-0.03	<0.02	-
Biphenyl	<0.04	<0.04	<0.04-0.08	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
C2 sub'd benzo(a)anthracene/chrysene	<0.04	<0.04	<0.04-0.83	<0.04	<0.04-0.05	<0.04	<0.04-0.12	<0.04	-
C2 sub'd benzo(b&k)fluoranthene/ benzo(a)pyrene	<0.04	<0.04	<0.04-0.18	<0.04	<0.04-0.04	<0.04	<0.04-0.07	<0.04	-
C2 sub'd biphenyl	<0.04	<0.04	<0.04-0.25	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
C2 sub'd dibenzothiophene	<0.04	<0.04	<0.04-2.2	<0.04	<0.1-0.52	<0.04	<0.04-0.19	<0.04	-
C2 sub'd fluorene	<0.04	<0.04	<0.04-1.1	<0.04-0.28	<0.04-0.35	<0.04	<0.04-0.16	<0.04	-
C2 sub'd naphthalene	<0.04	<0.04	<0.04-0.25	<0.04-0.07	0.25-0.3	<0.04	<0.04-0.04	<0.04	-
C2 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-4.5	<0.04-0.06	<0.1-0.39	<0.04	<0.04-0.22	<0.04	-
C3 sub'd dibenzothiophene	<0.04	<0.04	<0.04-4.1	<0.04	<0.1-0.08	<0.04	<0.04-0.12	<0.04	-
C3 sub'd naphthalene	<0.04	<0.04	<0.04-0.3	<0.04-0.27	<0.1-0.78	<0.04	<0.04-0.34	<0.04	-
C3 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-3.6	<0.06-0.12	<0.1-0.21	<0.04	<0.04-0.25	<0.04	-
C4 sub'd dibenzothiophene	<0.04	<0.04	<0.04-4.4	<0.04	<0.1-0.06	<0.04	<0.04	<0.04	-
C4 sub'd naphthalene	<0.04	<0.04	<0.04-2	0.04-0.56	<0.1-0.6	<0.04	<0.04-0.09	<0.04	-
C4 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-1.7	<0.04-0.06	<0.04-<0.1	<0.04	<0.04-0.33	<0.04	-
Dibenzo(a,h)anthracene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Dibenzothiophene	<0.02	<0.02	<0.02-0.07	<0.02	<0.02-0.03	<0.02	<0.02-0.09	<0.02	-
Fluoranthene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.03	<0.02	<0.02	<0.02	-
Fluorene	<0.02	<0.02	<0.02-0.03	<0.02	<0.02-0.14	<0.02	<0.02	<0.02	-
Indeno(c,d-123)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Methyl acenaphthene	<0.04	<0.04	<0.04-0.19	<0.04-0.28	<0.04-<0.1	<0.04	<0.04	<0.04	-
Methyl benzo(a)anthracene/chrysene	<0.04	<0.04	<0.04-0.5	<0.04	<0.04-0.11	<0.04	<0.04-0.12	<0.04	-

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SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

Page 2 of 5

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Methyl benzo(b&k) fluoranthene/ methyl benzo(a)pyrene	<0.04	<0.04	<0.04-0.3	<0.04	<0.04-0.05	<0.04	<0.04-0.07	<0.04	-
Methyl biphenyl	<0.04	<0.04	<0.04-<0.08	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
Methyl dibenzothiophene	<0.04	<0.04	<0.04-0.65	<0.04-0.05	<0.1-0.21	<0.04	<0.04-0.21	<0.04	-
Methyl fluoranthene/pyrene	<0.04	<0.04	<0.04-0.65	<0.04-0.08	<0.1-0.12	<0.04	<0.04-0.31	<0.04	-
Methyl fluorene	<0.04	<0.04	<0.04-0.3	<0.04-0.26	<0.04-0.25	<0.04	<0.04	<0.04	-
Methyl naphthalene	<0.02-<0.1	<0.02	<0.02-<0.08	<0.02-0.05	<0.02-0.34	<0.02	<0.02-0.1	<0.02	-
Methyl phenanthrene/anthracene	<0.04	<0.04	<0.04-0.79	<0.04-0.07	<0.1-0.46	<0.04	<0.04-0.19	<0.04	-
Naphthalene	<0.02	<0.02-0.02	<0.02-0.05	<0.02-0.09	0.23-0.56	<0.02	<0.02	<0.02	-
Phenanthrene	<0.02	<0.02	<0.02-0.09	<0.02	<0.02-0.12	<0.02	<0.02	<0.02	-
Pyrene	<0.02	<0.02	<0.02-0.04	<0.02	<0.02-0.09	<0.02	<0.02-0.16	<0.02	-
Polycyclic Aromatic Nitrogen Heterocycles (µg/L)									
7-Methyl quinoline	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12-0.46	<0.02	-
Acridine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02-0.13	<0.02	-
C2 Alkyl subst'd carbazoles	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
C2 Alkyl subst'd quinolines	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.09-0.4	<0.02	-
C3 Alkyl subst'd quinolines	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Carbazole	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Methyl acridine	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02	<0.02	<0.02-0.6	<0.02	-
Methyl carbazoles	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Phenanthridine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02-0.21	<0.02	-
Quinoline	<0.02	<0.02	<0.02	<0.02-0.09	<0.02	<0.02	<0.02-0.71	<0.02	-
Phenols (µg/L)									
2,4-Dimethylphenol	<0.1	<0.1	<0.2-1	<0.02	<0.1	<0.1	<0.1-1	<0.1	-
2,4-Dinitrophenol	<2	<2	<4-<20	<1-<20	<20	<2	<2	<2	-
2-Nitrophenol	<0.2	<0.2	<0.4-<2	<0.4-<2	<2	<0.2	<0.2	<0.2	-
4,6-Dinitro-2-methylphenol	<2	<2	<20	<4-<20	<20	<2	<2	<2	-
4-Nitrophenol	<2	<2	<4-<20	<4-<20	<20	<2	<2	<2	-
m-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
o-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
p-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
Phenol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
Phenols	-	-	<0.002	<0.002	-	<0.002	<0.002	<0.002	-
Volatiles (µg/L)									
1,1,1-Trichloroethane	<1	<1	<1-<15	<1	<1	<1	<1-4	<1	-
1,1,2,2-Tetrachloroethane	<5	<5	<5-<75	<5	<5	<5	<5	<5	-
1,1,2-Trichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,1-Dichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,1-Dichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,2,3-Trichloropropane	<2	<2	<2-<30	<2	<2	<2	<2	<2	-
1,2-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-

TABLE 3.2-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
1,2-Dichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,2-Dichloropropane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,3-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,4-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
2-Butanone (MEK)	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
2-Chloroethylvinylether	<5	<5	<5-<75	<5	<5	<5	<5	<5	-
2-Hexanone	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
4-Methyl-2-pentanone (MIBK)	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
Acetone	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Acrolein	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Acrylonitrile	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Benzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromodichloromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromoform	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromomethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
Carbon disulfide	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Carbon tetrachloride	<1	<1	<1-<15	<1	<1	<1	<1-3	<1	-
Chlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Chloroethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
Chloroform	<1	<1	<1-<15	<1	<1	<1	<1-3	<1	-
Chloromethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
cis-1,3-Dichloropropene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
cis-1,4-Dichloro-2-butene	<2	<2	<2-<30	<2	<2	<2	<2	<2	-
Dibromochloromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Dibromomethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Dichlorodifluoromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Ethanol	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Ethyl methacrylate	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
Ethylbenzene	<1	<1	<1-<15	<1-1.5	<1	<1-1.2	<1-1.2	<1-1.5	-
Ethylene dibromide	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Iodomethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
m+p-Xylenes	<1	<1	<1-15	<1-5	<1	<1 - 4.1	<1-4.5	<1-5.7	-
Methylene chloride	<1	<1	<1-<30	<1	<1	<1	<1-5.7	<1	-
o-Xylene	<1	<1	<1-15	<1-2.7	<1	<1-1.7	<1-2.2	<1-2.8	-
Styrene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Tetrachloroethylene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Toluene	<1	<1	<1-<15	<1	<1	<1	<1-1	<1	-
trans-1,2-Dichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
trans-1,3-Dichloropropene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
trans-1,4-Dichloro-2-butene	<5	<5-5	<5-<75	<5	<5	<5	<5	<5	-
Trichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-

TABLE 3.2-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Trichlorofluoromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Vinyl acetate	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Vinyl chloride	<20	<20	<20-<300	<20	<20	<20	<20	<20	-
INORGANICS									
General (mg/L)									
pH (pH units)	7.63-7.82	7.4-8.18	7.91-8.54	7.99-8.2	8.01-8.07	7.66-8.31	6.8-8.9	7.3-8.4	6.6
Specific Conductance (µS/cm)	200-268	159-572	1891-4900	1325-1514	1740-1790	588-747	381-1650	209-465	-
Calcium	27-33	19-60	33.3-118	23.5-57.1	29.9-43.2	54-99	32-69	26-55	-
Chloride	3.1-14.8	<0.5-57	45.4-510	15.3-17.3	<0.5-33.4	29-41	30-354	1.0-18	-
Magnesium	7.9-21	6.4-18.4	7.2-28	8.7-11.3	2.73-18.1	19-30	8-18.7	6.0-16	-
Potassium	0.9-2.65	0.41-2.2	<11.5-29	8.4-10.8	0.5-18.9	1.9-3.1	1.2-9.3	0.7-8	-
Sodium	8.6-25	7.5-61	347-1170	273-335	7.7-16600	26-53	28-246	5.0-23	-
Bicarbonate	108-267	97-29	330.84-800	847-884	34-1210	222-309	116-220	116-207	-
Carbonate	<0.5-10	<0.5	<0.05-20	<0.5	<0.5	<0.5-4	<0.5-10	<0.5-5	-
Biological Oxygen Demand	0.1-3.3	-	1.6-6.9	5-9.6	-	<0.1-0.9	<0.1-11.2	<0.1-2.5	-
Chemical Oxygen Demand	<5-28	-	200-430	120-360	-	19-47	11-305	<5-49	-
Dissolved Organic Carbon	1-17.2	12-27.5	52-65.3	36.1-42.5	-	9.8-15	5.0-42	4.0-17	-
Nitrate & Nitrite	<0.001-0.19	<0.003-0.1	<0.003-0.05	0.11-0.26	0.011	<0.003-0.01	<0.003-0.01	<0.003-0.12	0.2
Phenols	<0.001-0.01	<0.001-0.005	<0.002-0.02	<0.001-0.004	0.01	<0.001-0.08	<0.001	<0.001-0.001	-
Sulphate	13.1-58	1.6-53	555-1290	29.1-143	6.7-118	60-142	30-116	15-49	-
Sulphide	<0.001-0.002	-	-	-	-	-	-	-	-
Total Ammonia	<0.01-0.08	<0.01-0.11	0.098-3.98	4.37-6.01	17.2-19.9	<0.001-0.04	<0.006-25	<0.01-0.22	-
Total Dissolved Solids	117-319	87-339	1400-1805	878-1007	1090-1100	365-518	440-510	145-175	-
Total Kjeldahl Nitrogen	0.26-0.46	-	0.95-6.8	7.4-8.75	-	0.3-0.44	0.5-36.3	0.19-0.7	-
Total Organic Carbon	3.2-19	-	56.1-68	38.4-45	-	10.1-12.2	8.2-16	6.5-15.3	-
Total Phosphorus	0.003-0.39	0.014-0.20	0.006-0.1	0.14-0.43	<0.1-0.2	0.01-0.04	<0.003-0.29	0.02-0.17	-
Total Sulphur	6.6	2.1-17.3	186-266	12.7-48.4	5.6-12.2	20.5-44	15-19	5.9-7.9	-
Total Suspended Solids	4-624	0.4-211	<0.4-17	17-64		<0.4-20	6.0-27	2-126	-
Metals and Trace Elements (mg/L)									
Aluminum	<0.01-8.64	<0.01-1.89	<0.01-1.92	0.08-1.15	<0.01-0.88	<0.01-0.07	0.23-5.93	0.05-1.15	-
Antimony	<0.0002 - 0.0002	<0.0002-0.0003	-	-	0.0006	-	0.002	-	<0.2
Arsenic	0.0004-0.007	<0.0002-0.002	0.0007-0.0058	0.0026-0.003	0.0036	<0.0002-0.002	<0.0001-0.17	0.0002-0.004	<0.2
Barium	0.04-0.2	0.02-0.07	0.05-0.18	0.08-0.1	0.15-0.77	0.07-0.12	0.05-0.1	0.05-0.1	0.13
Beryllium	<0.001-0.004	<0.001-0.004	<0.001-0.004	<0.001-0.002	<0.001	<0.001-0.003	<0.001-0.005	<0.001-0.002	<0.01
Boron	0.01-0.09	0.05-0.14	2.26-4.26	1.65-1.88	0.21-2.31	0.12-0.22	0.05-0.15	0.01-0.07	1.21
Cadmium	<0.0002-0.003	<0.003-0.005	<0.003-0.007	<0.003-0.004	<0.0002-<0.001	<0.003-0.003	<0.001-0.01	<0.001-0.003	<0.01
Chromium	<0.002-0.032	<0.002-0.014	<0.002-0.003	<0.002-0.002	<0.002-0.03	<0.002-0.002	<0.0002-0.03	<0.002-0.01	<0.005
Cobalt	<0.001-0.01	<0.003-0.005	<0.003-0.007	<0.003-0.005	0.003-0.02	<0.003-0.01	<0.001-0.01	<0.001-0.004	<0.02
Copper	<0.001-0.01	<0.001-0.002	<0.001-0.004	0.002-0.01	<0.001	<0.001-0.01	<0.001-0.064	0.006-0.03	0.01
Cyanide	<0.001-0.005	<0.001-0.03	<0.001-0.06	0.001-0.002	-	<0.001-0.002	<0.002-0.003	<0.001-0.001	0.07
Fluoride	0.08-0.18	0.14-0.24	-	-	2.1-2.8	-	0.07-0.38	-	0.9

TABLE 3.2-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Iron	0.101-17.9	0.38-4.81	<0.01-1.01	1.24-2.21	0.01-22.5	0.007-0.3	0.005-2.56	0.22-2.28	0.35
Lead	<0.001-0.01	<0.02	<0.0003-0.02	<0.02	<0.0003-<0.01	<0.02	<0.002-0.05	<0.02-<0.05	<0.05
Lithium	<0.005-0.02	0.006-0.02	0.16-0.27	0.12-0.14	0.19-0.23	<0.013-0.02	0.009-0.022	0.004-0.01	-
Manganese	<0.004-0.51	0.014-0.21	<0.001-0.06	0.12-0.21	0.06 - 1.76	0.02-0.11	<0.001-0.12	0.012-0.15	1.41
Mercury(µg/L)	<0.05-0.2	<0.05	<0.05-0.05	<0.05-0.26	0.4	<0.05-0.52	<0.05-0.62	<0.05-0.52	<0.1
Molybdenum	<0.001-0.01	<0.003-0.004	0.15-1.42	<0.003-0.02	<0.003-0.07	<0.003-0.003	<0.004-0.6	<0.002-0.002	2.23
Nickel	<0.005-0.01	<0.005-0.012	<0.005-0.03	<0.005-0.01	0.005-0.06	<0.005-0.01	<0.002-0.15	<0.001-0.02	0.5
Selenium	<0.0001-0.0004	<0.0002-0.0003	<0.0002-0.04	<0.0002-0.0002	<0.00004	<0.0002	<0.0001-0.006	<0.0001-0.0005	<0.2
Silicon	2.12	1.13-3.6	2.32-5.58	5.63-10.1	1.1-6.12	2.82-3.89	2.45-3.53	2.17-5.05	-
Silver	<0.001-0.001	<0.002-0.003	<0.0002-0.002	<0.002	<0.0002-<0.001	<0.002-0.002	<0.002-0.05	<0.002-0.05	<0.01
Strontium	0.18-0.36	0.073-0.21	0.75-2.12	0.27-0.34	0.42-0.77	0.15-0.28	0.24-0.29	0.18-0.22	-
Thallium	-	-	-	-	<0.0003-<0.01	-	<0.01-<1	<0.1	<0.05
Tin	-	-	-	-	<0.0003-0.44	-	-	-	-
Titanium	0.004-0.09	<0.003-0.05	<0.003-0.02	<0.003-0.02	0.004-0.01	<0.003-0.003	<0.003-0.047	<0.003-0.01	-
Uranium	<0.5	<0.5	0.007-0.5	<0.5	<0.0002-<0.1	<0.5	<0.5-0.5	<0.5-0.5	<0.2
Vanadium	<0.002-0.02	<0.002-0.008	<0.002-0.17	0.003-0.01	<0.002-0.05	<0.002-0.005	0.005-1.61	<0.002-0.013	0.13
Zinc	<0.001-0.09	0.012-0.16	0.003-0.06	0.01-0.06	0.01-0.07	0.003-0.04	0.001-0.273	<0.005-0.05	0.12
Zirconium	-	-	-	-	0.0012-0.0013	-	-	-	-

[1] Golder, 1995 unpublished data (site: upstream of L19, n= 1 to 4); NAQUADAT (code: 00AL07CC0600, 1985-1995, n= 1 to 26).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996b; n= 1 to 20).

[3] Suncor and Syncrude, 1995 unpublished data from CT field studies, (n= 6 to 18).

[4] Suncor, 1995 unpublished data from Lease 86 Study, ID: RW 127, (n= 1 to 4).

[5] Suncor, 1995 unpublished data, samples from Plant 4 Beach #2 aqueous extract and RG088/089, (n=1 to 4).

[6] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW250 & 252, n= 2 to 8).

[7] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW254, n= 2 to 4); NAQUADAT (codes: 20AL07DA1000/1001, 1980-1995, (n=1 to 80); Suncor's Monthly Water Monitoring Reports.

[8] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW256, n= 1 to 4); NAQUADAT (code: 20AL07DA1013, 1980-1995, n= 1 to 18); Suncor's Monthly Water Monitoring Reports.

[9] Suncor, 1995 unpublished FGD Pilot Study (Sample is 50% gypsum : 50% flyash, n=1).

TABLE 4.2-1

TOXICITY OF SUNCOR'S OPERATIONAL AND RECLAMATION WATERS TO AQUATIC BIOTA

Test	Type/Length	Endpoint Statistic	TID Water[1]			CT Pit[2]			Mine Drainage[3]			Wastewater System[4]			Cooling Pond E[5]			Sewage Lagoon[6]		
			Range	Median	n	Range	Median	n	Range	Median	n	Range	Median	n	Range	Median	n	Range	Median	n
Algal Growth Inhibition Test[7]	72-hour	IC25 (%)	42-62	52.5	4		45	1	10 ->100	>100	11	12->100	>100	4	46 - >100	>100	4		58	1
		IC50 (%)	92->100	>99.5	4		78	1		>100	11		>100	4		>100	4		79	1
		NOEC (%)	25-50	37.5	4		25	1	6.25-100	100	11	6.25-100	50	4	50 - 100	100	4		50	1
		LOEC (%)	50-100	75	4		50	1	12.5->100	>100	10	12.25 - >10	100	4	100 - >100	>100	4		100	1
Bacterial Luminescence Test[8]	Screening Test	% of Control	15-42	31.5	4		40	1	83 - 114	106	9	74 - 99	81	4	91 - 129	100	4		100	1
Trout Survival Test[9]	96-hour Acute	IC25 (%)					31	1		>100	9		>100	4		>100	4			
		IC50 (%)	35-55	49	4		37	1		>100	9		>100	4		>100	4		80	1
		NOEC (%)		25	3		25	1		100	9	50 - 100	100	4		100	4		50	1
		LOEC (%)		50	3		50	1		>100	9	100->100	>100	4		>100	4		100	1
Ceriodaphnia Survival Test[10]	7-day Static Renewal	IC25 (%)	43.8-96	73	4		43.8	1	88 - >100	>100	9	30 - >100	>100	4		>100	4		69	1
		IC50 (%)	66.7->100	>86	4		64.3	1		>100	9	38 - >100	>100	4		>100	4		92	1
		NOEC (%)		50	4		50	1	50-100	100	9	25 - 100	100	4		100	4		50	1
		LOEC (%)		100	4		100	1	100 - >100	>100	9	50 - >100	>100	4		>100	4		100	1
Ceriodaphnia Reproduction Test[10]	7-day Static Renewal	IC25 (%)	16-25	21.7	4		13.9	1	12->100	>100	9	25 - 99	36	4	34 - 87	83	4		36	1
		IC50 (%)	22-52	31.9	4		19.9	1	100->100	>100	9	35 - >100	59	4		>100	4		64	1
		NOEC (%)	12.5-25	12.5	4		12.5	1	6.25-100	100	9	25 - 50	25	4	12.5 - 50	50	4		25	1
		LOEC (%)	25-50	25	4		25	1	12.5->100	>100	9	50 - 100	50	4	25 - 100	100	4		50	1
Daphnia Survival Test[11]	48-hour Acute	IC25 (%)		>100	3		>100	1		>100	8		>100	4		>100	4		>100	1
		IC50 (%)		>100	4		>100	1		>100	9		>100	4		>100	4		>100	1
		NOEC (%)		100	3		100	1		100	8		100	4		100	4		100	1
		LOEC (%)		>100	3		>100	1		>100	8		>100	4		>100	4		>100	1

NOTES:

[1] TID water taken from TID collection system, sample RW127.

[2] CT water is composite sample from CT pits, sample RW159.

[3] Mine Drainage water is taken from Suncor's drainage collection system, samples RW250, 251, 252.

[4] Wastewater System water is taken from Suncor's wastewater collection system, sample RW254.

[5] Cooling Pond E water is taken from Suncor's cooling water system, sample RW256.

[6] Sewage Lagoon water was obtained from sewage effluent system, sample RW258.

[7] Algal growth test was performed with fresh water alga, *Selanastrum capricornutum*.

[8] Bacterial luminescence test was performed with either, *Photobacterium phosphoreum* or *Vibrio fischeri*.

[9] Trout toxicity test performed with *Oncorhynchus mykiss*.

[10] Ceriodaphnia tests performed with the cladoceran, *Ceriodaphnia dubia*.

[11] Daphnia toxicity test performed with *Daphnia magna*.

TABLE 4.3-1

CONCENTRATIONS OF METALS IN BENTHIC INVERTEBRATE TISSUE FROM THE ATHABASCA RIVER, AUGUST 1994 AND OCTOBER 1995

Parameter	Units	August 1994[1]	October 1995 Station AT003
Antimony	µg/g	-	<0.2
Aluminum	µg/g	1330	1070
Arsenic	µg/g	0.9	<20
Barium	µg/g	24	29
Beryllium	µg/g	0.1	<0.1
Boron	µg/g	12	<1
Cadmium	µg/g	<0.3	<0.3
Calcium	µg/g	5110	3030
Chromium	µg/g	64.6	10.5
Cobalt	µg/g	3.3	1.4
Copper	µg/g	15.9	45
Iron	µg/g	3170	2400
Lead	µg/g	<2	<2
Lithium	µg/g	1.8	1.3
Magnesium	µg/g	1530	1530
Manganese	µg/g	166	314
Mercury	µg/kg	78	55
Molybdenum	µg/g	6.2	0.9
Nickel	µg/g	41	8.8
Phosphorus	µg/g	5640	5620
Potassium	µg/g	6610	6640
Selenium	µg/g	<0.2	<4
Silicon	µg/g	359	546
Silver	µg/g	2.4	0.4
Sodium	µg/g	7000	5140
Strontium	µg/g	15.4	16.4
Titanium	µg/g	22	16.4
Uranium	µg/g	<50	<50
Vanadium	µg/g	4.6	3.6
Zinc	µg/g	103	133

[1] Data from Golder (1994b).

TABLE 4.3-2

FISH SPECIES UTILIZATION OF THE STEEPBANK RIVER

SPECIES	1995 STUDY	PREVIOUS STUDIES	SPAWNING	REARING	FEEDING (LOWER REACHES ONLY)	FEEDING (UPPER AND LOWER REACHES	OVERWINTERING
*Arctic Grayling	●	●	✓	✓		✓	YOY?
*Brook Stickleback		●	✓	✓		✓	✓
*Lake Chub	●	●	✓?			✓	
*Longnose Dace	●	●	✓	✓		✓	✓
*Longnose Sucker	●	●	✓			✓	YOY?
*Northern Pike	●	●			✓	✓	
*Pearl Dace		●				✓	
*Slimy Sculpin		●	✓	✓		✓	✓
*Trout-perch	●	●	✓			✓	
*White Sucker	●	●	✓	✓		✓	YOY?
Brassy Minnow		●				✓	
Bull Trout		●			✓		
Burbot	●	●			✓		
Flathead Chub		●			✓		
Flathead Minnow		●				✓	
Goldeye	●	●			✓		
Lake Cisco		●			✓		
Lake Whitefish	●	●			✓		
Longnose Dace	●	●				✓	
Mountain Whitefish	●	●				✓	
Northern Redbelly Dace		●				✓	
Spoonhead Sculpin	●	●	✓	✓		✓	✓
Spottail Shiner		●				✓	
Yellow Perch		●			✓		
Walleye	●	●			✓		

*Common, wide-spread species in the Steepbank River. Pearl dace, brook stickleback, and slimy sculpin were not captured in 1995, likely because they are not easily susceptible to capture with a boat electrofisher. All species without an asterisk have been documented in the lower reaches of the Steepbank River but are not common inhabitants of it.

-Data from Sekerak and Walder (1980), Machniak and Bond (1979) and Bond (1980). See Golder (1996b) for details.

●present in study area

✓habitat use of study area

? may use habitat but use not confirmed

TABLE 4.3-3

FISH SPECIES UTILIZATION OF THE ATHABASCA RIVER NEAR SUNCOR

SPECIES	1995 STUDY	PREVIOUS STUDIES	SPAWNING	REARING	FEEDING	OVERWINTERING	MIGRATING
*Arctic Grayling		●			✓	✓	✓
*Burbot	●	●	✓	✓	✓		✓
*Emerald Shiner	●	●	✓	✓	✓	✓?	✓
*Flathead Chub	●	●	✓	✓	✓	✓?	
*Goldeye	●	●	✓?	✓	✓		✓
*Lake Chub	●	●	✓	✓	✓	✓	
*Lake Whitefish	●	●			✓		✓
*Longnose Sucker	●	●		✓	✓		✓
*Northern Pike	●	●			✓	✓	
*Spottail Shiner	●	●	✓	✓	✓	✓	
*Trout-perch	●	●		✓	✓	✓	
*Walleye	●	●		✓	✓		✓
*White Sucker	●	●		✓	✓		✓
Brassy Minnow	●	●			✓		
Brook Stickleback		●			✓		
Bull Trout		●			✓		
Fathead Minnow		●			✓		
Finescale Dace		●			✓		
Iowa Darter		●			✓		
Longnose Dace	●	●			✓		
Mountain Whitefish	●	●			✓		
Ninespine Stickleback		●			✓		
Northern Redbelly Dace		●			✓		
Pearl Dace		●			✓		
Slimy Sculpin	●	●	✓	✓	✓	✓	
Spoonhead Sculpin	●	●			✓		
Yellow Perch	●	●			✓		

*Common, wide-spread species in the Athabasca River. Note that Arctic grayling are mainly found in the tributaries during the open-water season.

-Data from Bond (1980), McCart et al. (1977), Tripp and McCart (1979), Tripp and Tsui, (1980) and R.L.and L. (1994). See Golder (1996b) for details.

● present in study area

✓kind of habitat use

? may use habitat but use not confirmed

TABLE 4.3-4

CONDITION FACTOR, LIVER-SOMATIC INDEX, AND GONAD-SOMATIC INDEX FOR FISH FROM THE ATHABASCA RIVER

Parameter	Species	Sex	Site	
			Above Oil Sands Region[4]	Oil Sands Region[5] (Steepbank Mine Study Area)
Condition Factor[1]	Longnose Sucker	F	1.26±0.118 (23)	1.33±0.074 (21)
		M	1.25±0.130 (13)	1.30±0.175 (20)
	Walleye	F	0.92±0.113 (20)	1.05±0.091 (23)
		M	0.96±0.137(25)	1.09±0.098 (23)
Liver-Somatic Index[2]	Longnose Sucker	F	1.56±0.435 (20)	1.62±0.266 (21)
		M	1.57±0.606(13)	1.51±0.259 (20)
	Walleye	F	1.05±0.314 (20)	0.82±0.169 (14)
		M	0.99±0.333 (24)	0.94±0.424 (23)
Gonad-Somatic Index[3]	Longnose Sucker	F	10.7±2.24 (23)	11.2±2.36 (21)
		M	3.86±0.80(13)	4.88±0.88 (20)

[1] Condition Factor is a generalized indicator of overall fitness and can reflect the integrated effect of both nutrition and metabolic cost induced by stress (Adams et al. 1989). Condition Factor (K) = $W/L^3 \times 10^5$, where W=weight in grams, L=length in millimeteres, 10^5=scaling factor.

[2] Liver-Somatic Index (LSI) is a measure of the liver size relative to the body where LSI=liver weight/ total body weight x 10^2.

[3] Gonad-Somatic Index (GSI) is a measure of the size of the gonad relative to body size where GSI= gonad weight/ total body weightx10^2.

[4] Data from above oil sands region from SENTAR (1994).

[5] Data from oil sands region from Golder (1996b).

TABLE 4.3-5

FECUNDITY DATA FOR LONGNOSE SUCKER FROM THE ATHABASCA RIVER REGION, 1979 - PRESENT

Waterbody	Mean Fecundity (+/-SD) (eggs per female)	n	Source
Muskeg River	30,512 +/- 9,677	21	Golder 1996b
Lower Athabasca River	34,597 +/-12,251	14	McCart et al. 1977
Muskeg River	23,639	-	Bond and Machniak 1979
Lower Athabasca River	21,843	30	Tripp and McCart 1979
Steepbank River	29,502	14	Machniak and Bond 1979
Lower Athabasca River	29,203	12	Bond 1980
Athabasca River	39, 363 +/- 49,010	24	Unpublished, SENTAR
Christina and Gregoire Rivers	16,180 +/- 5,605	15	Tripp and Tsui 1980

Note: Standard deviation and number of fish was not available for all studies listed

TABLE 4.3-6

LEVELS OF MIXED FUNCTION OXIDASE ACTIVITY (AS EROD ACTIVITY (NMOL/MIN/MG)) MEASURED IN THE LIVER OF FISH COLLECTED FROM SITES IN THE ATHABASCA DRAINAGE BASIN, NORTH SASKATCHEWAN, PEACE AND BEAVER-COWAN RIVER SYSTEMS

Watercourse	EROD Activity (pmol/min/mg)			
	Longnose Sucker	Walleye	Goldeye	Reference
Other Rivers North Saskatchewan River Peace River Beaver-Cowan River	6 ± 5 (20) to 19 ± 10 (6)	6 ± 5 (20)	126 ± 128 (9)	Kloepper-Sams and Benton (1994) Brownlee pers. comm.
Athabasca River Above Oil Sands Region	11 ± 12 (12) to 34 ± 37 (12)	34 ± 25 (2) to 106 ± 68 (4)	36 ± 29 (5) to 71 ± 36 (5)	SENTAR (1994) Brownlee et al. (1993) Brownlee pers. comm.
Athabasca River In Oil Sands Region	195 ± 177 (2)	57 ± 31 (11) to 201 ± 143 (14)	125 ± 50 (5) to 431± 280 (6)	Golder (1996b) Brownlee et al. (1993) Brownlee pers. comm.

See Golder (1996b) for details.
Values are mean ± STD (n)

TABLE 4.3-7

LEVELS OF BENZO-A-PYRENE (µg/g) MEASURED IN BILE OF LONGNOSE SUCKER, WALLEYE AND GOLDEYE COLLECTED FROM SITES IN THE ATHABASCA DRAINAGE BASIN

Site	Date	Species			Reference
		Longnose Sucker	Walleye	Goldeye	
Baseline Data - Athabasca River Near-field downstream of Al-Pac mill	Fall 1992	0.257±0.161(4)	0.034±0.037(12)	0.036±0.029(5)	SENTAR 1994
Baseline Data - Athabasca River Far-field downstream of Al-Pac mill		0.158±0.950(3)	0.034±0.025(12)	0.071±0.036(5)	
Baseline Data - Muskeg and Athabasca Rivers (SUNCOR/SYNCRUDE Site)	Spring/ Summer 1995	3.05±1.061(2) (composite samples)	12±10.1(4)	4.5±2.49(8)	Golder 1996b

Values are mean±SD(n).

TABLE 4.3-8

SUMMARY OF EROD ACTIVITY (pmol/min/mg protein) IN FISH EXPOSED TO OIL SANDS WATERS

PERCENT (%) DILUTION	TROUT 4-DAY EXPOSURE[1]			TROUT 4-DAY	7-Day Exposure[2]					
					Tar Island Dyke			ATHABASCA RIVER		
	Consolidated Tailings	Dyke Seepage Water	Athabasca River	Suncor Wastewater	Small Trout	Large Trout	Walleye	Small Trout	Large Trout	Walleye
0.1	nd	nd	nd	0.5	7.8	1.9	5.7			
0.32	2.5	3.2		1						
1	2	1.8	3	1.9	10.4	2.7	4.7			
3.2	2.5	2.5	2.2	3.7						
10	5	3.3	1.9	6.9	5.4	3.3	5			
32	12	4.1	2.1	13						
50						1.8				
100	nd	nd	1.3	24.3				3	1.5	1.3

nd = not detected.

[1] Parrott (1996; pers. comm.).

[2] HydroQual (1996).

TABLE 4.3-9

SUMMARY OF OBSERVATIONS FOR THE 28-DAY FISH HEALTH EXPERIMENT (using 0.1%, 1% and 10% concentrations)

END POINT	Tar Island Dyke		1 % NAPHTHENIC ACID	ATHABASCA RIVER
	LOEL[1]	NOEL[2]		
Survival	No Effect	No Effect	No Effect	No Effect
Growth	No Effect	> 10%	No Effect	Increase
Condition Factor	No Effect	> 10%	Decrease	No Effect
Liver Somatic Index	No Effect	> 10%	Increase	No Effect
Gross Pathology	No Effect	> 10%	No Effect	No Effect
Histopathology	10%	1%	Increase	No Effect
Hematocrit	10%	1%	Decrease	No Effect
Hemoglobin	No Effect	> 10%	No Effect	No Effect
Glucose	10%	1%	Decrease	No Effect
Protein	No Effect	> 10%	No Effect	No Effect
Lactic Acid	10%	1%	Increase	No Effect
White Blood Cells	No Effect	> 10%	No Effect	No Effect
EROD Activity	10%	1%	No Effect	No Effect
Disease Resistance	No Effect	> 10%	No Effect	Decrease
Swimming Stamina	No Effect	> 10%	No Effect	Decrease

[1] LOEL - lowest observed effect level

[2] NOEL - no observed effect level

Data from HydroQual (1996)

TABLE 5.1-1

SCREENING LEVEL CRITERIA FOR CHEMICALS IN DRINKING WATER FOR HUMANS

Page 1 of 3

Chemicals	HWC[1] Drinking Water Criteria (mg/L)	U.S. EPA[2] Drinking Water Criteria (mg/L)	BC MOE[3] Drinking Water Criteria (mg/L)	Screening Level[4] Criteria (mg/L)
PAHS AND SUBSTITUTED PAHS				
Acenaphthylene	-[6]	-[6]	-[6]	-[6]
Acenaphthene group[5]	-[6]	0.0001	-[6]	0.0001
Benzo(a)anthracene group[5]	-[6]	0.0001	-[6]	0.0001
Benzo(ghi)perylene	-[6]	-[6]	-[6]	-[6]
Benzo(a)pyrene group[5]	0.00001	0.0002	0.00001	0.00001
Biphenyl	-[6]	-[6]	-[6]	-[6]
Dibenzothiophene group[5]	-[6]	-[6]	-[6]	-[6]
Fluoranthene group[5]	-[6]	-[6]	-[6]	-[6]
Fluorene group[5]	-[6]	-[6]	-[6]	-[6]
Naphthalene group[5]	-[6]	-[6]	-[6]	-[6]
Phenanthrene group[5]	-[6]	-[6]	-[6]	-[6]
Pyrene	-[6]	-[6]	-[6]	-[6]
SUBSTITUTED PANH COMPOUNDS				
Acridine group[5]	-[6]	-[6]	-[6]	-[6]
Quinoline group[5]	-[6]	-[6]	-[6]	-[6]
NAPHTHENIC ACIDS				
Naphthenic acids	-[6]	-[6]	-[6]	-[6]
VOLATILES				
Carbon tetrachloride	0.005	0.005	0.005	0.005
Chloroform	0.35	0.1	0.1	0.1
Ethylbenzene	0.0024[7]	0.7	-[6]	0.0024[7]
Methylene chloride	0.05	-[6]	0.05	0.05
Toluene	0.024[7]	1	-[6]	0.024[7]
m-+p-xylenes	0.3[7]	10	-[6]	0.3[7]
o-xylene	0.3[7]	10	-[6]	0.3[7]

TABLE 5.1-1

SCREENING LEVEL CRITERIA FOR CHEMICALS IN DRINKING WATER FOR HUMANS

Page 2 of 3

Chemicals	HWC[1] Drinking Water Criteria (mg/L)	U.S. EPA[2] Drinking Water Criteria (mg/L)	BC MOE[3] Drinking Water Criteria (mg/L)	Screening Level[4] Criteria (mg/L)
PHENOLS				
Phenol	-[6]	-[6]	-[6]	-[6]
2,4-Dimethylphenol	-[6]	-[6]	-[6]	-[6]
m-cresol	-[6]	-[6]	-[6]	-[6]
INORGANICS				
Aluminum	-[6]	0.2[7]	0.2	0.2[7]
Ammonia	-[6]	-[6]	-[6]	-[6]
Antimony	-[6]	0.05	0.006	0.006
Arsenic	0.025	0.05	0.05	0.025
Barium	1	2	1	1
Beryllium	-[6]	0.004	-[6]	0.004
Boron	5	-[6]	5	5
Cadmium	0.005	0.005	0.005	0.005
Calcium	-[6]	-[6]	-[6]	-[6]
Chloride	250[7]	-[6]	250[7]	250[7]
Chromium	0.05	0.1	0.05	0.05
Cobalt	-[6]	-[6]	-[6]	-[6]
Copper	1[7]	1.3	0.5	0.5
Cyanide	0.2	0.2	0.2	0.2
Iron	0.3[7]	-[6]	0.3[7]	0.3[7]
Lithium	-[6]	-[6]	-[6]	-[6]
Magnesium	-[6]	-[6]	100[8]	100[8]
Manganese	0.05[7]	-[6]	0.05[7]	0.05[7]
Mercury	0.001	0.002	0.001	0.001
Molybdenum	-[6]	-[6]	0.25	0.25
Nickel	-[6]	0.1	0.2	0.1

TABLE 5.1-1

SCREENING LEVEL CRITERIA FOR CHEMICALS IN DRINKING WATER FOR HUMANS

Page 3 of 3

Chemicals	HWC[1] Drinking Water Criteria (mg/L)	U.S. EPA[2] Drinking Water Criteria (mg/L)	BC MOE[3] Drinking Water Criteria (mg/L)	Screening Level[4] Criteria (mg/L)
Phosphorus	–[6]	–[6]	0.01	0.01
Potassium	–[6]	–[6]	–[6]	–[6]
Selenium	0.01	0.05	0.01	0.01
Silicon	–[6]	–[6]	–[6]	–[6]
Silver	–[6]	0.1	–[6]	0.1
Sodium	200[7]	–[6]	–[6]	200[7]
Strontium	–[6]	–[6]	–[6]	–[6]
Sulphate	500[7]	–[6]	500[7]	500[7]
Sulphide	0.05[7]	–[6]	0.05[7]	0.05[7]
Tin	–[6]	–[6]	–[6]	–[6]
Titanium	–[6]	–[6]	0.1	0.1
Uranium	–[6]	0.02	0.1	0.02
Vanadium	–[6]	–[6]	0.1	0.1
Zinc	5[7]	–[6]	5[7]	5[7]
Zirconium	–[6]	–[6]	–[6]	–[6]

[1] Health and Welfare Canada Maximum Acceptable Concentrations (MAC) have been derived to safeguard health assuming lifelong consumption of drinking water containing the substance at that concentration (HWC 1993).

[2] U.S. Environmental Protection Agency Maximum Contaminants Level for drinking water for human health (U.S. EPA as cited in CRWQCB 1993).

[3] BC criteria are generally intended to serve as benchmarks related to the protection of human health (BCE 1994).

[4] Screening Level Criteria were based on lowest available criteria.

[5] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix I.

[6] No criterion.

[7] Based on an aesthetic objective for drinking water.

[8] Based on taste threshold for sensitive people.

TABLE 5.1-2

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR HUMANS

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS				
Acenaphthylene	<0.00002[4]	<0.00002	-[6]	No criterion
Acenaphthene group[5]	<0.00004	<0.00004	-[6]	No criterion
Benzo(a)anthracene group[5]	<0.00004	<0.00004	0.0001	Does not exceed.
Benzo(ghi)perylene	<0.00002	<0.00002	-[6]	No criterion
Benzo(a)pyrene group[5]	<0.00004	<0.00004	0.00001	Does not exceed.
Biphenyl	<0.00004	<0.00004	-[6]	
Dibenzothiophene group[5]	<0.00004	<0.00004	-[6]	No criterion
Fluorene group[5]	<0.00004	<0.00004	-[6]	No criterion
Fluoranthene group[5]	<0.00004	<0.00004	-[6]	No criterion
Naphthalene group[5]	<0.00002	0.00002	-[6]	No criterion.
Phenanthrene group[5]	<0.00004	<0.00004	-[6]	No criterion
Pyrene	<0.00002	<0.00002	-[6]	No criterion
SUBSTITUTED PANH COMPOUNDS				
Acridine group[5]	<0.00002	<0.00002	-[6]	No criterion
Quinoline group[5]	<0.00002	<0.00002	-[6]	No criterion
NAPHTHENIC ACIDS				
Naphthenic acids	<1	<1	-[6]	No criterion
VOLATILES				
Carbon tetrachloride	<0.001	<0.001	0.005	Does not exceed.
Chloroform	<0.001	<0.001	0.1	Does not exceed.
Ethylbenzene	<0.001	<0.001	0.0024[7]	Does not exceed.
Methylene chloride	<0.001	<0.001	0.05	Does not exceed.
Toluene	<0.001	<0.001	0.024	Does not exceed.
m-+p-xylenes	<0.001	<0.001	0.3[7]	Does not exceed.
o-xylene	<0.001	<0.001	0.3[7]	Does not exceed.

TABLE 5.1-2

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR HUMANS

Page 2 of 3

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
PHENOLS				
2,4-Dimethylphenol	<0.0001	<0.0001	–[6]	No criterion
m-cresol	<0.0001	<0.0001	–[6]	No criterion
INORGANICS				
Aluminum	8.64	1.89	0.2[7]	EXCEEDS
Ammonia	0.08	0.11	–[6]	No criterion.
Antimony	0.0002	0.0003	0.006	Does not exceed.
Arsenic	0.007	0.0015	0.025	Does not exceed.
Barium	0.2	0.07	1	Does not exceed.
Beryllium	0.004	0.004	0.004	Does not exceed.
Boron	0.09	0.14	5	Does not exceed.
Cadmium	0.003	0.005	0.005	Does not exceed.
Calcium	74	60	–[6]	No criterion
Chloride	14.8	56.9	250[7]	Does not exceed.
Chromium	0.032	0.014	0.05	Does not exceed.
Cobalt	0.01	0.005	–[6]	No criterion.
Copper	0.01	0.002	0.5	Does not exceed.
Cyanide	0.005	0.025	0.2	Does not exceed.
Iron	17.9	4.81	0.3[7]	EXCEEDS
Lithium	0.02	0.02	–[6]	No criterion.
Magnesium	21	18.4	100[8]	Does not exceed.
Manganese	0.509	0.21	0.05[7]	EXCEEDS
Mercury	0.0002	<0.00005	0.001	Does not exceed.
Molybdenum	0.01	0.004	0.25	Does not exceed.
Nickel	0.01	0.012	0.1	Does not exceed.
Phosphorus	0.4	<0.1	0.01	EXCEEDS

TABLE 5.1-2

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR HUMANS

Page 3 of 3

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
Potassium	2.65	2.2	-[6]	No criterion
Selenium	0.0004	0.0003	0.01	Does not exceed.
Silicon	2.12	3.76	-[6]	No criterion
Silver	0.0003	0.003	0.1	Does not exceed.
Sodium	24.6	61.3	200[7]	Does not exceed.
Strontium	0.36	0.21	-[6]	No criterion.
Sulphate	58	53.2	500[7]	Does not exceed.
Sulphide	-[6]	-[6]	0.05	No data
Tin	-[6]	-[6]	-[6]	No criterion.
Titanium	0.085	0.046	0.1	Does not exceed.
Uranium	<0.5	<0.5	0.1	Does not exceed.
Vanadium	0.02	0.008	0.1	Does not exceed.
Zinc	0.085	0.162	5[7]	Does not exceed.
Zirconium	-[6]	-[6]	-[6]	Does not exceed.

[1] Athabasca River upstream of Lease 19 sampled by Golder during 1995 (Suncor EIA data, Golder 1996b) and NAQUADAT data (n=26) sampled in 1985-1995 (site: 00AL07CC0600).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996b).

[3] Screening Level Criteria were based on water quality criteria for human drinking water. Please see table 5.1-1 for derivation of values.

[4] These compounds were not detected above detection limits.

[5] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[6] No data or criterion.

[7] Based on an aesthetic objective for drinking water.

[8] Based on taste threshold for sensitive people.

TABLE 5.1-3

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR PEOPLE FOR OFF-SITE RELEASES

Page 1 of 3

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS								
Acenaphthylene	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	-[10]	No criterion.
Acenaphthene group[8]	<0.00002	<0.00002	<0.00004[9]	0.00012	0.00028	0.00019	-[10]	No criterion.
Benzo(a)anthracene group[8]	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	0.0001	EXCEEDS
Benzo(a)pyrene group[8]	0.00014	<0.00004	<0.00004	0.00011	<0.00004	0.00048	0.00001	EXCEEDS
Benzo(ghi)perylene	<0.00004	<0.00002	<0.00002	0.00003	<0.00002	<0.00002	-[10]	No criterion.
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	-[10]	No criterion.
Dibenzothiophene group[8]	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	-[10]	No criterion.
Fluoranthene group[8]	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	-[10]	No criterion.
Fluorene group[8]	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	-[10]	No criterion.
Naphthalene group[8]	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	-[10]	No criterion.
Phenanthrene group[8]	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	-[10]	No criterion.
Pyrene	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	-[10]	No criterion.
SUBSTITUTED PANH COMPOUNDS								
Acridine group[8]	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	-[10]	No criterion.
Quinoline Group[8]	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	-[10]	No criterion.
NAPHTHENIC ACIDS								
Naphthenic acids	4	5	11	-[10]	55	94	-[10]	No criterion.
VOLATILES								
Carbon tetrachloride	0.003	<0.001	<0.001	<0.001	<0.001	<0.015	0.005	Does not exceed
Chloroform	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.1	Does not exceed
Ethylbenzene	0.0012	0.0015	0.0012	<0.001	0.0015	<0.015	0.0024[11]	Does not exceed
Methylene chloride	0.0057	<0.001	0.004	<0.001	<0.001	<0.001	0.05	Does not exceed
Toluene	0.001	<0.001	<0.001	<0.001	<0.001	<0.015	0.024[11]	Does not exceed
m-+p-xylenes	0.0045	0.0057	0.0041	<0.001	0.005	<0.015	0.3[11]	Does not exceed
o-xylene	0.0022	0.0028	0.0017	<0.001	0.0027	0.015	0.3[11]	Does not exceed
PHENOLS								
2,4-Dimethylphenol	0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.001	-[10]	No criterion
m-cresol	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	-[10]	No criterion
INORGANICS								
Aluminum	5.93	1.15	0.1	0.88	1.15	1.92	0.2[11]	EXCEEDS
Ammonia	25	0.22	0.05	19.9	6.01	3.98	-[10]	No criterion.

TABLE 5.1-3

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR PEOPLE FOR OFF-SITE RELEASES

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments
Antimony	–[10]	–[10]	–[10]	0.0006	–[10]	–[10]	0.006	Does not exceed
Arsenic	0.17	0.004	0.0007	0.0036	0.003	0.0058	0.025	EXCEEDS
Barium	0.101	0.102	0.12	0.772	0.1	0.18	1	Does not exceed
Beryllium	0.002	0.002	0.003	<0.001	0.002	0.004	0.004	Does not exceed
Boron	0.15	0.07	0.375	2.31	1.88	4.26	5	Does not exceed
Cadmium	0.01	0.003	<0.003	<0.001	0.004	0.007	0.005	EXCEEDS
Calcium	69	55	99.3	43.2	57.1	118	–[10]	No criterion.
Chloride	354	18	190	33.4	17.3	510	250[11]	EXCEEDS
Chromium	0.029	0.008	0.004	0.028	0.002	0.003	0.05	Does not exceed
Cobalt	0.01	0.004	0.005	0.018	0.005	0.007	–[10]	No criterion.
Copper	0.064	0.029	0.009	<0.001	0.006	0.004	0.5	Does not exceed
Cyanide	0.003	0.001	0.002	–[10]	0.002	0.055	0.2	Does not exceed
Iron	2.56	2.28	0.45	22.5	2.21	1.01	0.3[11]	EXCEEDS
Lithium	0.022	0.01	0.035	0.229	0.144	0.272	–[10]	No criterion.
Magnesium	18.7	16	34.4	18.1	11.3	28	100[12]	Does not exceed
Manganese	0.121	0.153	0.111	1.76	0.213	0.058	0.05[11]	EXCEEDS
Mercury	0.00062	0.00052	0.00052	0.0004	0.00026	<0.00005	0.001	Does not exceed
Molybdenum	0.6	0.002	0.018	0.071	0.018	1.42	0.25	EXCEEDS
Nickel	0.148	0.02	0.012	0.055	0.005	0.0295	0.1	EXCEEDS
Phosphorus	0.29	0.171	0.046	0.2	0.43	0.096	0.01	EXCEEDS
Potassium	9.3	8	5.9	18.9	10.8	29	–[10]	No criterion.
Selenium	0.0059	0.0005	0.0002	<0.00004	0.0002	0.0036	0.01	Does not exceed
Silicon	3.53	5.05	3.89	6.12	10.1	5.58	–[10]	No criterion.
Silver	0.005	<0.002	0.002	<0.001	<0.002	0.002	0.1	Does not exceed
Sodium	246	23	131	16600	335	1170	200[11]	EXCEEDS
Strontium	0.29	0.22	0.496	0.771	0.337	2.12	–[10]	No criterion.
Sulphate	116	49	211	118	143	1290	500[11]	EXCEEDS
Tin	–[10]	–[10]	–[10]	0.44	–[10]	–[10]	–[10]	No criterion.
Titanium	0.047	0.009	0.003	0.013	0.02	0.02	0.1	Does not exceed
Uranium	<0.5	<0.5	<0.5	<0.1	<0.5	0.007	0.1	Does not exceed
Vanadium	1.61	0.013	0.005	0.05	0.01	0.17	0.1	EXCEEDS
Zinc	0.273	0.047	0.06	0.068	0.058	0.056	5[11]	Does not exceed

TABLE 5.1-3

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR PEOPLE FOR OFF-SITE RELEASES

Page 3 of 3

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments
Zirconium	-[10]	-[10]	-[10]	0.0013	-[10]	-[10]	-[10]	No criterion.

[1] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1to 80). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[2] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[3] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory. Chemex Labs and Syncrude Research Centre.

[4] Groundwater samples (ID: RG088 and RG089) and Plant 4 tailings water sample (ID: Beach #2 E504203-02).

[5] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127)

[6] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164; 1995 Suncor and Syncrude CT field study.

[7] The Screening Level Criteria were based on water quality criteria for human drinking water. Please see table 5.1-1 for derivation of values.

[8] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[9] These compounds were not detected above detection limits.

[10] No data or criterion.

[11] Based on an aesthetic objective for drinking water.

[12] Based on taste threshold for sensitive people.

TABLE 5.1-4

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES

Page 1 of 2

Chemical	Athabasca River[1] Water (mg/L)	Reference[2] Tributaries Water (mg/L)	Suncor[3] Wastewater (mg/L)	Cooling Pond E[4] Wastewater (mg/L)	Mine Drainage[5] Water (mg/L)	Plant 4[6] Tailings Sand Water (mg/L)	Tar Island[7] Dyke Water (mg/L)	Consolidated[8] Tailings Water (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS									
Acenaphthylene	<0.00002[10]	<0.00002	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	EXCEEDS
Acenaphthene group[9]	<0.00004	<0.00004	<0.00002	<0.00002	<0.000049	0.00012	0.00028	0.00019	EXCEEDS
Benzo(a)anthracene group[9]	<0.00004	<0.00004	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	EXCEEDS
Benzo(ghi)perylene	<0.00002	<0.00002	<0.00004	<0.00002	<0.00002	0.00003	<0.00004	<0.00002	EXCEEDS
Benzo(a)pyrene group[9]	<0.00004	<0.00004	0.00014	<0.00004	<0.00004	0.00011	<0.00002	0.00048	EXCEEDS
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	EXCEEDS
Dibenzothiophene group[9]	<0.00004	<0.00004	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	EXCEEDS
Fluoranthene group[9]	<0.00004	<0.00004	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	EXCEEDS
Fluorene group[9]	<0.00004	<0.00004	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	EXCEEDS
Naphthalene group[9]	<0.00002	0.00002	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	EXCEEDS
Phenanthrene group[9]	<0.00004	<0.00004	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	EXCEEDS
Pyrene	<0.00002	<0.00002	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	EXCEEDS
SUBSTITUTED PANH COMPOUNDS									
Acridine group[9]	<0.00002	<0.00002	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	EXCEEDS
Quinoline group[9]	<0.00002	<0.00002	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	EXCEEDS
NAPHTHENIC ACIDS									
Naphthenic acids	<1	<1	4	5	11	-[11]	55	94	EXCEEDS
PHENOLS									
2,4-Dimethyphenol	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.001	EXCEEDS
m-cresol	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.001	<0.0001	<0.0001	EXCEEDS
INORGANICS									
Aluminum	8.64	1.89	5.93	1.15	0.1	0.88	1.15	1.92	Does not exceed
Ammonia	0.08	0.11	25	0.22	0.05	19.9	6.01	3.98	EXCEEDS
Arsenic	0.007	0.0015	0.17	0.004	0.0007	0.0036	0.003	0.0058	EXCEEDS
Cadmium	0.003	0.005	0.01	0.003	<0.003	<0.001	0.004	0.007	EXCEEDS
Calcium	74	60	69	55	99.3	43.2	57.1	118	EXCEEDS
Chloride	14.8	56.9	354	18	190	33.4	17.3	510	EXCEEDS
Cobalt	0.01	0.005	0.01	0.004	0.005	0.018	0.005	0.007	EXCEEDS
Iron	17.9	4.81	2.56	2.28	0.45	22.5	2.21	1.01	EXCEEDS
Lithium	0.02	0.02	0.022	0.01	0.035	0.229	0.144	0.272	EXCEEDS

TABLE 5.1-4

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES

Page 2 of 2

Chemical	Athabasca River[1] Water (mg/L)	Reference[2] Tributaries Water (mg/L)	Suncor[3] Wastewater (mg/L)	Cooling Pond E[4] Wastewater (mg/L)	Mine Drainage[5] Water (mg/L)	Plant 4[6] Tailings Sand Water (mg/L)	Tar Island[7] Dyke Water (mg/L)	Consolidated[8] Tailings Water (mg/L)	Comments
Manganese	0.509	0.21	0.121	0.153	0.111	1.76	0.213	0.058	EXCEEDS
Molybdenum	0.01	0.004	0.6	0.002	0.018	0.071	0.018	1.42	EXCEEDS
Nickel	0.01	0.012	0.148	0.02	0.012	0.055	0.005	0.0295	EXCEEDS
Phosphorus	0.4	<0.1	0.29	0.171	0.046	0.2	0.43	0.096	EXCEEDS
Potassium	2.65	2.2	9.3	8	5.9	18.9	10.8	29	EXCEEDS
Silicon	2.12	3.76	3.53	5.05	3.89	6.12	10.1	5.58	EXCEEDS
Sodium	24.6	61.3	246	23	131	16600	335	1170	EXCEEDS
Sulphate	58	53.2	116	49	211	118	143	1290	EXCEEDS
Strontium	0.36	0.21	0.29	0.22	0.496	0.771	0.337	2.12	EXCEEDS
Tin	-[11]	-[11]	-[11]	-[11]	-[11]	0.44	-[11]	-[11]	No background data
Vanadium	0.02	0.008	1.61	0.013	0.005	0.05	0.01	0.17	EXCEEDS
Zirconium	-[11]	-[11]	-[11]	-[11]	-[11]	0.0013	-[11]	-[11]	No background data

[1] Athabasca River upstream of Lease 19 sampled by Golder during 1995 (Golder 1996b) and NAQUADAT data (n=26) sampled in 1985-1995 (site: 00AL07CC0600).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996b).

[3] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1to 80). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[4] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[5] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory. Chemex Labs and Syncrude Research Centre.

[6] Groundwater samples (ID: RG088 and RG089) and Plant 4 Beach #2 Tailings water sample (ID: E504203-02).

[7] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127).

[8] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164 and Syncrude CT water.

[9] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[10] These compounds were not detected above detection limits.

[11] Not analyzed.

TABLE 5.1-5

COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES

Chemical	Muskeg River[1] Longnose Sucker (ug/g) Max	Athabasca River[1] Walleye (ug/g) Max	Athabasca River[1] Goldeye (ug/g) Max	10%TID[2] Walleye (ug/g) Max - Lab	Athabasca River[3] Walleye (ug/g) Max - Lab	Athabasca River[3] Rainbow trout (ug/g) Max - Lab	Comments
PAHS AND SUBSTITUTED PAHS							
Naphthalene group[4]	0.09	<0.02[5]	<0.02	<0.02	<0.02	0.05	EXCEEDS
INORGANICS							
Aluminum	11	3	2	12	14	18	Does not exceed
Arsenic	<0.5	<0.5	<0.5	1.1	2.3	<0.1	Does not exceed
Barium	<0.5	<0.5	<0.5	0.9	0.9	<0.5	Does not exceed
Calcium	880	662	627	7660	7090	2260	EXCEEDS
Copper	<1	1	2	<1	<1	<1	EXCEEDS
Iron	16	12	12	<1	8	23	Does not exceed
Magnesium	661	321	377	371	457	380	EXCEEDS
Manganese	0.9	1.2	<0.5	6.1	5.1	0.9	EXCEEDS
Mercury	-[6]	-[6]	-[6]	0.44	0.45	0.04	Does not exceed
Nickel	<1	<1	2	<2	<2	<2	EXCEEDS
Phosphorus	2960	2880	2590	5820	6060	3620	Does not exceed
Potassium	5190	4880	4380	4390	5090	4840	EXCEEDS
Selenium	0.3	<0.5	<0.5	0.4	0.4	0.3	Does not exceed
Silicon	12	4	7	<50	<50	<50	EXCEEDS
Sodium	409	440	360	748	635	471	EXCEEDS
Strontium	0.9	0.6	<0.5	8	8	2	Does not exceed
Zinc	6	9	6	17.5	17.2	8.9	EXCEEDS

[1] Data from fish sampled by Golder during 1995 (Golder 1996b).

[2] Data from fish exposed to Tar Island Dyke Water (10%) in laboratory (HydroQual 1996).

[3] Data from fish exposed in laboratory to Athabasca River water taken upstream of Fort McMurray (HydroQual 1996). These are considered to be background samples.

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[5] These compounds were not detected above detection limits.

[6] No data

TABLE 5.1-6

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO RISK-BASED CONCENTRATIONS (RBCS) FOR PEOPLE FOR OFF-SITE RELEASES

Page 1 of 2

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond[2] Wastewater (mg/L)	Mine Drainage [3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	RBC for[7] Water Ingestion (RBC) (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS								
Acenaphthylene	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	2.2	Does not exceed
Acenaphthene group[8]	<0.00002	<0.00002	<0.00004[9]	0.00012	0.00028	0.00019	2.2	Does not exceed
Benzo(a)anthracene group[8]	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	0.000092	EXCEEDS
Benzo(ghi)perylene	<0.00004	<0.00002	<0.00002	0.00003	<0.00002	<0.00002	1.1	Does not exceed
Benzo(a)pyrene group[8]	0.00014	<0.00004	<0.00004	0.00011	<0.00002	0.00048	0.0000092	EXCEEDS
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	1.8	Does not exceed
Dibenzothiophene group[8]	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	1.1	Does not exceed
Fluoranthene group[8]	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	1.5	Does not exceed
Fluorene group[8]	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	1.5	Does not exceed
Naphthalene group[8]	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	1.5	Does not exceed
Phenanthrene group[8]	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	1.1	Does not exceed
Pyrene	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	1.1	Does not exceed
SUBSTITUTED PANH COMPOUNDS								
Acridine group[6]	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	11	Does not exceed
Quinoline Group[6]	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	0.037	Does not exceed
NAPHTHENIC ACIDS								
Naphthenic acids	4	5	11	–[10]	55	94	–[10]	No RBC
PHENOLS								
2,4-Dimethylphenol	0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.001	0.73	Does not exceed
m-cresol	<0.0001	<0.0001	0.0002	<0.001	<0.0001	<0.0001	1.8	Does not exceed
INORGANICS								
Ammonia	25	0.22	0.05	19.9	6.01	3.98	1	EXCEEDS
Arsenic	0.17	0.004	0.0007	0.0036	0.003	0.0058	0.000038	EXCEEDS
Cadmium	0.01	0.003	<0.003	<0.001	0.004	0.007	0.018	Does not exceed
Calcium	69	55	99.3	43.2	57.1	118	–[10]	No RBC
Chloride	354	18	190	33.4	17.3	510	3.7	EXCEEDS
Cobalt	0.01	0.004	0.005	0.018	0.005	0.007	2.2	Does not exceed
Iron	2.56	2.28	0.45	22.5	2.21	1.01	–[10]	No RBC
Lithium	0.022	0.01	0.035	0.229	0.144	0.272	0.73	Does not exceed

TABLE 5.1-6

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO RISK-BASED CONCENTRATIONS (RBCS) FOR PEOPLE FOR OFF-SITE RELEASES

Page 2 of 2

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	RBC for[7] Water Ingestion (RBC) (mg/L)	Comments
Manganese	0.121	0.153	0.111	1.76	0.213	0.058	0.18	EXCEEDS
Molybdenum	0.6	0.002	0.018	0.071	0.018	1.42	0.18	EXCEEDS
Nickel	0.148	0.02	0.012	0.055	0.005	0.0295	0.73	Does not exceed
Phosphorus	0.29	0.171	0.046	0.2	0.43	0.096	-[10]	No RBC
Potassium	9.3	8	5.9	18.9	10.8	29	-[10]	No RBC
Silicon	3.53	5.05	3.89	6.12	10.1	5.58	-[10]	No RBC
Sodium	246	23	131	16600	335	1170	-[10]	No RBC
Strontium	0.29	0.22	0.496	0.771	0.337	2.12	22	Does not exceed
Sulphate	116	49	211	118	143	1290	-[10]	No RBC
Tin	-[10]	-[10]	-[10]	0.44	-[10]	-[10]	22	Does not exceed
Vanadium	1.61	0.013	0.005	0.05	0.01	0.17	0.26	EXCEEDS
Zirconium	-[10]	-[10]	-[10]	0.0013	-[10]	-[10]	-[10]	No RBC

[1] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1 to 80). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[2] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[3] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory. Chemex Labs and Syncrude Research Centre.

[4] Groundwater samples (ID: RG088 and RG089) and Plant 4 tailings water sample (ID: Beach #2 E504203-02).

[5] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127)

[6] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164 and Syncrude CT water.

[7] Risk-Based Concentrations were based on EPA Region III Risk-Based Concentrations (Smith 1995).

[8] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[9] These compounds were not detected above detection limits.

[10] No data.

TABLE 5.1-7

COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO RISK-BASED CONCENTRATIONS

Chemical	Muskeg River[1] Longnose Sucker (ug/g) Max	Athabasca River[1] Walleye (ug/g) Max	Athabasca River[1] Goldeye (ug/g) Max	10%TID[2] Walleye (ug/g) Max - Lab	RBC for[3] Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS						
Naphthalene group[4]	0.09	<0.02[5]	<0.02	<0.02	54	Does not exceed
INORGANICS						
Calcium	880	662	627	7660	-[6]	No RBC
Copper	<1	1	2	<1	50	Does not exceed
Magnesium	661	321	377	371	-6	No RBC
Manganese	0.9	1.2	<0.5	6.1	6.8	Does not exceed
Nickel	<1	<1	2	<2	27	Does not exceed
Potassium	5190	4880	4380	4390	-[6]	No RBC
Silicon	12	4	7	<50	-[6]	No RBC
Sodium	409	440	360	748	-[6]	No RBC
Zinc	6	9	6	17.5	410	Does not exceed

[1] Data from fish sampled by Golder during 1995 (Golder 1996b).

[2] Data from fish exposed to Tar Island Dyke Water (10%) in laboratory (HydroQual 1996).

[3] Risk-Based Concentrations were based on EPA Region III Risk-Based Concentrations (Smith 1995).

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[5] These compounds were not detected above detection limits.

[6] No data

TABLE 5.1-8

SCREENING LEVEL CRITERIA FOR CHEMICALS IN WATER FOR WILDLIFE

Page 1 of 3

Chemicals	CCREM[1] (mg/L) (livestock)	BC MOE[2] (mg/L) (livestock/ wildlife)	Screening[3] Level Criteria (mg/L)
PAHS AND SUBSTITUTED PAHS			
Acenaphthylene	-[4]	-[4]	-[4]
Acenaphthene group[5]	-[4]	-[4]	-[4]
Benzo(a)anthracene group[5]	-[4]	-[4]	-[4]
Benzo(ghi)perylene	-[4]	-[4]	-[4]
Benzo(a)pyrene group[5]	-[4]	-[4]	-[4]
Biphenyl	-[4]	-[4]	-[4]
Dibenzothiophene group[5]	-[4]	-[4]	-[4]
Fluoranthene group[5]	-[4]	-[4]	-[4]
Fluorene group[5]	-[4]	-[4]	-[4]
Naphthalene group[5]	-[4]	-[4]	-[4]
Phenanthrene group[5]	-[4]	-[4]	-[4]
Pyrene	-[4]	-[4]	-[4]
SUBSTITUTED PANH COMPOUNDS			
Acridine group[5]	-[4]	-[4]	-[4]
Quinoline group[5]	-[4]	-[4]	-[4]
NAPHTHENIC ACIDS			
Naphthenic acids	-[4]	-[4]	-[4]
VOLATILES			
Carbon tetrachloride	-[4]	0.005	0.005
Chloroform	-[4]	-[4]	-[4]
Ethylbenzene	-[4]	-[4]	-[4]
Methylene chloride	-[4]	0.05	0.05
Toluene	-[4]	-[4]	-[4]
m-+p-xylenes	-[4]	-[4]	-[4]
o-xylene	-[4]	-[4]	-[4]

TABLE 5.1-8

SCREENING LEVEL CRITERIA FOR CHEMICALS IN WATER FOR WILDLIFE

Page 2 of 3

Chemicals	CCREM[1] (mg/L) (livestock)	BC MOE[2] (mg/L) (livestock/ wildlife)	Screening[3] Level Criteria (mg/L)
PHENOLS			
Phenol	-[4]	-[4]	-[4]
2,4-Dimethylphenol	-[4]	-[4]	-[4]
m-cresol	-[4]	-[4]	-[4]
o-cresol	-[4]	-[4]	-[4]
INORGANICS			
Aluminum	5	5	5
Ammonia	-[4]	-[4]	-[4]
Antimony	-[4]	-[4]	-[4]
Arsenic	0.5	0.5	0.5
Barium	-[4]	-[4]	-[4]
Beryllium	0.1	0.1	0.1
Boron	5	5	5
Cadmium	0.02	0.02	0.02
Calcium	1000	1000	1000
Chloride	-[4]	-[4]	-[4]
Chromium	1	1	1
Cobalt	1	1	1
Copper	0.5	0.3	0.3
Cyanide	-[4]	-[4]	-[4]
Iron	-[4]	-[4]	-[4]
Lithium	-[4]	5	5
Magnesium	-[4]	-[4]	-[4]
Manganese	-[4]	-[4]	-[4]
Mercury	0.003	0.003	0.003
Molybdenum	0.5	0.05	0.05

TABLE 5.1-8

SCREENING LEVEL CRITERIA FOR CHEMICALS IN WATER FOR WILDLIFE

Page 3 of 3

Chemicals	CCREM[1] (mg/L) (livestock)	BC MOE[2] (mg/L) (livestock/ wildlife)	Screening[3] Level Criteria (mg/L)
Nickel	1	1	1
Phosphorus	-[4]	-[4]	-[4]
Potassium	-[4]	-[4]	-[4]
Selenium	0.05	0.05	0.05
Silicon	-[4]	-[4]	-[4]
Silver	-[4]	-[4]	-[4]
Sodium	-[4]	-[4]	-[4]
Strontium	-[4]	-[4]	-[4]
Sulphate	1000	1000	1000
Tin	-[4]	-[4]	-[4]
Titanium	-[4]	-[4]	-[4]
Vanadium	0.1	0.1	0.1
Uranium	0.2	0.2	0.2
Zinc	50	50	50
Zirconium	-[4]	-[4]	-[4]

[1] Canadian Council of Resource and Environment Ministers Water Quality Guidelines for Livestock Drinking Water Quality (CCREM 1987).

[2] BC Water Quality Criteria are safe levels of contaminants for the protection of livestock and/or wildlife (BCE 1994).

[3] Screening Level Criteria are the lowest of the listed criteria values.

[4] No criterion

[5] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

TABLE 5.1-9

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR WILDLIFE

Page 1 of 3

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS				
Acenaphthylene	<0.00002[4]	<0.00002	-[5]	No criterion
Acenaphthene group[6]	<0.00004	<0.00004	-[5]	No criterion
Benzo(a)anthracene group[6]	<0.00004	<0.00004	-[5]	No criterion
Benzo(ghi)perylene	<0.00002	<0.00002	-[5]	No criterion
Benzo(a)pyrene group[6]	<0.00004	<0.00004	-[5]	No criterion
Biphenyl	<0.00004	<0.00004	-[5]	No criterion
Dibenzothiophene group[6]	<0.00004	<0.00004	-[5]	No criterion
Fluorene group[6]	<0.00004	<0.00004	-[5]	No criterion
Fluoranthene group[6]	<0.00004	<0.00004	-[5]	No criterion
Naphthalene group[6]	<0.00002	0.00002	-[5]	No criterion
Phenanthrene group[6]	<0.00004	<0.00004	-[5]	No criterion
Pyrene	<0.00002	<0.00002	-[5]	No criterion
SUBSTITUTED PANH COMPOUNDS				
Acridine group[6]	<0.00002	<0.00002	-[5]	No criterion
Quinoline group[6]	<0.00002	<0.00002	-[5]	No criterion
NAPHTHENIC ACIDS				
Naphthenic acids	<1	<1	-[5]	No criterion
VOLATILES				
Carbon tetrachloride	<0.001	<0.001	0.005	Does not exceed.
Chloroform	<0.001	<0.001	-[5]	No criterion
Ethylbenzene	<0.001	<0.001	-[5]	No criterion
Methylene chloride	<0.001	<0.001	0.05	Does not exceed.
Toluene	<0.001	<0.001	-[5]	No criterion
m-+p-xylenes	<0.001	<0.001	-[5]	No criterion
o-xylene	<0.001	<0.001	-[5]	No criterion

TABLE 5.1-9

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR WILDLIFE

Page 2 of 3

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
PHENOLS				
2,4-Dimethylphenol	<0.0001	<0.0001	–[5]	No criterion
m-cresol	<0.0001	<0.0001	–[5]	No criterion
INORGANICS				
Aluminum	8.64	1.89	5	EXCEEDS
Ammonia	0.08	0.11	–[5]	No criterion.
Antimony	0.0002	0.0003	–[5]	No criterion.
Arsenic	0.007	0.0015	0.5	Does not exceed.
Barium	0.2	0.07	–[5]	No criterion
Beryllium	0.004	0.004	0.1	Does not exceed.
Boron	0.09	0.14	5	Does not exceed.
Cadmium	0.003	0.005	0.02	Does not exceed.
Calcium	74	60	1000	Does not exceed.
Chloride	14.8	56.9	–[5]	No criterion
Chromium	0.032	0.014	1	Does not exceed.
Cobalt	0.01	0.005	1	Does not exceed.
Copper	0.01	0.002	0.3	Does not exceed.
Cyanide	0.005	0.025	–[5]	No criterion.
Iron	17.9	4.81	–[5]	No criterion.
Lithium	0.02	0.02	5	Does not exceed.
Magnesium	21	18.4	–[5]	No criterion
Manganese	0.509	0.21	–[5]	No criterion
Mercury	0.0002	<0.00005	0.003	Does not exceed.
Molybdenum	0.01	0.004	0.05	Does not exceed.
Nickel	0.01	0.012	1	Does not exceed.
Phosphorus	0.4	<0.1	–[5]	No criterion

TABLE 5.1-9

COMPARISON OF CHEMICAL CONCENTRATIONS IN REFERENCE BACKGROUND SAMPLES TO SCREENING LEVEL CRITERIA FOR WATER FOR WILDLIFE

Page 3 of 3

Chemical	Athabasca River Water[1] (mg/L)	Reference Tributaries[2] (mg/L)	Screening Level[3] Criteria (mg/L)	Comments
Potassium	2.65	2.2	-[5]	No criterion
Selenium	0.0004	0.0003	0.05	Does not exceed.
Silicon	2.12	3.76	-[5]	No criterion
Silver	0.0003	0.003	-[5]	No criterion.
Sodium	24.6	61.3	-[5]	No criterion.
Strontium	0.36	0.21	-[5]	No criterion.
Sulphate	58	53.2	1000	Does not exceed.
Tin	-[5]	-[5]	-[5]	No data
Titanium	0.085	0.046	-[5]	No criterion.
Uranium	<0.5	<0.5	0.2	Does not exceed.
Vanadium	0.02	0.008	0.1	Does not exceed.
Zinc	0.085	0.162	50	Does not exceed.
Zirconium	-[5]	-[5]	-[5]	No data

[1] Athabasca River upstream of Lease 19 sampled by Golder during 1995 (Suncor EIA data, Golder 1996b) and NAQUADAT data (n=26) sampled in 1985-1995 (site: 00AL07CC0600).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996b).

[3] Screening Level Criteria were based on water quality criteria for livestock and wildlife drinking water. Please see table 5.1-8 for derivation of values.

[4] These compounds were not detected above detection limits.

[5] No data or criterion.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

TABLE 5.1-10

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR WILDLIFE FOR OFF-SITE RELEASES

Page 1 of 3

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS								
Acenaphthylene	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	-[10]	No criterion.
Acenaphthene group[8]	<0.00002	<0.00002	<0.00004[9]	0.00012	0.00028	0.00019	-[10]	No criterion.
Benzo(a)anthracene group[8]	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	-[10]	No criterion.
Benzo(ghi)perylene	<0.00004	<0.00002	<0.00002	0.00003	<0.00004	<0.00002	-[10]	No criterion.
Benzo(a)pyrene group[8]	0.00014	<0.00004	<0.00004	0.00011	<0.00002	0.00048	-[10]	No criterion.
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	-[10]	No criterion.
Dibenzothiophene group[8]	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	-[10]	No criterion.
Fluoranthene group[8]	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	-[10]	No criterion.
Fluorene group[8]	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	-[10]	No criterion.
Naphthalene group[8]	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	-[10]	No criterion.
Phenanthrene group[8]	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	-[10]	No criterion.
Pyrene	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	-[10]	No criterion.
SUBSTITUTED PANH COMPOUNDS								
Acridine group[8]	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	-[10]	No criterion.
Quinoline Group[8]	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	-[10]	No criterion.
NAPHTHENIC ACIDS								
Naphthenic acids	4	5	11	-[10]	55	94	-[10]	No criterion.
VOLATILES								
Carbon tetrachloride	0.003	<0.001	<0.001	<0.001	<0.001	<0.015	0.005	Does not exceed
Chloroform	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	-[10]	No criterion.
Ethylbenzene	0.0012	0.0015	0.0012	<0.001	0.0015	<0.015	-[10]	No criterion.
Methylene chloride	0.0057	<0.001	0.004	<0.001	<0.001	<0.001	0.05	Does not exceed
Toluene	0.001	<0.001	<0.001	<0.001	<0.001	<0.015	-[10]	No criterion.
m-+p-xylenes	0.0045	0.0057	0.0041	<0.001	0.005	<0.015	-[10]	No criterion.
o-xylene	0.0022	0.0028	0.0017	<0.001	0.0027	0.015	-[10]	No criterion.
PHENOLS								
2,4-Dimethylphenol	0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.001	-[10]	No criterion.
m-cresol	<0.0001	<0.0001	0.0002	<0.001	<0.0001	<0.0001	-[10]	No criterion.
INORGANICS								
Aluminum	5.93	1.15	0.1	0.88	1.15	1.92	5	EXCEEDS
Ammonia	25	0.22	0.05	19.9	6.01	3.98	-[10]	No criterion.
Antimony	-[10]	-[10]	-[10]	0.0006	-[10]	-[10]	-[10]	No criterion.

TABLE 5.1-10

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR WILDLIFE FOR OFF-SITE RELEASES

Page 2 of 3

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments
Arsenic	0.17	0.004	0.0007	0.0036	0.003	0.0058	0.5	Does not exceed
Barium	0.101	0.102	0.12	0.772	0.1	0.18	-[10]	No criterion.
Beryllium	0.002	0.002	0.003	<0.001	0.002	0.004	0.1	Does not exceed
Boron	0.15	0.07	0.375	2.31	1.88	4.26	5	Does not exceed
Cadmium	0.01	0.003	<0.003	<0.001	0.004	0.007	0.02	Does not exceed
Calcium	69	55	99.3	43.2	57.1	118	1000	Does not exceed
Chloride	354	18	190	33.4	17.3	510	-[10]	No criterion.
Chromium	0.029	0.008	0.004	0.028	0.002	0.003	1	Does not exceed
Cobalt	0.01	0.004	0.005	0.018	0.005	0.007	1	Does not exceed
Copper	0.064	0.029	0.009	<0.001	0.008	0.004	0.3	Does not exceed
Cyanide	0.003	0.001	0.002	-[10]	0.002	0.055	-[10]	No criterion.
Iron	2.56	2.28	0.45	22.5	2.21	1.01	-[10]	No criterion.
Lithium	0.022	0.01	0.035	0.229	0.144	0.272	5	Does not exceed
Magnesium	18.7	16	34.4	18.1	11.3	28	-[10]	No criterion.
Manganese	0.121	0.153	0.111	1.76	0.213	0.058	-[10]	No criterion.
Mercury	0.00062	0.00052	0.00052	0.0004	0.00026	<0.00005	0.003	Does not exceed
Molybdenum	0.6	0.002	0.018	0.071	0.018	1.42	0.05	EXCEEDS
Nickel	0.148	0.02	0.012	0.055	0.005	0.0295	1	Does not exceed
Phosphorus	0.29	0.171	0.046	0.2	0.43	0.098	-[10]	No criterion.
Potassium	9.3	8	5.9	18.9	10.8	29	-[10]	No criterion.
Selenium	0.0059	0.0005	0.0002	<0.00004	0.0002	0.0036	0.05	Does not exceed
Silicon	3.53	5.05	3.89	6.12	10.1	5.58	-[10]	No criterion.
Silver	0.005	<0.002	0.002	<0.001	<0.002	0.002	-[10]	No criterion.
Sodium	246	23	131	16600	335	1170	-[10]	No criterion.
Strontium	0.29	0.22	0.496	0.771	0.337	2.12	-[10]	No criterion.
Sulphate	116	49	211	118	143	1290	1000	EXCEEDS
Tin	-[10]	-[10]	-[10]	0.44	-[10]	-[10]	-[10]	No criterion.
Titanium	0.047	0.009	0.003	0.013	0.02	0.02	-[10]	No criterion.
Uranium	<0.5	<0.5	<0.5	<0.1	<0.5	0.007	0.2	Does not exceed
Vanadium	1.61	0.013	0.005	0.05	0.01	0.17	0.1	EXCEEDS
Zinc	0.273	0.047	0.06	0.068	0.058	0.056	50	Does not exceed
Zirconium	-[10]	-[10]	-[10]	0.0013	-[10]	-[10]	-[10]	No criterion.

TABLE 5.1-10

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO SCREENING LEVEL CRITERIA FOR WILDLIFE FOR OFF-SITE RELEASES

Page 3 of 3

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	Screening[7] Level Criteria (mg/L)	Comments

[1] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1 to 80).
Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[2] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18).
Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[3] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory. Chemex Labs and Syncrude Research Centre.

[4] Groundwater samples (ID: RG088 and RG089) and Plant 4 tailings water sample (ID: Beach #2 E504203-02).

[5] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127)

[6] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164 and Syncrude CT water.

[7] The Screening Level Criteria were based on water quality criteria for human drinking water. Please see table 5.1-8 for derivation of values.

[8] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[9] These compounds were not detected above detection limits.

[10] No data or criterion.

TABLE 5.1-11

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES FOR WILDLIFE

Page 1 of 2

Chemical	Athabasca River[1] Water (mg/L)	Reference[2] Tributaries Water (mg/L)	Suncor[3] Wastewater (mg/L)	Cooling Pond E[4] Wastewater (mg/L)	Mine Drainage[5] Water (mg/L)	Plant 4[6] Tailings Sand Water (mg/L)	Tar Island[7] Dyke Water (mg/L)	Consolidated[8] Tailings Water (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS									
Acenaphthylene	<0.00002[10]	<0.00002	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	EXCEEDS
Acenaphthene group[9]	<0.00004	<0.00004	<0.00002	<0.00002	<0.000049	0.00012	0.00028	0.00019	EXCEEDS
Benzo(a)anthracene group[9]	<0.00004	<0.00004	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	EXCEEDS
Benzo(ghi)perylene	<0.00002	<0.00002	<0.00004	<0.00002	<0.00002	0.00003	<0.00002	<0.00002	EXCEEDS
Benzo(a)pyrene group[9]	<0.00004	<0.00004	0.00014	<0.00004	<0.00004	0.00011	<0.00004	0.00048	EXCEEDS
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	EXCEEDS
Dibenzothiophene group[9]	<0.00004	<0.00004	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	EXCEEDS
Fluoranthene group[9]	<0.00004	<0.00004	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	EXCEEDS
Fluorene group[9]	<0.00004	<0.00004	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	EXCEEDS
Naphthalene group[9]	<0.00002	0.00002	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	EXCEEDS
Phenanthrene group[9]	<0.00004	<0.00004	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	EXCEEDS
Pyrene	<0.00002	<0.00002	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	EXCEEDS
SUBSTITUTED PANH COMPOUNDS									
Acridine group[7]	<0.00002	<0.00002	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	EXCEEDS
Quinoline group[7]	<0.00002	<0.00002	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	EXCEEDS
NAPHTHENIC ACIDS									
Naphthenic acids	<1	<1	4	5	11	-[11]	55	94	EXCEEDS
VOLATILES									
Chloroform	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	EXCEEDS
Ethylbenzene	<0.001	<0.001	0.0012	0.0015	0.0012	<0.001	0.0015	<0.015	EXCEEDS
Toluene	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.015	EXCEEDS
m-+p-xylenes	<0.001	<0.001	0.0045	0.0057	0.0041	<0.001	0.005	<0.015	EXCEEDS
o-xylene	<0.001	<0.001	0.0022	0.0028	0.0017	<0.001	0.0027	0.015	EXCEEDS
PHENOLS									
2,4-Dimethylphenol	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.001	0.001	EXCEEDS
m-cresol	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	EXCEEDS
INORGANICS									
Aluminum	8.64	1.89	5.93	1.15	0.1	0.88	1.15	1.92	Does not exceed
Ammonia	0.08	0.11	25	0.22	0.05	19.9	6.01	3.98	EXCEEDS
Antimony	0.0002	0.0003	-[11]	-[11]	-[11]	0.0006	-[11]	-[11]	EXCEEDS
Barium	0.2	0.07	0.101	0.102	0.12	0.772	0.1	0.18	EXCEEDS
Chloride	14.8	56.9	354	18	190	33.4	17.3	510	EXCEEDS
Cyanide	0.005	0.025	0.003	0.001	0.002	-[11]	0.002	0.055	EXCEEDS

TABLE 5.1-11

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO BACKGROUND CONCENTRATIONS AT REFERENCE SITES FOR WILDLIFE

Page 2 of 2

Chemical	Athabasca River[1] Water (mg/L)	Reference[2] Tributaries Water (mg/L)	Suncor[3] Wastewater (mg/L)	Cooling Pond E[4] Wastewater (mg/L)	Mine Drainage[5] Water (mg/L)	Plant 4[6] Tailings Sand Water (mg/L)	Tar Island[7] Dyke Water (mg/L)	Consolidated[8] Tailings Water (mg/L)	Comments
Iron	17.9	4.81	2.56	2.28	0.45	22.5	2.21	1.01	EXCEEDS
Magnesium	21	18.4	18.7	16	34.4	18.1	11.3	28	EXCEEDS
Manganese	0.509	0.21	0.121	0.153	0.111	1.76	0.213	0.058	EXCEEDS
Molybdenum	0.01	0.004	0.6	0.002	0.018	0.071	0.018	1.42	EXCEEDS
Phosphorus	0.4	<0.1	0.29	0.171	0.046	0.2	0.43	0.096	EXCEEDS
Potassium	2.65	2.2	9.3	8	5.9	18.9	10.8	29	EXCEEDS
Silicon	2.12	3.76	3.53	5.05	3.89	6.12	10.1	5.58	EXCEEDS
Silver	0.0003	0.003	0.005	<0.002	0.002	<0.001	<0.002	0.002	EXCEEDS
Sodium	24.6	61.3	246	23	131	16600	335	1170	EXCEEDS
Strontium	0.36	0.21	0.29	0.22	0.496	0.771	0.337	2.12	EXCEEDS
Sulphate	58	53.2	116	49	211	118	143	1290	EXCEEDS
Tin	-[11]	-[11]	-[11]	-[11]	-[11]	0.44	-[11]	-[11]	No background data
Titanium	0.085	0.046	0.047	0.009	0.003	0.013	0.02	0.02	Does not exceed
Vanadium	0.02	0.008	1.61	0.013	0.005	0.05	0.01	0.17	EXCEEDS
Zirconium	-[11]	-[11]	-[11]	-[11]	-[11]	0.0013	-[11]	-[11]	No background data

[1] Athabasca River upstream of Lease 19 sampled by Golder during 1995 (Golder 1996b) and NAQUADAT data (n=26) sampled in 1985-1995 (site: 00AL07CC0600).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996b).

[3] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1 to 80). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[4] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[5] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[6] Groundwater samples (ID: RG088 and RG089) and Plant 4 tailings water sample (ID: Beach #2 E504203-02).

[7] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127)

[8] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164 and Syncrude CT water.

[9] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[10] These compounds were not detected above detection limits.

[11] Not analyzed.

TABLE 5.1-12

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO RISK-BASED CONCENTRATIONS FOR WILDLIFE FOR OFF-SITE RELEASES

Page 1 of 2

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	RBC for[7] Water Shrew (mg/L)	RBC for[7] River Otter (mg/L)	RBC for[7] Killdeer (mg/L)	RBC for[7] Great Blue Heron (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS											
Acenaphthylene	<0.00002	<0.00002	<0.00002	<0.00005	<0.00002	0.00016	15130	34	221	172	Does not exceed
Acenaphthene group[8]	<0.00002	<0.00002	<0.00004[9]	0.00012	0.00028	0.00019	15130	34	221	172	Does not exceed
Benzo(a)anthracene group	0.00124	<0.00004	<0.00004	0.00026	<0.00004	0.0016	8646	19	0.80	0.62	Does not exceed
Benzo(ghi)perylene	<0.00004	<0.00002	<0.00002	0.00003	<0.00002	<0.00002	86458	195	8.0	6.2	Does not exceed
Benzo(a)pyrene group[8]	0.00014	<0.00004	<0.00004	0.00011	<0.00004	0.00048	865	1.9	0.081	0.063	Does not exceed
Biphenyl	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	0.00008	43229	97	-[10]	-[10]	Does not exceed
Dibenzothiophene group[8]	0.00061	<0.00004	<0.00004	0.0009	0.00005	0.01142	6484	15	221	172	Does not exceed
Fluoranthene group[8]	0.00031	<0.00004	<0.00004	0.00015	0.00008	0.00065	6484	15	221	172	Does not exceed
Fluorene group[8]	0.00016	<0.00004	<0.00004	0.00074	0.00054	0.00143	10807	24	221	172	Does not exceed
Naphthalene group[8]	0.00057	<0.00004	<0.00004	0.00258	0.00104	0.00268	11499	26	-[10]	-[10]	Does not exceed
Phenanthrene group[8]	0.0012	<0.00004	<0.00004	0.00118	0.00031	0.01068	3458	7.8	221	172	Does not exceed
Pyrene	0.00016	<0.00002	<0.00002	0.00009	<0.00002	0.00004	6484	15	221	172	Does not exceed
SUBSTITUTED PANH COMPOUNDS											
Acridine group[8]	0.00073	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	86458	195	163	127	Does not exceed
Quinoline Group[8]	0.00157	<0.00002	<0.00002	<0.00002	0.00009	<0.00002	1961	4.4	-[10]	-[10]	Does not exceed
NAPHTHENIC ACIDS											
Naphthenic acids	4	5	11	-[10]	55	94	-[10]	-[10]	-[10]	-[10]	No RBC
VOLATILES											
Chloroform	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	29413	66	-[10]	-[10]	Does not exceed
Ethylbenzene	0.0012	0.0015	0.0012	<0.001	0.0015	<0.015	19040	43	-[10]	-[10]	Does not exceed
Toluene	0.001	<0.001	<0.001	<0.001	<0.001	<0.015	22462	51	-[10]	-[10]	Does not exceed
m-+p-xylenes	0.0057	<0.001	0.0041	<0.001	0.005	<0.015	1781	4.0	-[10]	-[10]	Does not exceed
o-xylene	0.0045	0.0057	0.0017	<0.001	0.0027	<0.015	1781	4.0	-[10]	-[10]	Does not exceed
PHENOLS											
2,4-Dimethylphenol	0.0001	<0.0001	0.0001	<0.0001	<0.001	0.001	4323	9.7	-[10]	-[10]	Does not exceed
m-cresol	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	601571	1356	-[10]	-[10]	Does not exceed
INORGANICS											
Ammonia	25	0.22	0.05	19.9	6.01	3.98	-[10]	-[10]	-[10]	-[10]	No RBC
Antimony	-[10]	-[10]	-[10]	0.0006	-[10]	-[10]	108	0.24	-[10]	-[10]	Does not exceed
Barium	0.101	0.102	0.12	0.772	0.1	0.18	10668	24	102	79	Does not exceed
Chloride	354	18	190	33.4	17.3	510	-[10]	-[10]	-[10]	-[10]	No RBC
Iron	2.56	2.28	0.45	22.5	0.1	1.01	-[10]	-[10]	-[10]	-[10]	No RBC

TABLE 5.1-12

COMPARISON OF CHEMICAL CONCENTRATIONS IN WASTEWATER TO RISK-BASED CONCENTRATIONS FOR WILDLIFE FOR OFF-SITE RELEASES

Page 2 of 2

Chemical	Suncor[1] Wastewater (mg/L)	Cooling Pond E[2] Wastewater (mg/L)	Mine Drainage[3] Water (mg/L)	Plant 4[4] Tailings Sand Water (mg/L)	Tar Island[5] Dyke Water (mg/L)	Consolidated[6] Tailings Water (mg/L)	RBC for[7] Water Shrew (mg/L)	RBC for[7] River Otter (mg/L)	RBC for[7] Killdeer (mg/L)	RBC for[7] Great Blue Heron (mg/L)	Comments
Magnesium	18.7	16	34.4	18.1	11.3	28	-[10]	-[10]	-[10]	-[10]	No RBC
Manganese	0.121	0.153	0.111	1.76	0.213	0.058	172559	389	1584	1230	Does not exceed
Molybdenum	0.6	0.002	0.018	0.071	0.018	1.42	4596	10	79	61	Does not exceed
Phosphorus	0.29	0.171	0.046	0.2	0.43	0.096	-[10]	-[10]	-[10]	-[10]	No RBC
Potassium	9.3	8	5.9	18.9	10.8	29	-[10]	-[10]	-[10]	-[10]	No RBC
Silicon	3.53	5.05	3.89	6.12	10.1	5.58	-[10]	-[10]	-[10]	-[10]	No RBC
Silver	0.005	<0.002	0.002	<0.001	<0.002	0.002	156	0.35	46	36	Does not exceed
Sodium	246	23	131	16600	335	1170	-[10]	-[10]	-[10]	-[10]	No RBC
Strontium	0.29	0.22	0.496	0.771	0.337	2.12	515715	1163	-[10]	-[10]	Does not exceed
Sulphate	116	49	211	118	143	1290	-[10]	-[10]	-[10]	-[10]	No RBC
Tin	-[10]	-[10]	-[10]	0.44	-[10]	-[10]	1177	2.7	-[10]	-[10]	Does not exceed
Vanadium	1.61	0.013	0.005	0.05	0.01	0.17	373	0.84	118	91	EXCEEDS
Zirconium	-[10]	-[10]	-[10]	0.0013	-[10]	-[10]	1503	3.4	-[10]	-[10]	Does not exceed

[1] Samples collected from Suncor's wastewater systems (ID: RW254); Suncor's Monthly Water Report and NAQUADAT codes (20AL07DA1000/ 1001, 1980-1995, N= 1 to 80). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[2] Samples collected from Suncor's wastewater systems (ID: RW256); Suncor's Monthly Water Report; NAQUADAT code (20AL07DA1013, 1980-1995, N= 1 to 18). Analytical results obtained from Enviro-Test Laboratory, Chemex Labs and Syncrude Research Centre.

[3] Mine drainage water data from samples (ID: RW250 and RW252). Analytical results obtained from Enviro-Test Laboratory. Chemex Labs and Syncrude Research Centre.

[4] Groundwater samples (ID: RG088 and RG089) and Plant 4 tailings water sample (ID: Beach #2 E504203-02).

[5] Tar Island Dyke Seepage Water taken from TID collection system; composite sample from tanks (RW-127)

[6] Consolidated Tailings Release Waters samples RW-162, RW-163 and RW164 and Syncrude CT water.

[7] Risk-Based Concentrations were based on EPA Region III Risk-Based Concentrations (Smith 1995).

[8] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[9] These compounds were not detected above detection limits.

[10] No data.

TABLE 5.1-13

COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Muskeg River[1] Longnose Sucker (ug/g) Max	Athabasca River[1] Walleye (ug/g) Max	Athabasca River[1] Goldeye (ug/g) Max	10%TID[2] Walleye (ug/g) Max - Lab	RBC for[3] River Otter Fish Ingestion (ug/g)	RBC for[3] Great Blue Heron Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS							
Naphthalene group[4]	0.09	<0.02[5]	<0.02	<0.02	26	-[6]	Does not exceed
INORGANICS							
Calcium	880	662	627	7660	-[6]	-[6]	No RBC
Copper	<1	1	2	<1	124	468	Does not exceed
Magnesium	661	321	377	371	-[6]	-[6]	No RBC
Manganese	0.9	1.2	<0.5	6.1	657	2802	Does not exceed
Nickel	<1	<1	2	<2	299	1238	Does not exceed
Potassium	5190	4880	4380	4390	-[6]	-[6]	No RBC
Silicon	12	4	7	<50	-[6]	-[6]	No RBC
Sodium	409	440	360	748	-[6]	-[6]	No RBC
Zinc	6	9	6	17.5	1195	52	Does not exceed

[1] Data from fish sampled by Golder during 1995 (Golder 1996b).

[2] Data from fish exposed to Tar Island Dyke Water (105) in laboratory (HydroQual 1996).

[3] Risk-Based Concentrations as derived in Appendix III.

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix II.

[5] These compounds were not detected above detection limits.

[6] No data

TABLE 5.1-14

ON-SITE AIR QUALITY VERSUS OFF-SITE, RESIDENTIAL

Chemical	Suncor Pond[1] Shut-down and Post Shut-down (µg/m3)	Suncor Pond[1] Post Start-up (µg/m^3)	Suncor[1] API (µg/m^3)	Suncor[1] NTF (µg/m^3)	Risk-Based[2] Concentration (µg/m^3)
Benzene	11.8	1841	14.8	15.2	2.2[3]
Cyclohexane	31.5	852	47.6	7.8	-
Cyclopentane	9.5	363	13.2	5.6	-
Decane	15	-	20.7	6.4	-
Di-isopropyl benzene	1.9	-	-	3.8	-
Diethyl Benzene	2.8	-	2.3	1.1	-
2,5-Dimethyl hexane	18.5	-	22.4	-	-
2,4-Dimethyl pentane	4.8	-	-	1.94	-
Ethylbenzene	11	116	26.2	7	1000
Heptane	72.4	2075	108.9	18.2	-
Hexane	81	3890	107.4	29.9	210
Methyl cyclohexane	43.1	690	60.5	10.2	3100
3-Methyl hexane	31.7	535	48.7	8.7	-
2-Methyl pentane	36.1	1730	54.6	23.3	-
2-Methyl thiophene	9.8	166	12.3	2.2	-
Nonane	19.3	33.5	27.6	4.6	-
Octane	35.7	217	51.2	8.2	-
Styrene	5.5	39.3	6.4	3.6	1000
Thiophene	15.9	170	8	4.7	-

TABLE 5.1-14

ON-SITE AIR QUALITY VERSUS OFF-SITE, RESIDENTIAL

Chemical	Suncor Pond[1] Shut-down and Post Shut-down (μg/m3)	Suncor Pond[1] Post Start-up ($\mu g/m^3$)	Suncor[1] API ($\mu g/m^3$)	Suncor[1] NTF ($\mu g/m^3$)	Risk-Based[2] Concentration ($\mu g/m^3$)
Toluene	37.9	558	53.8	37.2	420
Trimethyl benzene	14.3	18.2	16.4	11.9	1.5
2,2,5-Trimethyl hexane	7.7	-	7.5	-	-
2,2,4-Trimethyl pentane	27.8	-	-	8.1	-
2,3,4-Trimethyl pentane	17.5	-	-	1.6	-
m-Xylene	23.9	47.7	32.1	18	730
o-Xylene	11.5	52.2	13	8.8	730
p-Xylene	10.3	44.6	12.1	7.4	310

[1] Data from BOVAR Environmental (1996).

[2] Risk-Based Concentrations as summarized in Smith (1995).

[3] Risk-Based Concentration corrected to a risk of one in one hundred thousand.

TABLE 5-1.15

PREDICTED DUST AIR CONCENTRATIONS COMPARED TO RISK-BASED CONCENTRATIONS

Chemical	Concentration[1] in Tailings sand (mg/kg)	Predicted Concentration in Air ($\mu g/m^3$)	EPA Risk-Based[2] Concentration (air) ($\mu g/m^3$)
PAHS			
Acenaphthene	0.01	0.0000027	220
Anthracene	0.01	0.0000027	1100
Benzo(a)anthracene	0.15	0.000041	0.01
Benzo(a)pyrene	0.01	0.0000027	0.001
Benzo(b&k)fluoranthene	0.03	0.0000082	0.01
Biphenyl	0.01	0.0000027	180
Dibenzo(a,h)anthracene	0.01	0.0000027	0.001
Fluoranthene	0.01	0.0000027	150
Fluorene	0.01	0.0000027	150
Naphthalene	0.01	0.0000027	150
Pyrene	0.04	0.0000109	110
INORGANICS			
Aluminum	172	0.047	3700
Antimony	0.05	0.000014	1.5
Arsenic	0.63	0.00017	1.1
Barium	4.9	0.0013	0.52
Beryllium	0.1	0.000027	0.0075
Boron	0.1	0.000027	21
Cadmium	0.3	0.000082	0.00099
Chromium	0.5	0.00014	0.00015
Cobalt	2	0.00055	220
Copper	0.5	0.00014	140
Lead	2	0.00055	0.00037
Manganese	56.5	0.015	0.052
Mercury	0.03	0.0000082	0.31
Molybdenum	2	0.00055	18
Nickel	2	0.00055	73
Phosphorus	22	0.0060	0.0073
Selenium	0.02	0.0000055	18
Vanadium	2.8	0.00076	26
Zinc	5.8	0.0016	1100

[1] ETL (1993), sample ID: CP5.

[2] Smith (1995).

TABLE 5.1-16

TOOLS FOR ASSESSING ECOLOGICAL RISKS
(adapted from Pastorok and Linder (1993))

Habitat:	**Aquatic[a]**		**Riparian/Upland[b]**	
Media:	**Water**	**Sediment**	**Sediment/Soil**	**Water/Sediment/Soil**
Receptors:	**Fish**	**Macroinvertebrates**	**Macroinvertebrates**	**Birds**
	Macroinvertebrates		**Plants**	**Mammals**
Field/Laboratory Data:				
Chemical Analysis (media)	●	●	●	●
Soil/Sediment/Water	●	●	●	●
Tissue (receptors)	●	●	●	○
Toxicity Tests	●	●	●	○
Community Analysis	●	●	●	
Models:				
Exposure Models[c]	●			●
Ecological Models[d]	●			●

● Primary Tool
○ Secondary Tool

[a] This report and Golder (1996b).
[b] Subject of a separate study - Golder (1996a).
[c] Includes transport and fate models to estimate exposure concentrations and doses.
[d] Includes models to extrapolate measurement endpoints (e.g., organism - level effects) to assessment endpoints (e.g., population - level effects).

TABLE 5.2-1

CHEMICAL-SPECIFIC EXPOSURE PARAMETERS FOR WATER RELEASE SCENARIOS

Chemical	Water Concentrations[1] (mg/L)					Dermal Permeability Const.[2], Kp (m/hr)
	1995	2001	2009	2020	Long-Term	
Benzo(a)anthracene	0.000012	0.0000034	0.0000081	0.0000085	0.00000062	0.0081
Benzo(a)pyrene	0.0000017	0.0000010	0.0000009	0.0000016	0.00000093	0.012
Naphthenic Acids	0.24	0.20	0.28	0.59	0.36	–[3]
Molybdenum	0.013	0.011	0.013	0.014	0.013	0.00001
Vanadium	0.0053	0.000077	0.0035	0.0031	0.00042	0.00001

[1] Predicted upper 95 percentile concentrations in the Athabasca River, immediately downstream of Suncor's operations.

[2] U.S. EPA (1992b).

[3] Dermal permeability constants are not available for naphthenic acids.

TABLE 5.2-2

HUMAN EXPOSURE PARAMETERS FOR WATER RELEASE SCENARIOS

Age Group	Body Weight[1] (kg)	Body Surface Area[2] (m^2)	Water Ingestion Rate[1] (L/day)	Exposure Time[3] (hours/event)	Exposure Frequency[3] (events/year)	Exposure Duration[3] (years)	Averaging Time Noncarcinogens[3] (years)	Averaging Time Carcinogens[1] (years)
SWIMMING SCENARIO								
Child (7 months to 4 years)	13	0.94	0.05[2]	2.6	7	3.5	3.5	70
Adult (20+ years)	70	1.82	0.05[2]	2.6	7	50	50	70
RECREATIONAL SCENARIO								
Child (7 months to 4 years)	13	-	0.8	-	104	3.5	3.5	70
Adult (20+ years)	70	-	1.5	-	104	50	50	70

[1] Health Canada (1994).
[2] U.S. EPA (1992b).
[3] Assumed for this report.

TABLE 5.2-3

CALCULATED INTAKES FOR THE WATER RELEASE SCENARIOS

Scenario	Chemical	Total Daily Intake Adult	Total Daily Intake Child
1995	**Swimming Scenario: Calculated Intakes (mg/kg-BW/day)**		
	benzo(a)anthracene	0.000000091	0.000000018
	benzo(a)pyrene	0.000000016	0.0000000032
	naphthenic acids	0.000010	0.0000031
	molybdenum	0.00000063	0.0000029
	vanadium	0.00000026	0.0000012
	Recreational Scenario: Calculated Intakes (mg/kg-BW/day)		
	benzo(a)anthracene	0.000000053	0.000000011
	benzo(a)pyrene	0.0000000064	0.0000000013
	naphthenic acids	0.0011	0.00021
	molybdenum	0.000079	0.00023
	vanadium	0.000032	0.000093
2001	**Swimming Scenario: Calculated Intakes (mg/kg-BW/day)**		
	benzo(a)anthracene	0.000000026	0.0000000050
	benzo(a)pyrene	0.000000011	0.0000000022
	naphthenic acids	0.0000086	0.0000026
	molybdenum	0.00000052	0.0000025
	vanadium	0.0000000037	0.000000017
	Recreational Scenario: Calculated Intakes (mg/kg-BW/day)		
	benzo(a)anthracene	0.000000015	0.0000000030
	benzo(a)pyrene	0.0000000044	0.00000000088
	naphthenic acids	0.00089	0.00018
	molybdenum	0.000066	0.00019
	vanadium	0.00000047	0.0000013
2010	**Swimming Scenario: Calculated Intakes (mg/kg-BW/day)**		
	benzo(a)anthracene	0.000000061	0.000000012
	benzo(a)pyrene	0.000000010	0.0000000019
	naphthenic acids	0.000012	0.0000035
	molybdenum	0.00000062	0.0000029
	vanadium	0.00000017	0.00000079
	Recreational Scenario: Calculated Intakes (mg/kg-BW/day)		
	benzo(a)anthracene	0.000000035	0.0000000071
	benzo(a)pyrene	0.0000000038	0.00000000076
	naphthenic acids	0.0012	0.00024
	molybdenum	0.000077	0.00022
	vanadium	0.000021	0.000061

TABLE 5.2-3

CALCULATED INTAKES FOR THE WATER RELEASE SCENARIOS

Scenario	Chemical	Total Daily Intake Adult	Total Daily Intake Child
2020	**Swimming Scenario: Calculated Intakes (mg/kg-BW/day)**		
	benzo(a)anthracene	0.000000064	0.000000012
	benzo(a)pyrene	0.000000018	0.0000000035
	naphthenic acids	0.000025	0.0000076
	molybdenum	0.00000067	0.0000031
	vanadium	0.00000015	0.00000070
	Recreational Scenario: Calculated Intakes (mg/kg-BW/day)		
	benzo(a)anthracene	0.000000037	0.0000000075
	benzo(a)pyrene	0.0000000070	0.0000000014
	naphthenic acids	0.0026	0.00052
	molybdenum	0.000084	0.00024
	vanadium	0.000019	0.000054
Equilibrium	**Swimming Scenario: Calculated Intakes (mg/kg-BW/day)**		
	benzo(a)anthracene	0.0000000047	0.00000000091
	benzo(a)pyrene	0.000000010	0.0000000020
	naphthenic acids	0.000015	0.0000046
	molybdenum	0.00000066	0.0000031
	vanadium	0.000000021	0.00000010
	Recreational Scenario: Calculated Intakes (mg/kg-BW/day)		
	benzo(a)anthracene	0.0000000027	0.00000000054
	benzo(a)pyrene	0.0000000041	0.00000000082
	naphthenic acids	0.0016	0.00032
	molybdenum	0.000082	0.00024
	vanadium	0.0000026	0.0000074

TABLE 5.3-1

EXPOSURE LIMITS FOR CHEMICALS UNDER CONSIDERATION

Chemical	Exposure Limit (mg/kg-BW/day)	RfD/RsD[1] Endpoint	Critical Effect	Reference
benzo(a)anthracene	1.37E-05	RsD	stomach tumours	U.S. EPA 1996.
benzo(a)pyrene	1.37E-06	RsD	stomach tumours	U.S. EPA 1996.
naphthenic acids	no data	no data	no data	no data
molybdenum	0.007	RfD	painful joints, increased uric acid	U.S. EPA 1996.
vanadium	0.005	RfD	growth, serum cholesterol	HEAST 1995

[1] Risk Specific Dose (RsD) = 10^{-5} risk / cancer slope factor; method used for carcinogenic chemicals.
[2] Reference Dose (RfD) = NOAEL / uncertainty factor, method used for noncarcinogenic chemicals.

TABLE 5.4-1

EXPOSURE RATIOS FOR THE WATER RELEASE SCENARIOS

pg: 1 of 2

		Adult	Child
Scenario	**Chemical**	**ER[1]**	**ER[1]**
1995	**Swimming Scenario**		
	benzo(a)anthracene	0.007	0.001
	benzo(a)pyrene	0.01	0.002
	naphthenic acids	–	–
	molybdenum	0.0001	0.0006
	vanadium	0.00004	0.0002
	Recreational Scenario		
	benzo(a)anthracene	0.004	0.0008
	benzo(a)pyrene	0.005	0.0009
	naphthenic acids	–	–
	molybdenum	0.02	0.05
	vanadium	0.005	0.01
2001	**Swimming Scenario**		
	benzo(a)anthracene	0.002	0.0004
	benzo(a)pyrene	0.008	0.002
	naphthenic acids	–	–
	molybdenum	0.0001	0.0005
	vanadium	0.0000005	0.000002
	Recreational Scenario		
	benzo(a)anthracene	0.001	0.0002
	benzo(a)pyrene	0.003	0.0006
	naphthenic acids	–	–
	molybdenum	0.01	0.04
	vanadium	0.00007	0.0002
2010	**Swimming Scenario**		
	benzo(a)anthracene	0.004	0.0009
	benzo(a)pyrene	0.007	0.001
	naphthenic acids	–	–
	molybdenum	0.0001	0.0006
	vanadium	0.00002	0.0001
	Recreational Scenario		
	benzo(a)anthracene	0.003	0.0005
	benzo(a)pyrene	0.003	0.0006
	naphthenic acids	–	–
	molybdenum	0.02	0.04
	vanadium	0.003	0.009
2020	**Swimming Scenario**		
	benzo(a)anthracene	0.005	0.0009
	benzo(a)pyrene	0.01	0.003
	naphthenic acids	–	–
	molybdenum	0.0001	0.0006
	vanadium	0.00002	0.0001
	Recreational Scenario		
	benzo(a)anthracene	0.003	0.0005
	benzo(a)pyrene	0.005	0.001
	naphthenic acids	–	–
	molybdenum	0.02	0.05
	vanadium	0.003	0.008

TABLE 5.4-1

EXPOSURE RATIOS FOR THE WATER RELEASE SCENARIOS

pg: 2 of 2

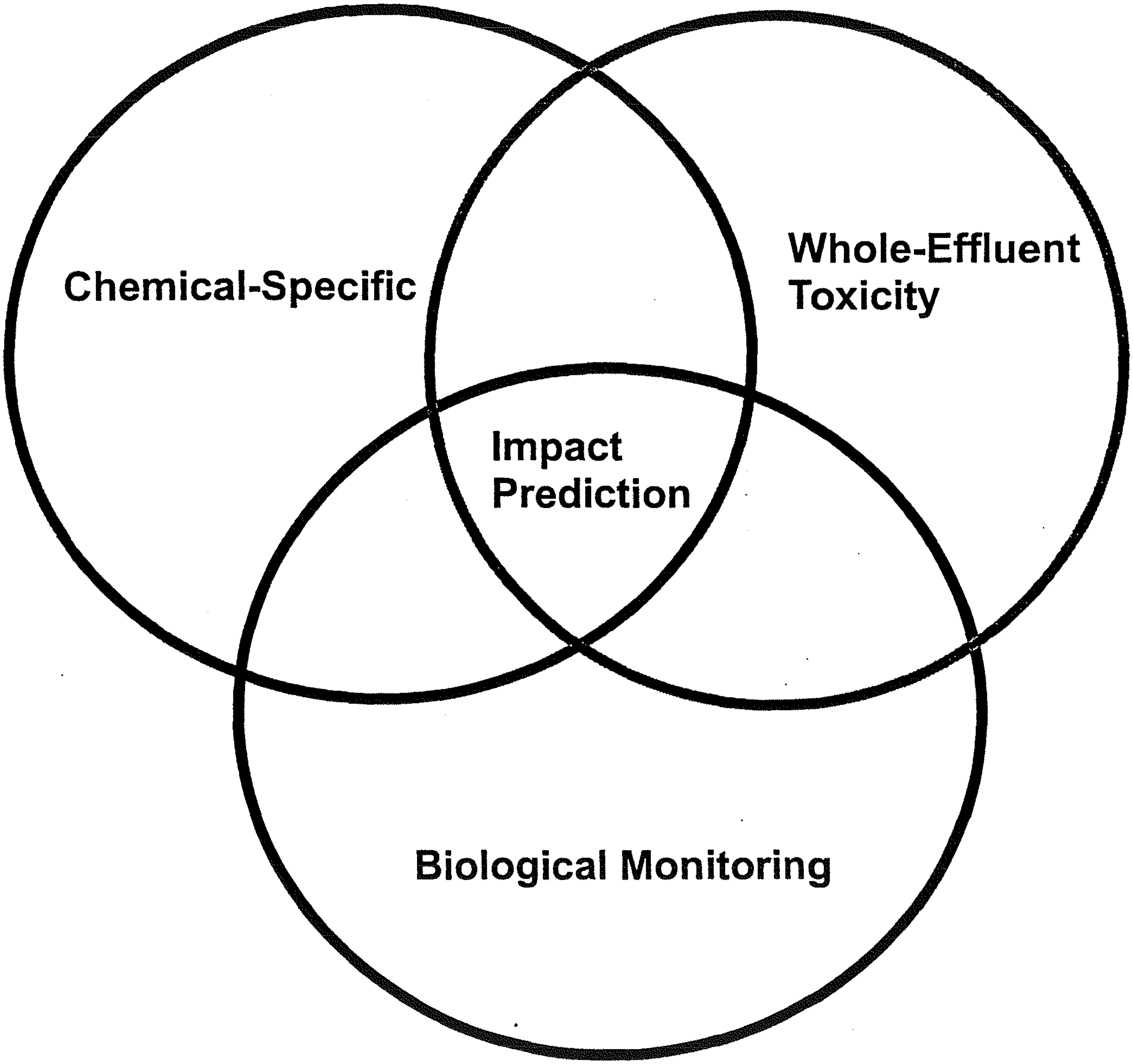
Scenario	Chemical	Adult ER[1]	Child ER[1]
EQ	**Swimming Scenario**		
	benzo(a)anthracene	0.0003	0.00007
	benzo(a)pyrene	0.008	0.001
	naphthenic acids	--	--
	molybdenum	0.0001	0.0006
	vanadium	0.000003	0.00001
	Recreational Scenario		
	benzo(a)anthracene	0.0002	0.00004
	benzo(a)pyrene	0.003	0.0006
	naphthenic acids	--	--
	molybdenum	0.02	0.05
	vanadium	0.0004	0.001

[1] For non-carcinogens, exposure ratio = Intake rate / exposure limit.
For carcinogens, exposure ratio = risk / acceptible risk.

FIGURES

Figure 2.1-1

Triad Approach for Assessing Water Quality Impacts



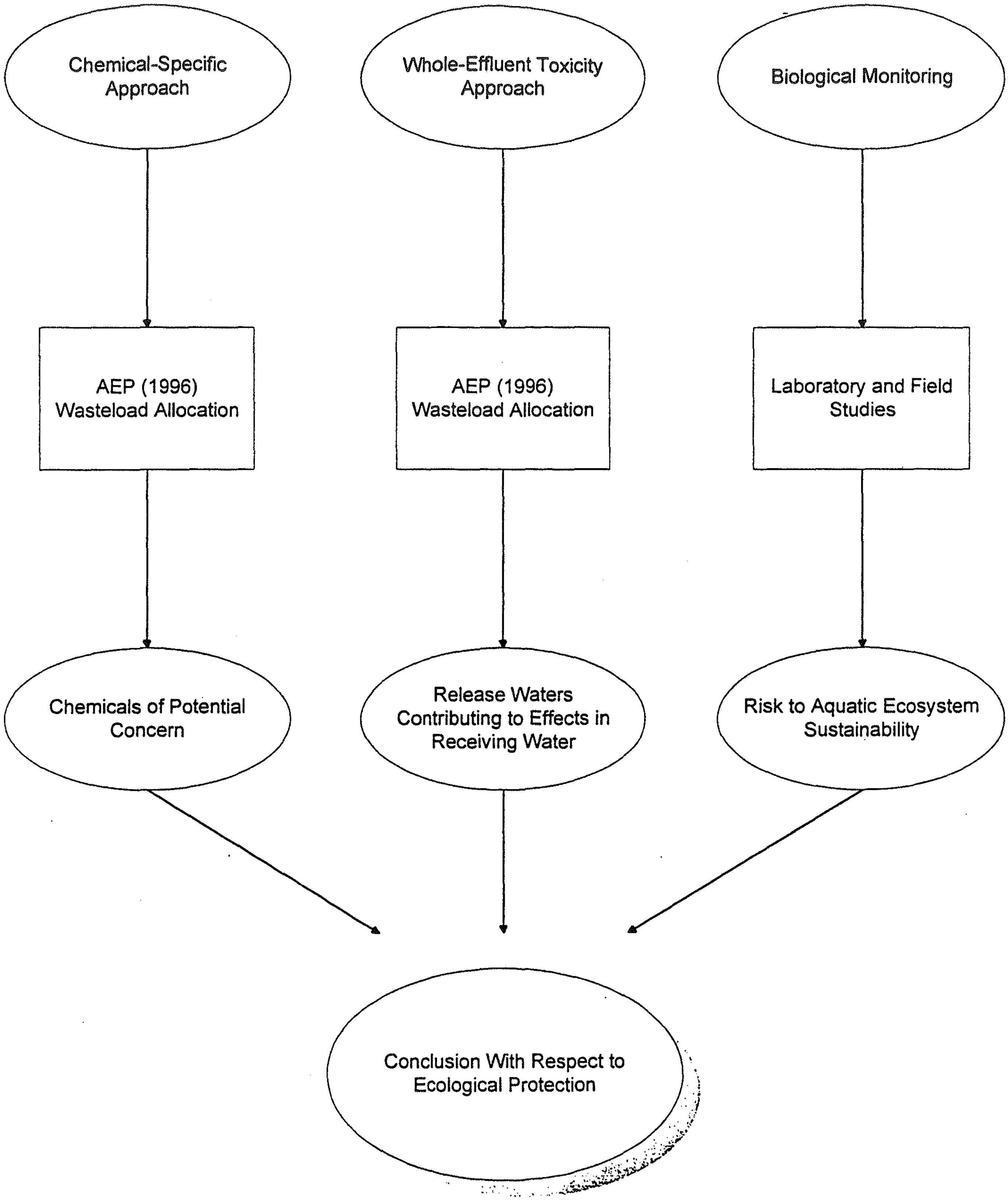
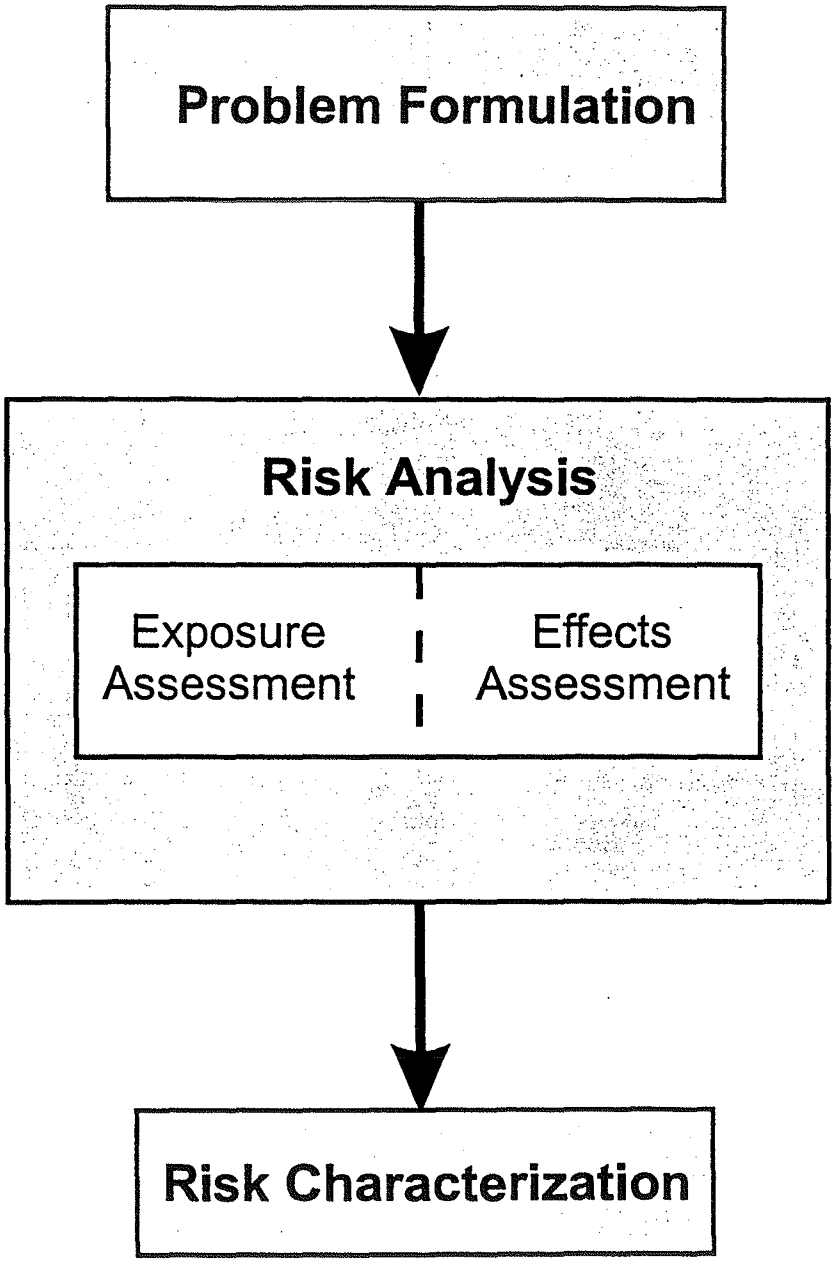


Figure 2.1-2
General Framework for Assessing Potential Impacts on Aquatic Biota

Figure 2.2-1

Environmental Risk Assessment (Human and Ecological)



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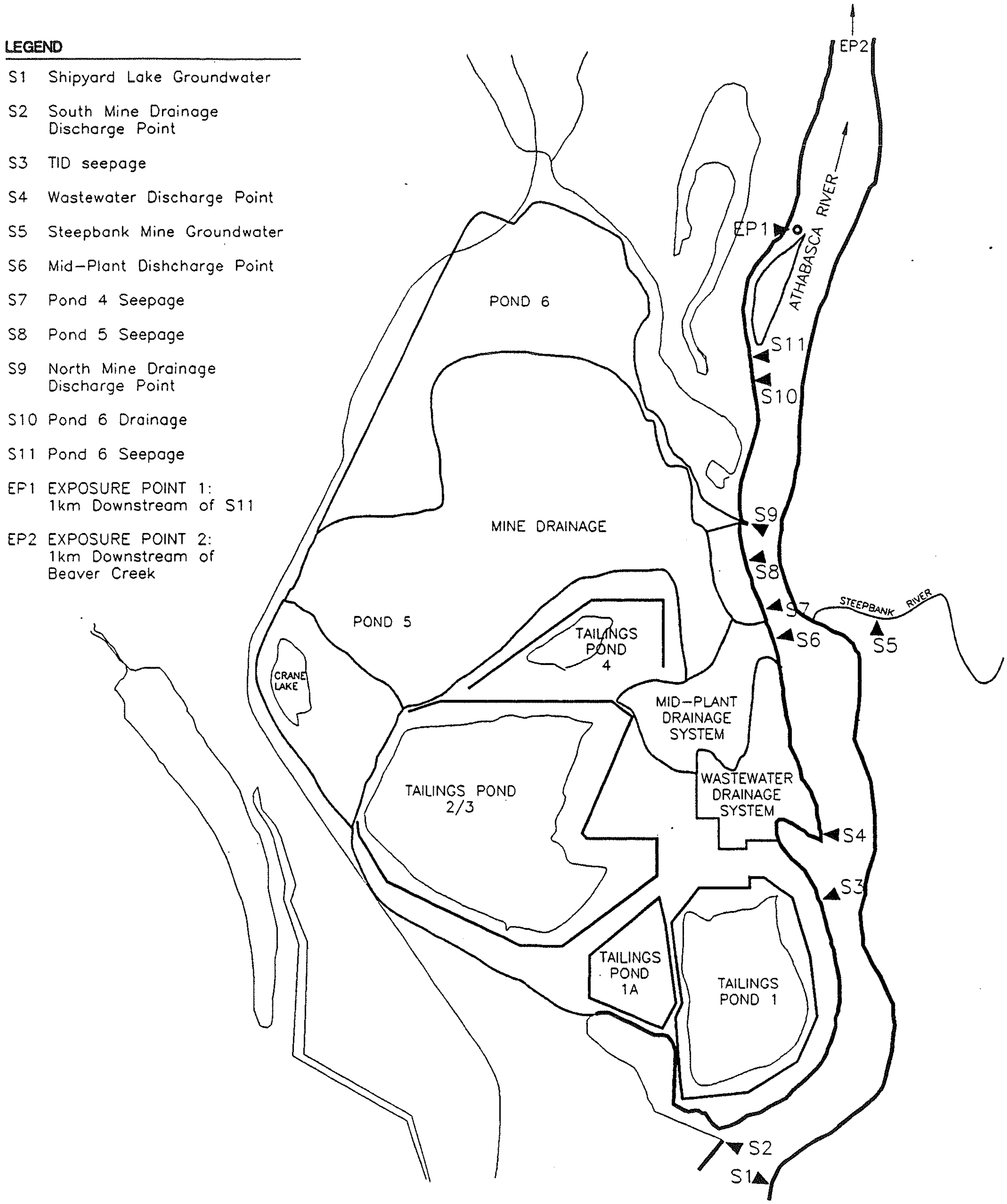
LOCATIONS OF KNOWN, POSSIBLE AND FUTURE DISCHARGE SOURCES

Figure 3.1-1



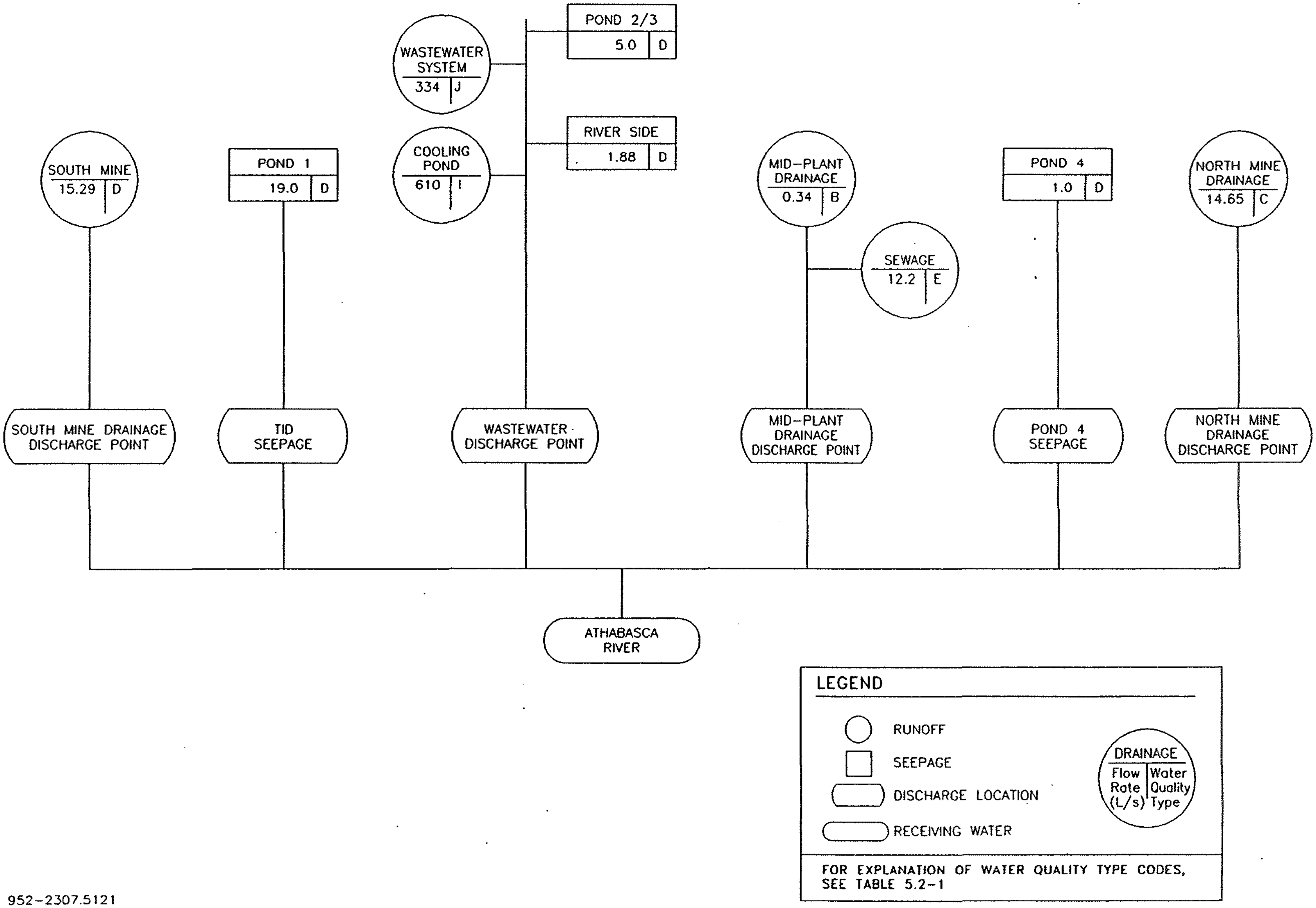
LEGEND

S1	Shipyard Lake Groundwater
S2	South Mine Drainage Discharge Point
S3	TID seepage
S4	Wastewater Discharge Point
S5	Steepbank Mine Groundwater
S6	Mid-Plant Dishcharge Point
S7	Pond 4 Seepage
S8	Pond 5 Seepage
S9	North Mine Drainage Discharge Point
S10	Pond 6 Drainage
S11	Pond 6 Seepage
EP1	EXPOSURE POINT 1: 1km Downstream of S11
EP2	EXPOSURE POINT 2: 1km Downstream of Beaver Creek

PROJECT 952-2307. DRAWN CG REVIEWED DATE 29 APR 96 SURFDRN

Figure 3.3-1

MINESITE DRAINAGE TO ATHABASCA RIVER
SCENARIO: 1995



952-2307.5121
\CH1.R13

Figure 3.3-2

MINESITE DRAINAGE TO ATHABASCA RIVER
SCENARIO: 2001

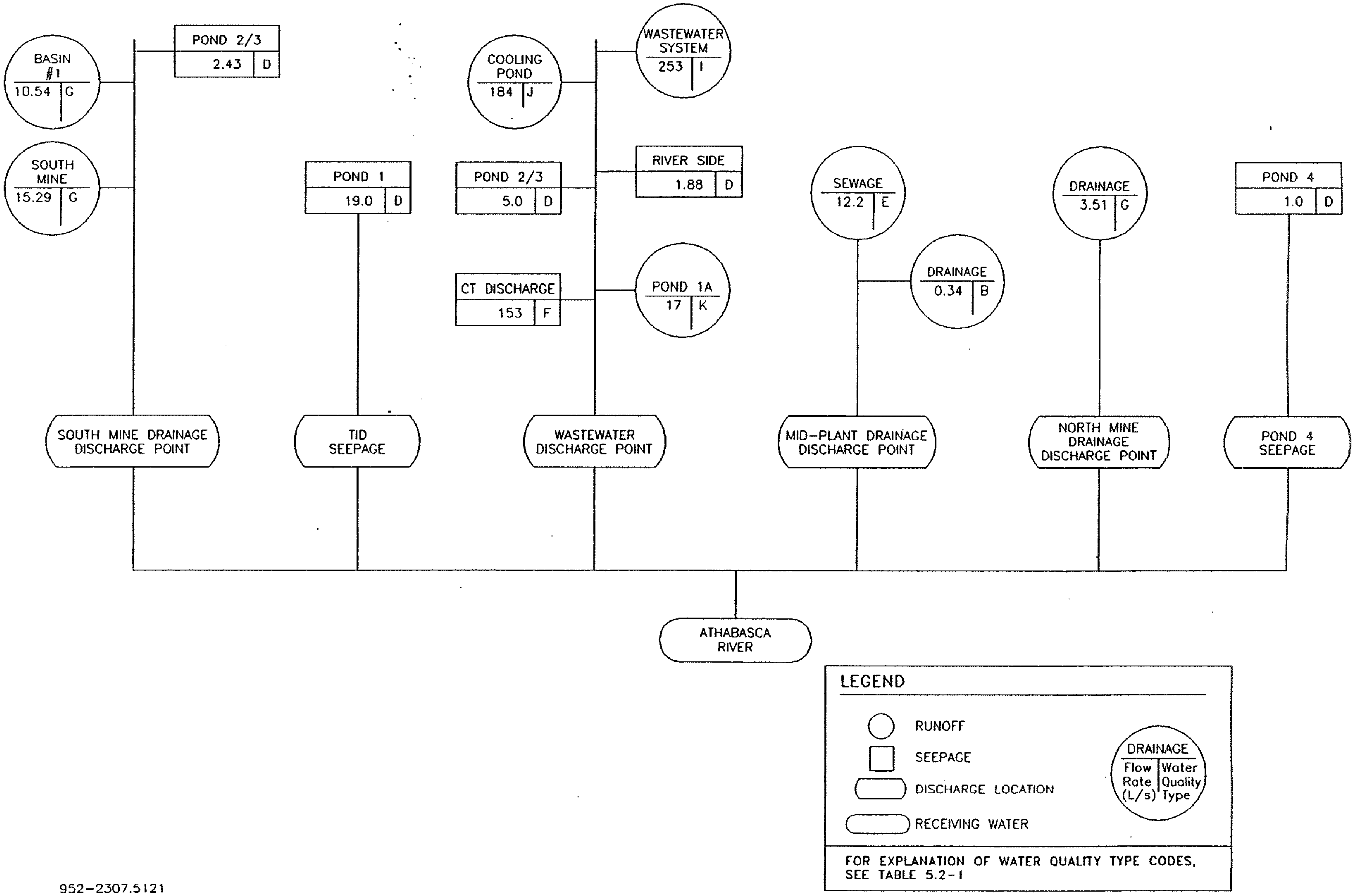


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Figure 3.3-3

MINESITE DRAINAGE TO ATHABASCA RIVER
SCENARIO: 2010

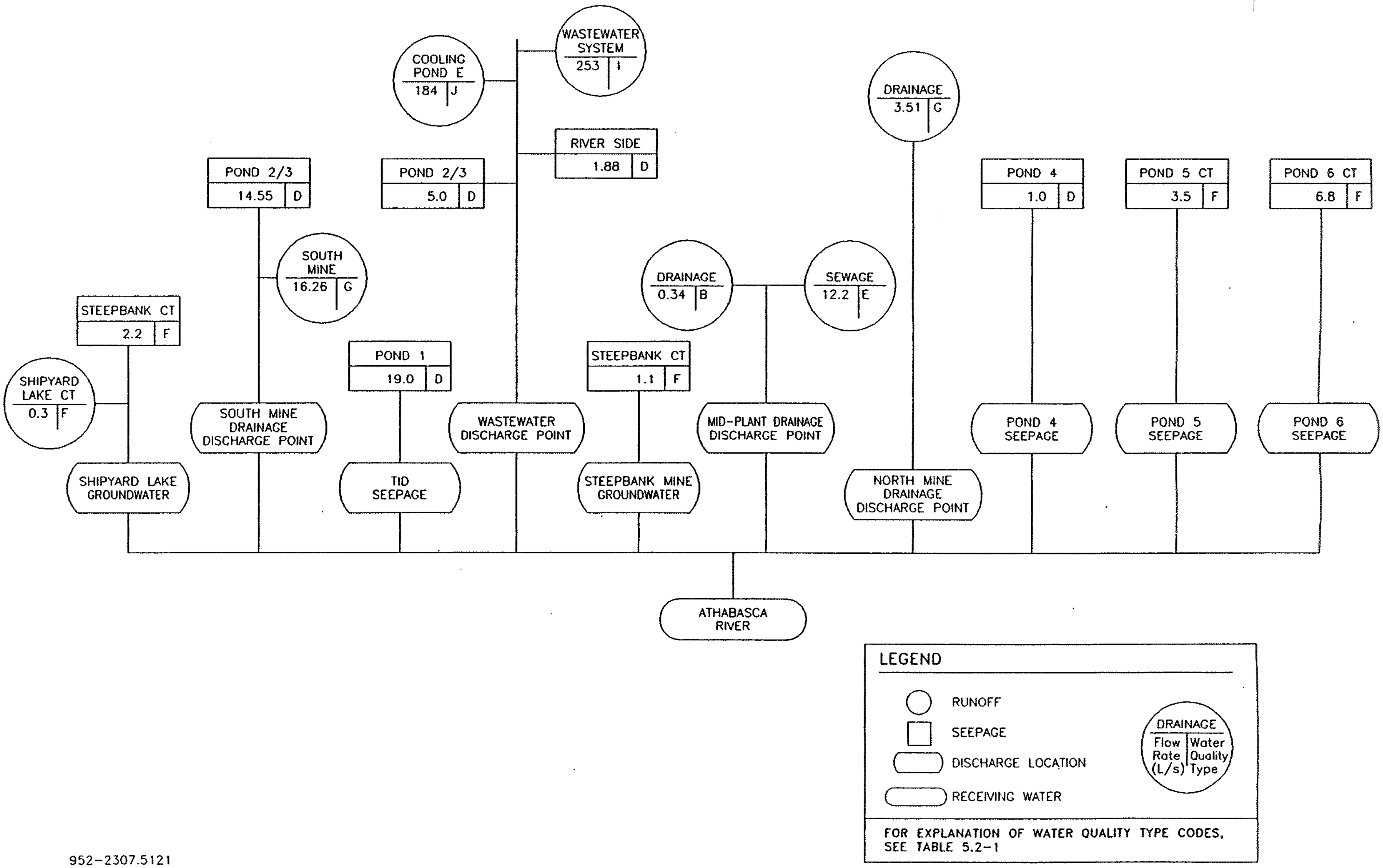
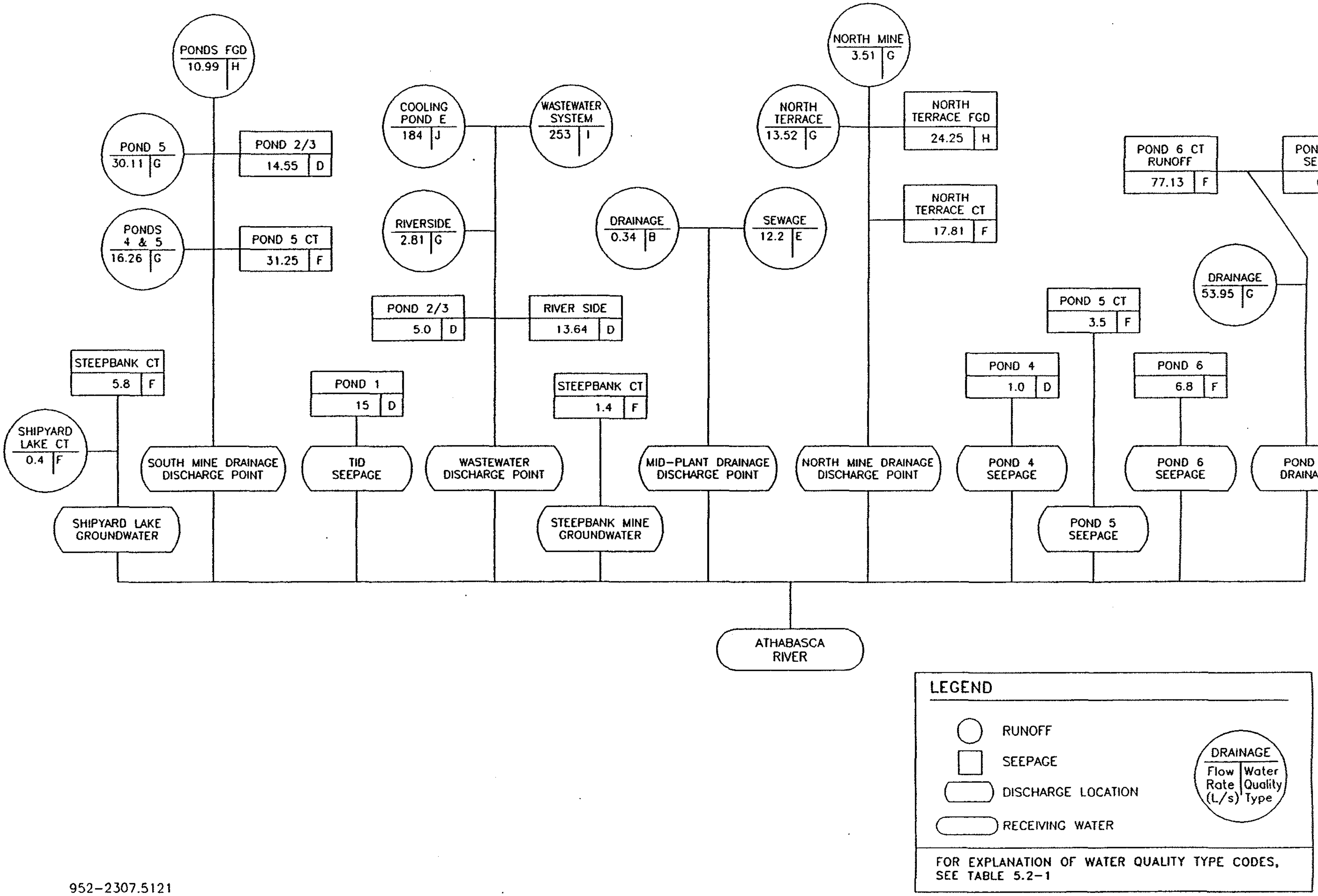


Figure 3.3-4

MINESITE DRAINAGE TO ATHABASCA RIVER
SCENARIO: 2020



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\CH5.R13

Figure 3.3-5

MINESITE DRAINAGE TO ATHABASCA RIVER
SCENARIO: POST-RECLAMATION

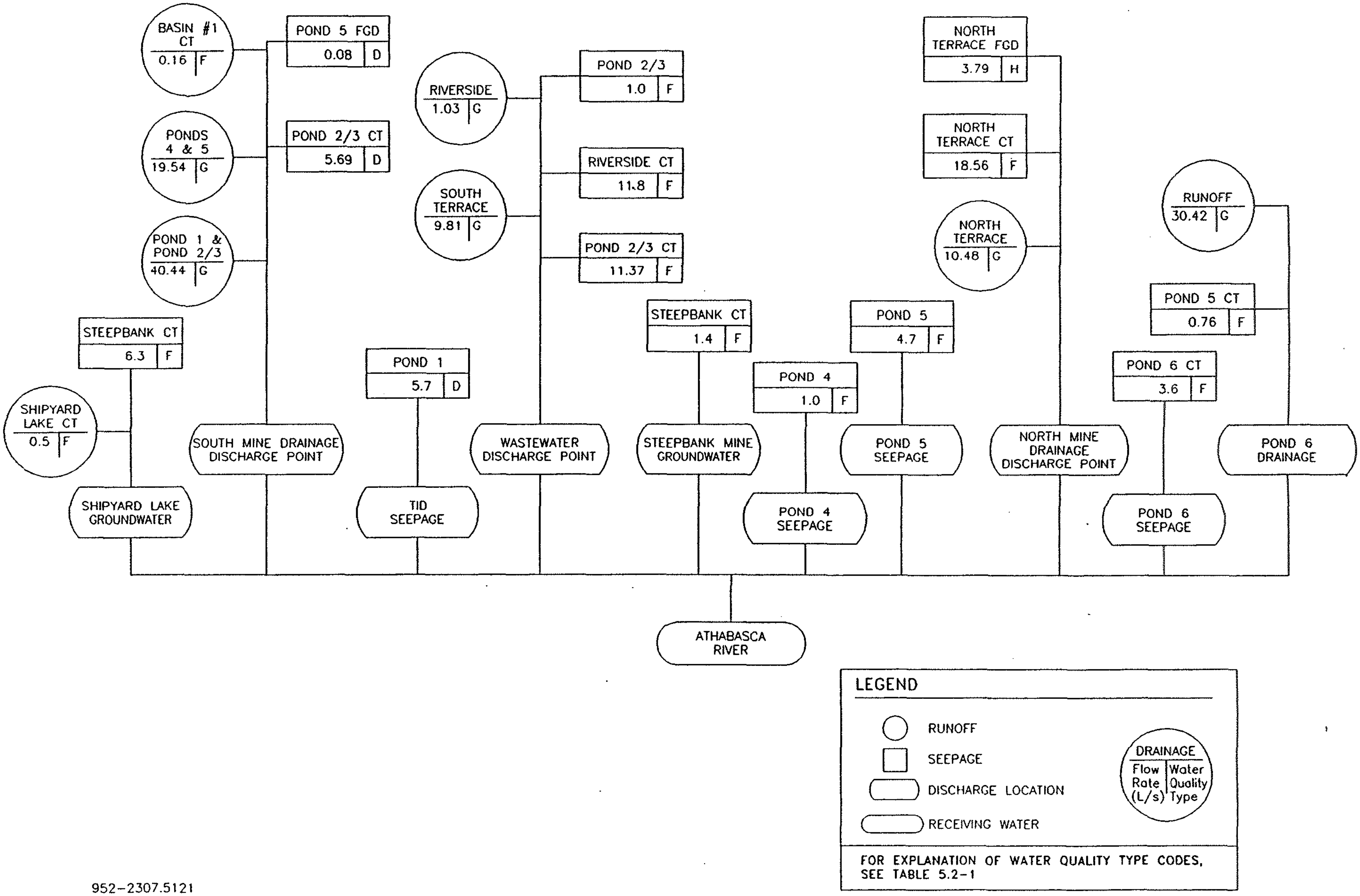

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FIGURE 4.1-1

PROTOCOL FOR SCREENING RELEASE WATER QUALITY FOR ATHABASCA RIVER IMPACT ASSESSMENT

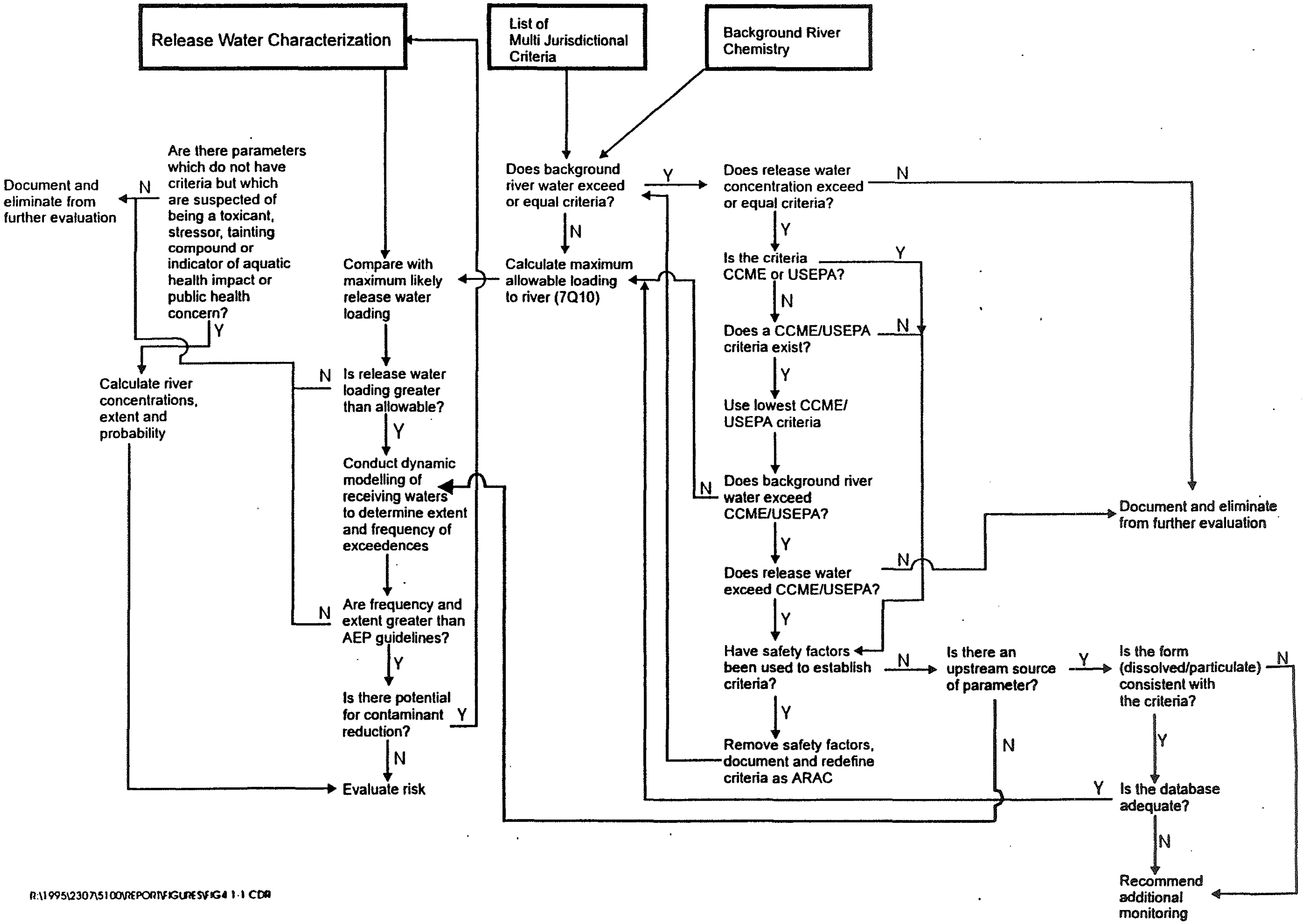

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Figure 4.2-1
Predicted Toxicity Levels (TUc) in the Athabasca River
7Q10 Flow, 1995

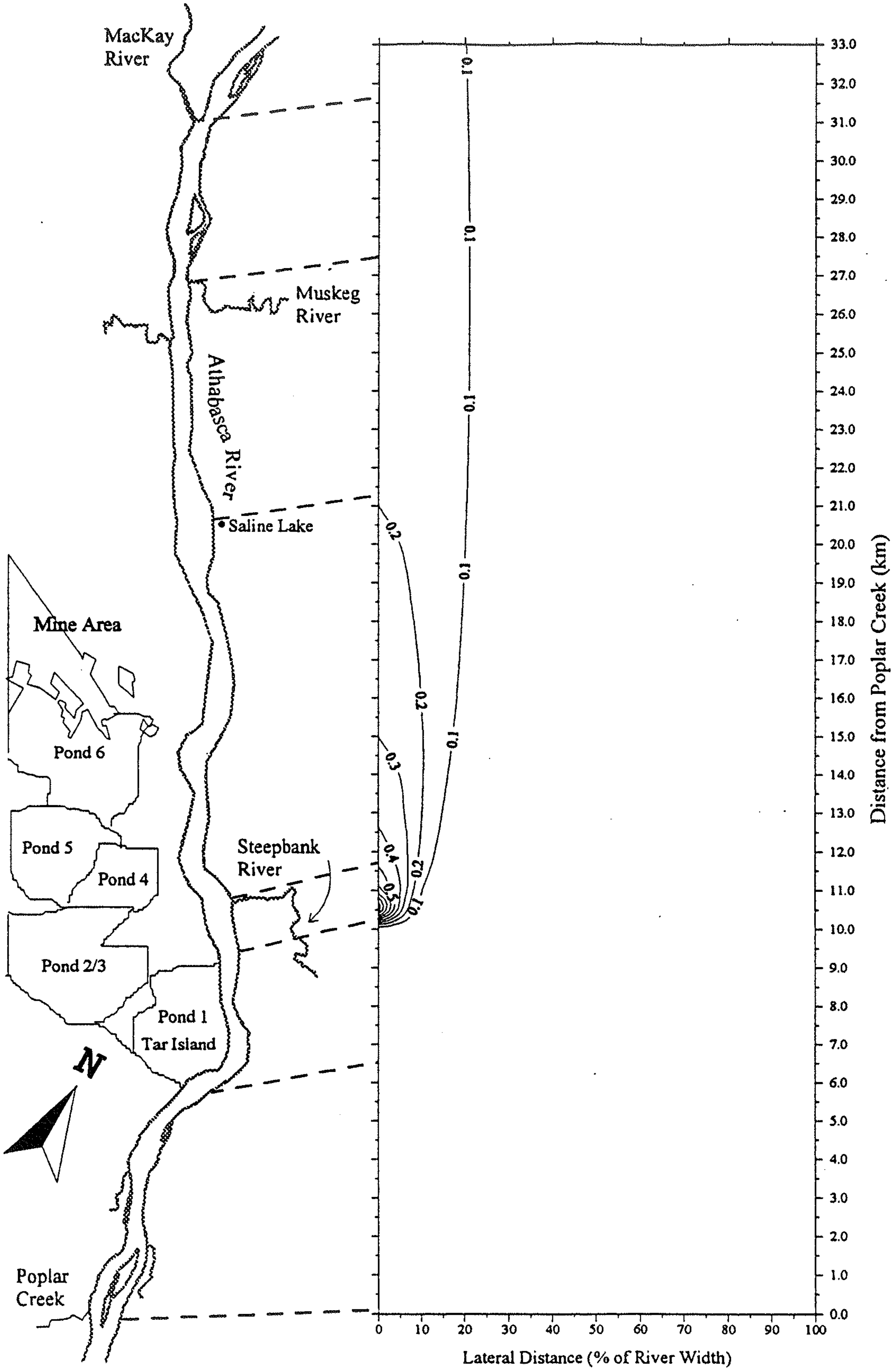

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Figure 4.2-2
Predicted Toxicity Levels (TUc) in the Athabasca River
7Q10 Flow, 2001

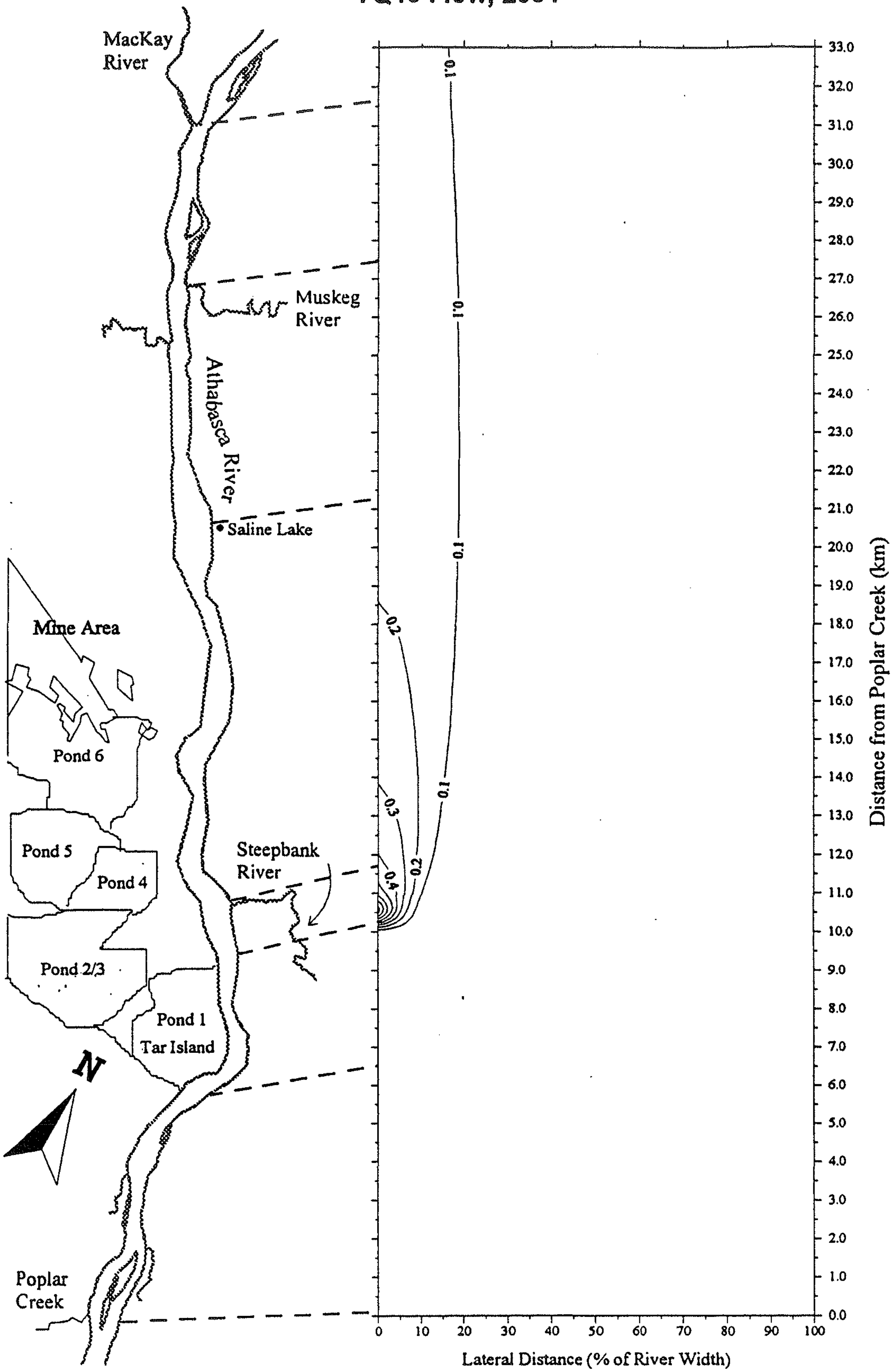

Figure 4.2-3
Predicted Toxicity Levels (TUc) in the Athabasca River
7Q10 Flow, 2010

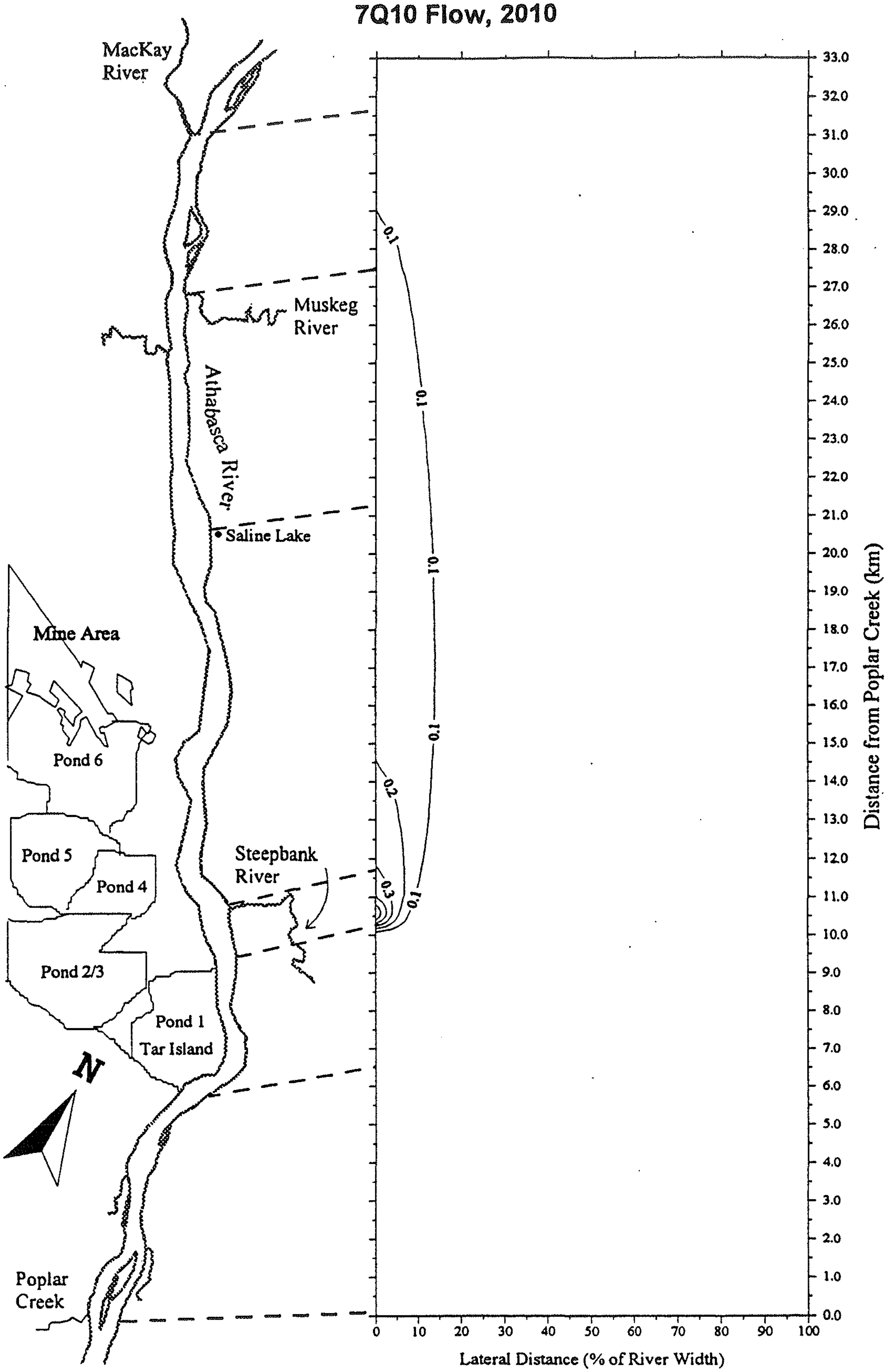

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Figure 4.2-4
Predicted Toxicity Levels (TUc) in the Athabasca River
7Q10 Flow, 2020

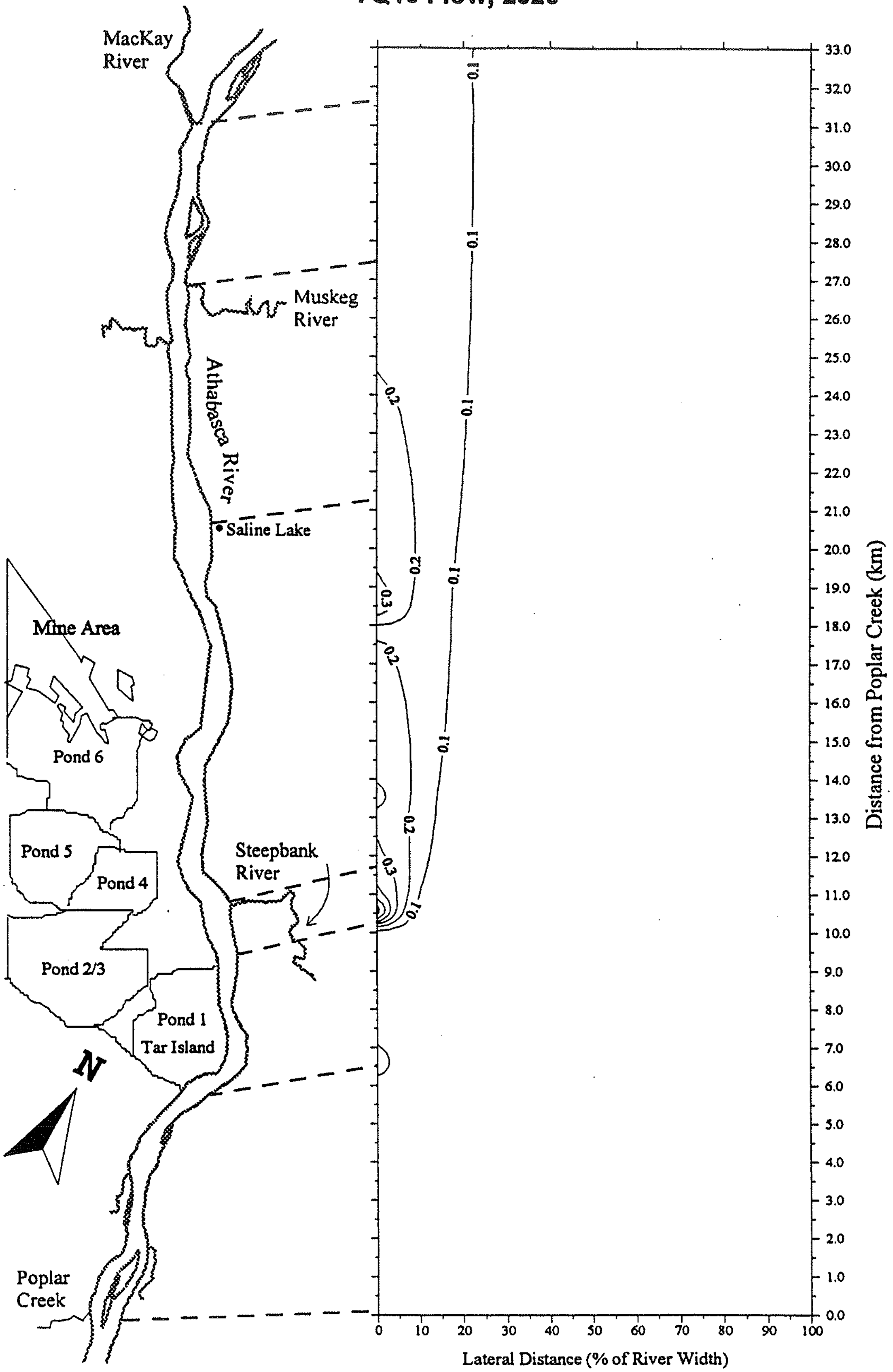
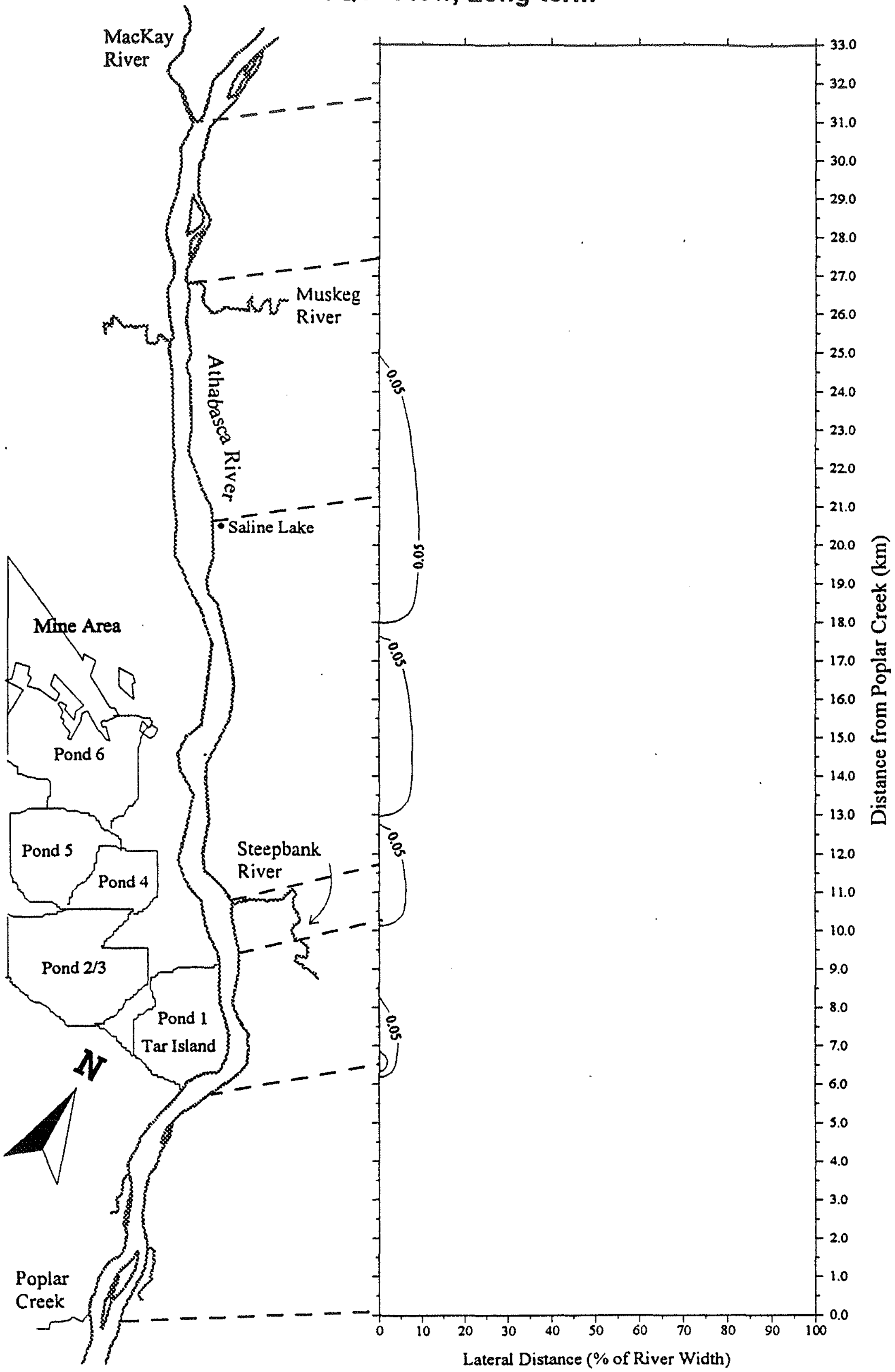


Figure 4.2-5
Predicted Toxicity Levels (TUc) in the Athabasca River
7Q10 Flow, Long-term



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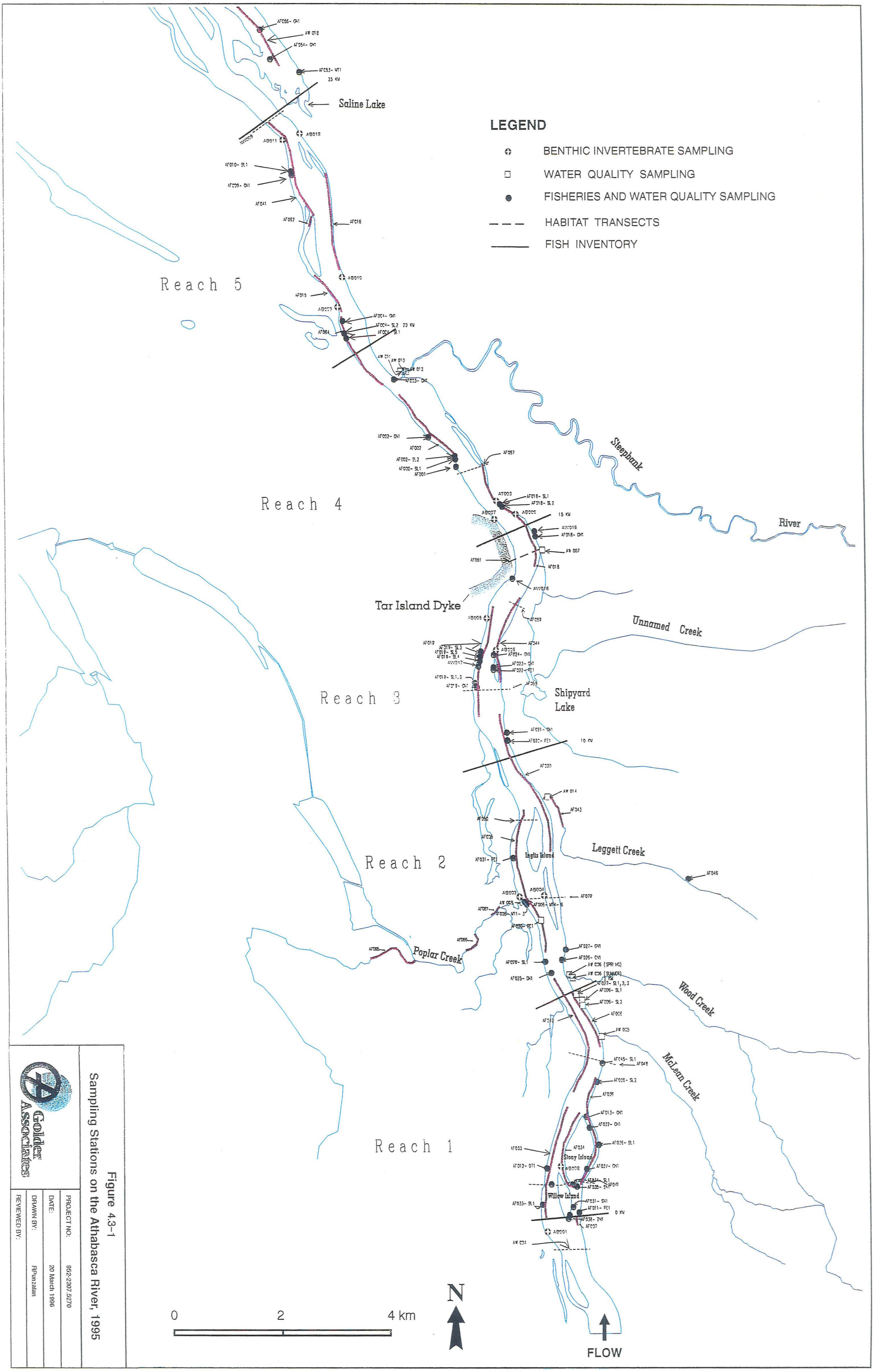


Figure 4.3-1
Sampling Stations on the Athabasca River, 1995

PROJECT NO: 952-2307.5270
DATE: 20 March 1996
DRAWN BY: RPunzalan
REVIEWED BY:

Golder Associates

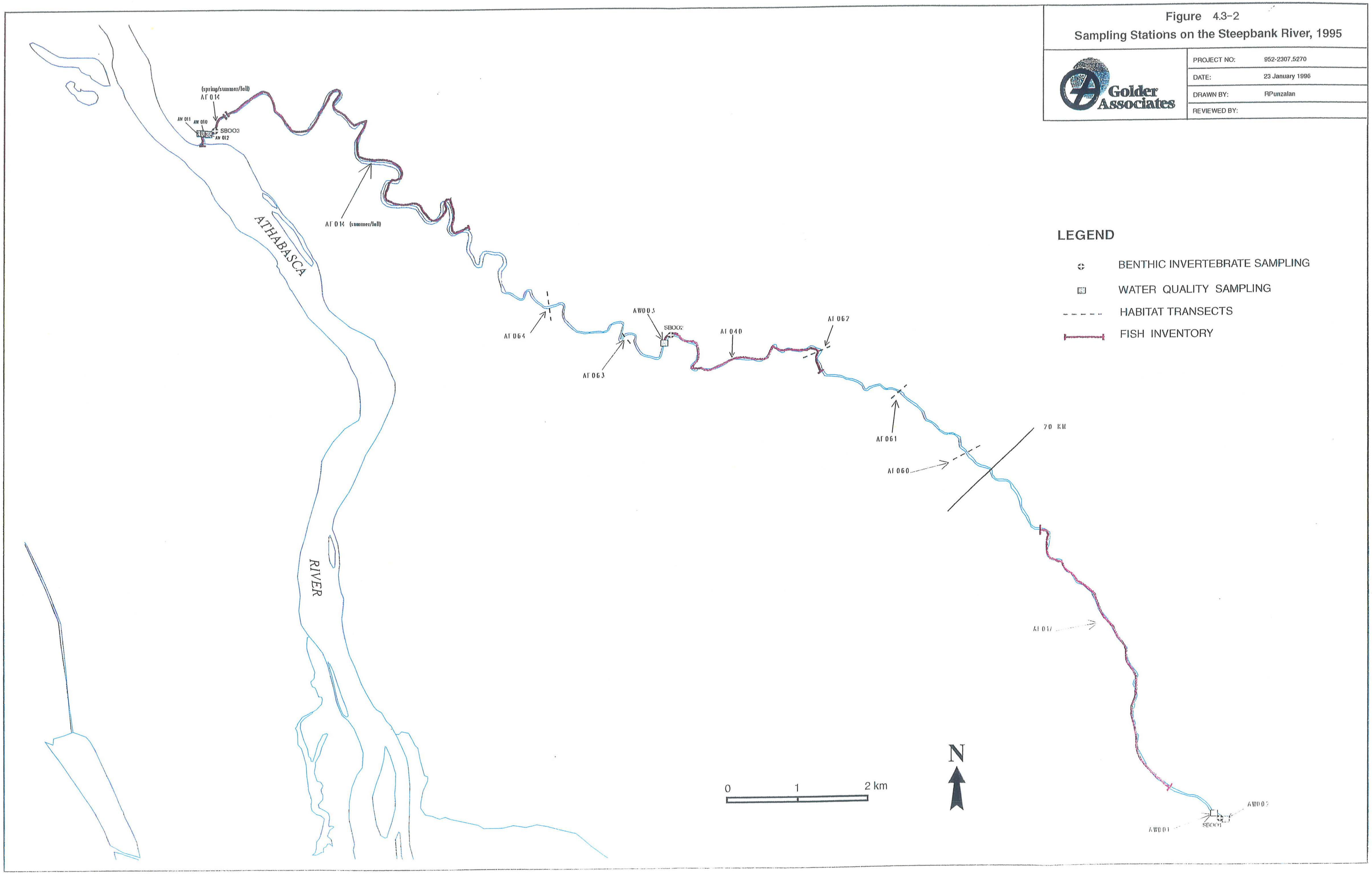


Figure 4.3-2
Sampling Stations on the Steepbank River, 1995

PROJECT NO: 952-2307.5270
DATE: 23 January 1996
DRAWN BY: RPunzalan
REVIEWED BY:

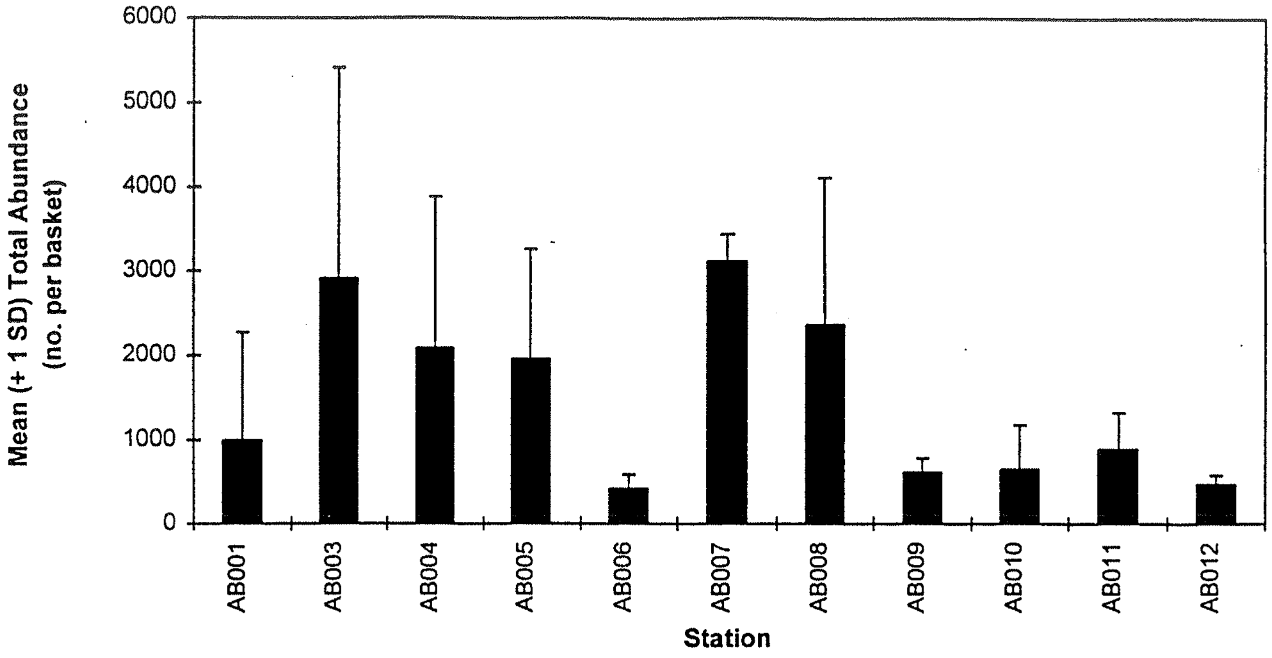


Figure 4.3-3A Mean Total Abundance of Benthic Invertebrates Collected in the Athabasca River Using Artificial Substrates (SD = standard deviation)

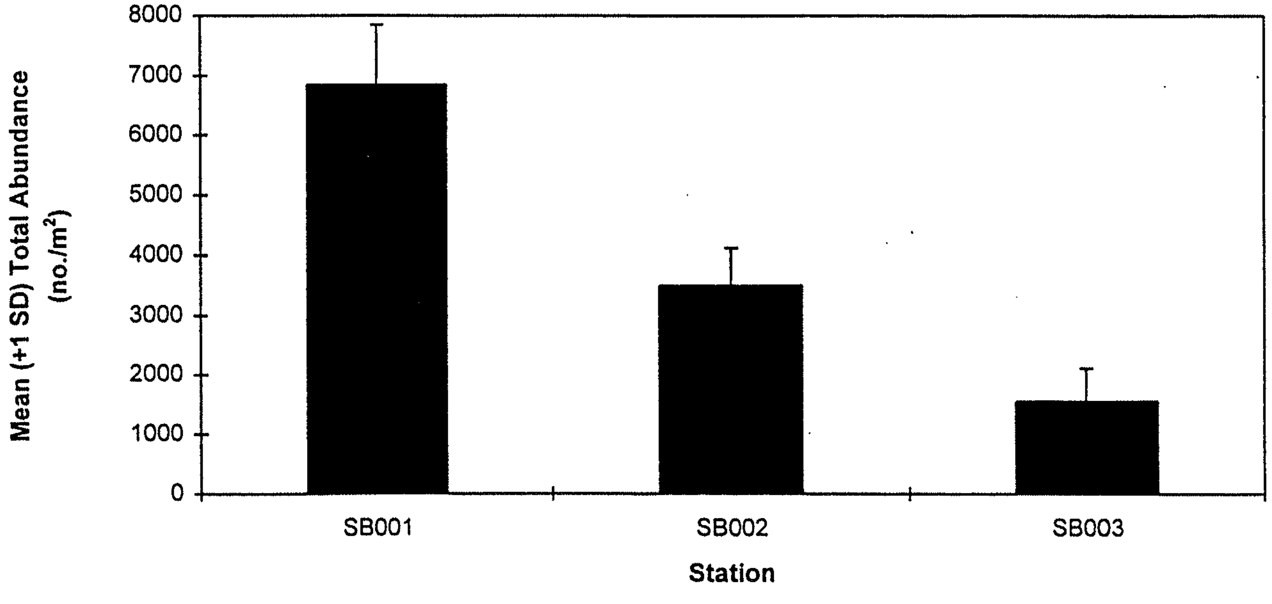


Figure 4.3-3B Mean Total Abundance of Benthic Invertebrates Collected in the Steepbank River Using a Hess Sampler (SD = standard deviation)

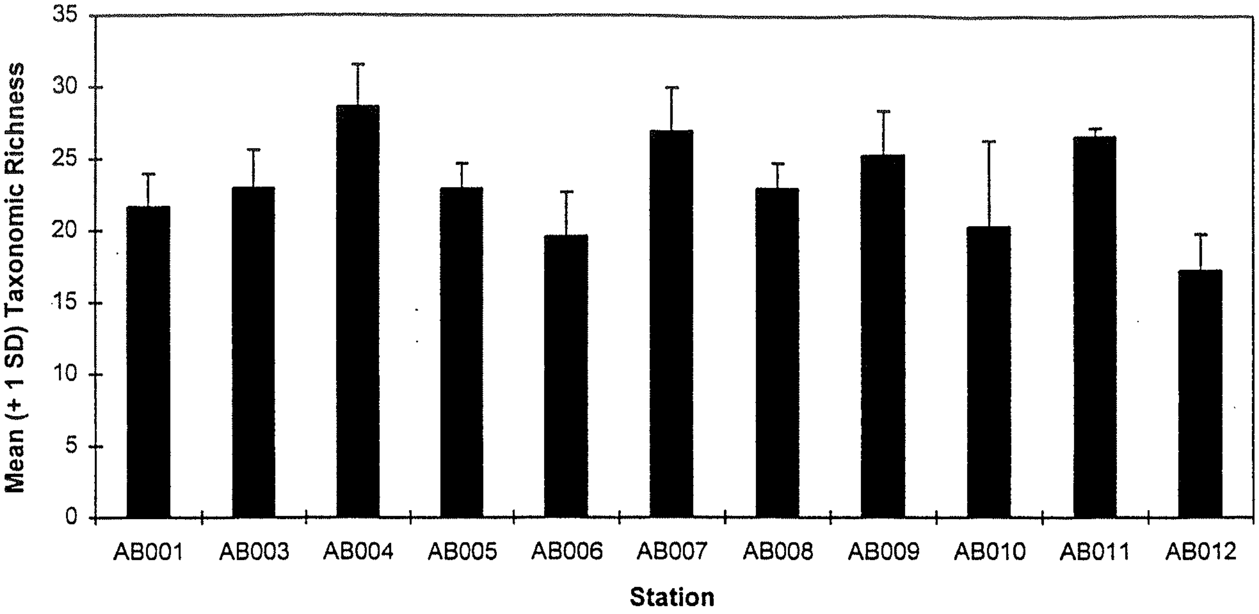


Figure 4.3-4A Mean Taxonomic Richness of Benthic Invertebrates Collected in the Athabasca River Using Artificial Substrates (SD = standard deviation)

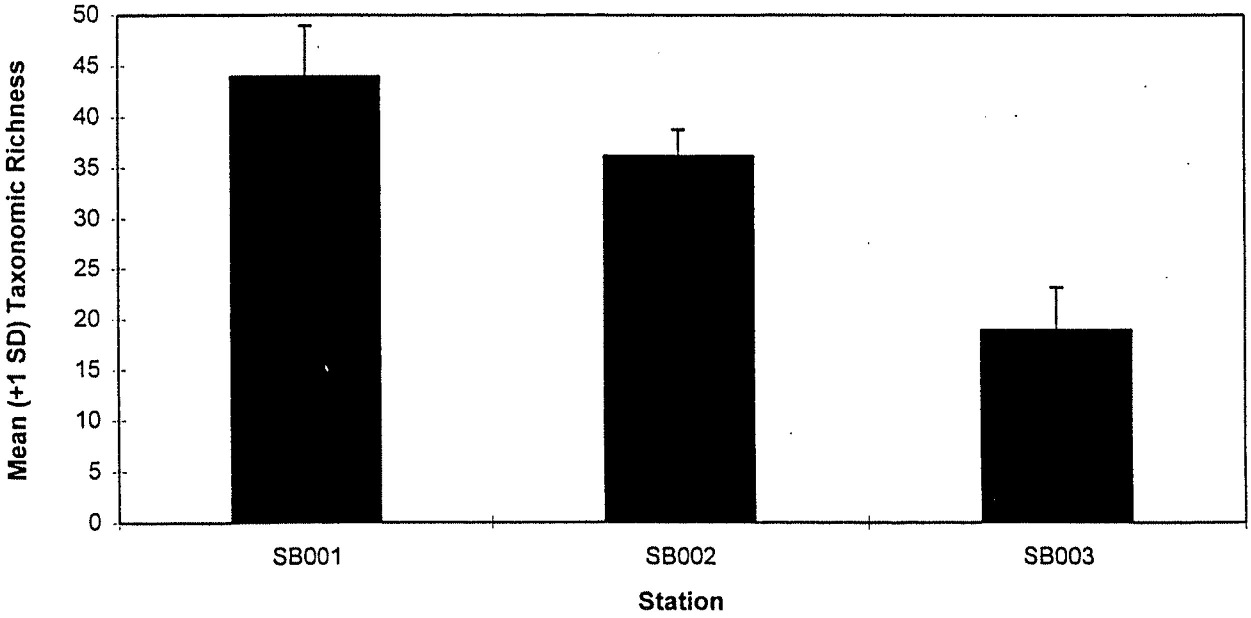


Figure 4.3-4B Mean Taxonomic Richness of Benthic Invertebrates Collected in the Steepbank River Using a Hess Sampler (SD = standard deviation)

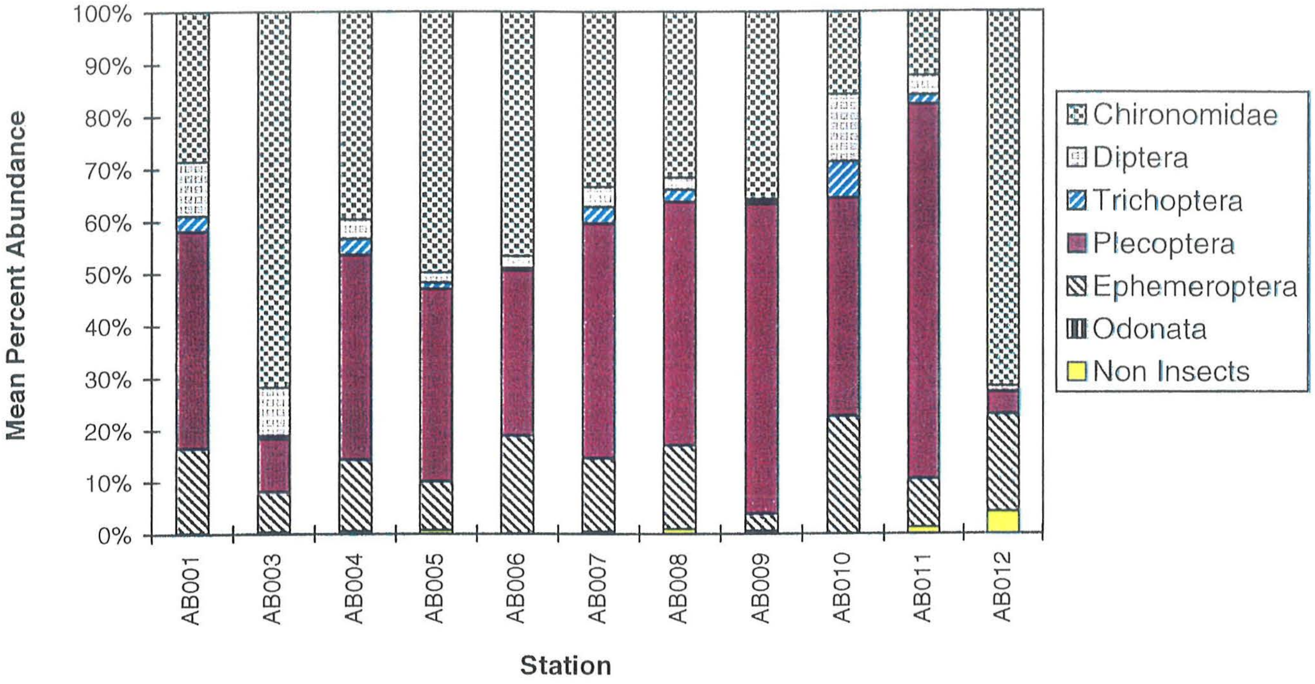


Figure 4.3-5A Percent Abundance of Major Taxonomic Groups Collected in the Athabasca River Using Artificial Substrates

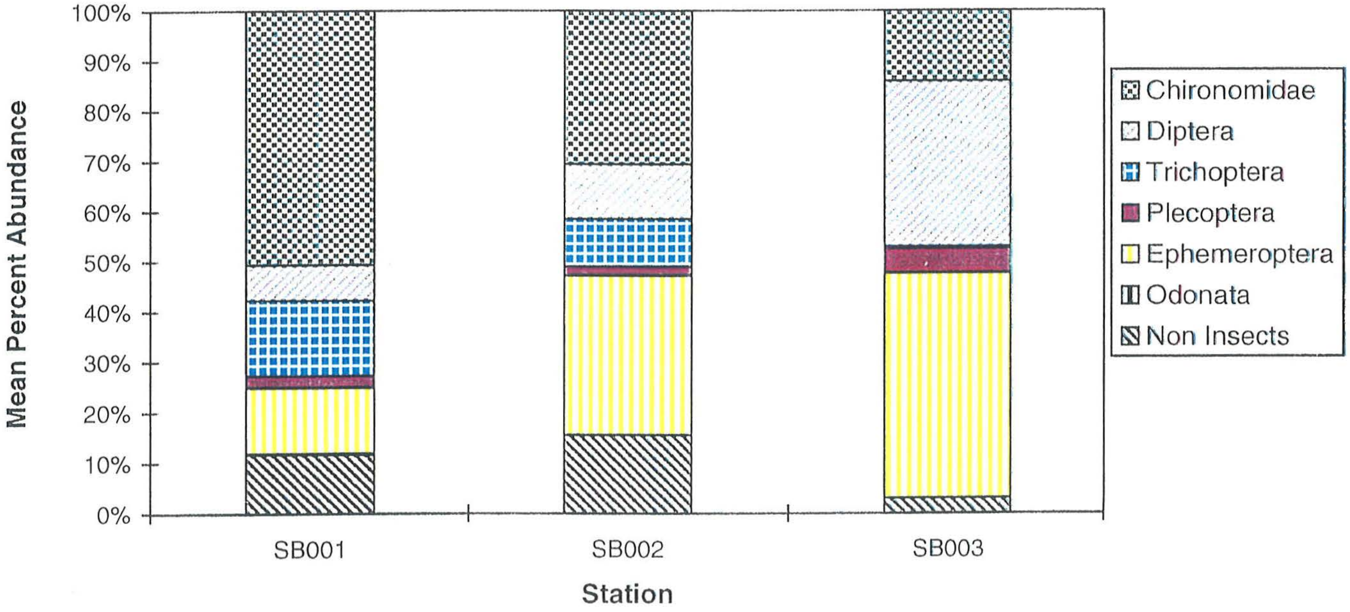
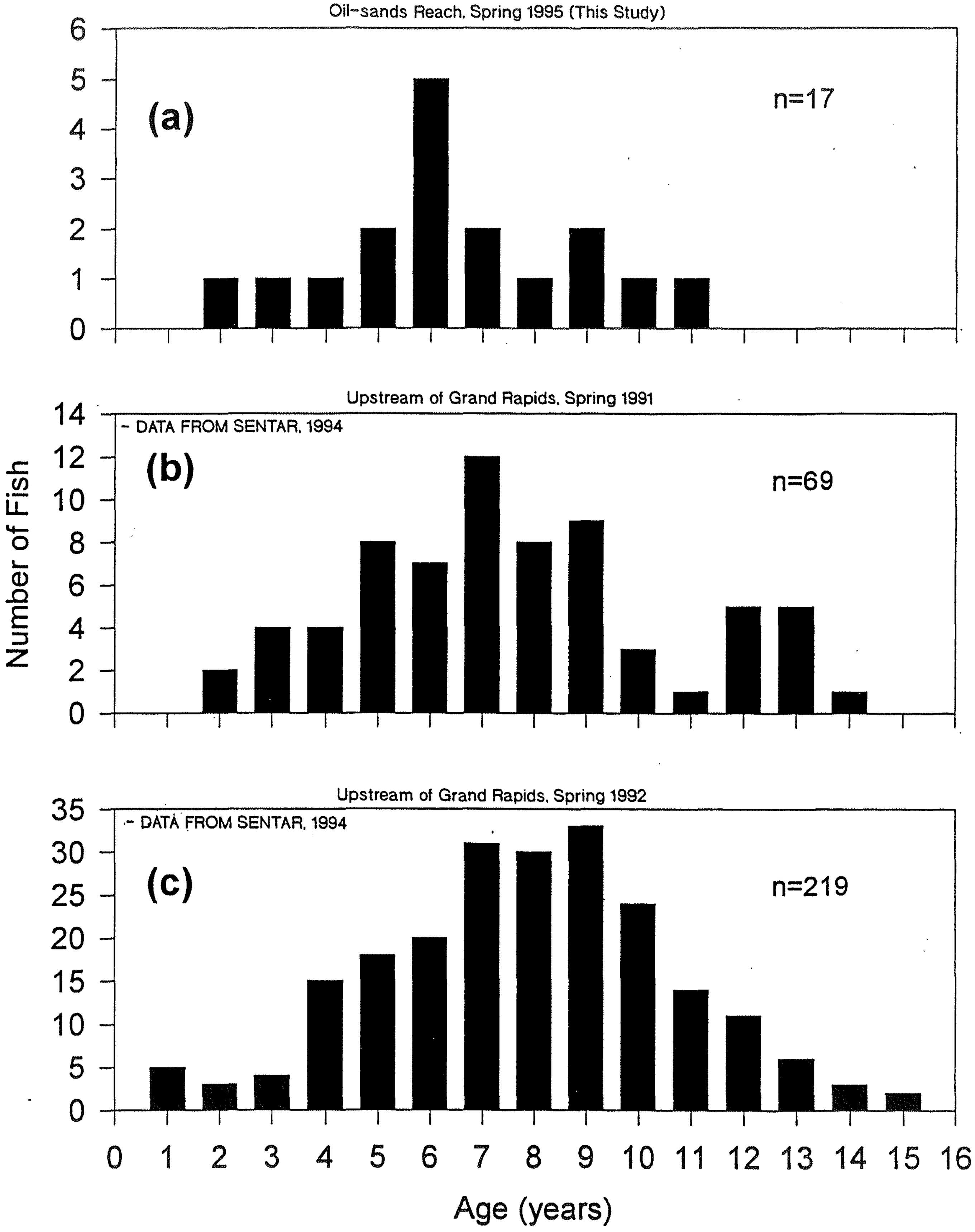


Figure 4.3-5B Percent Abundance of Major Taxonomic Groups Collected in the Steepbank River Using a Hess Sampler

Age-Frequency Distribution for Athabasca River System Longnose Sucker

Figure 4.3-6

* DATA ARE FROM A SUBSAMPLE OF FISH NON-DESTRUCTIVELY SAMPLED BY ALL COLLECTING METHODS



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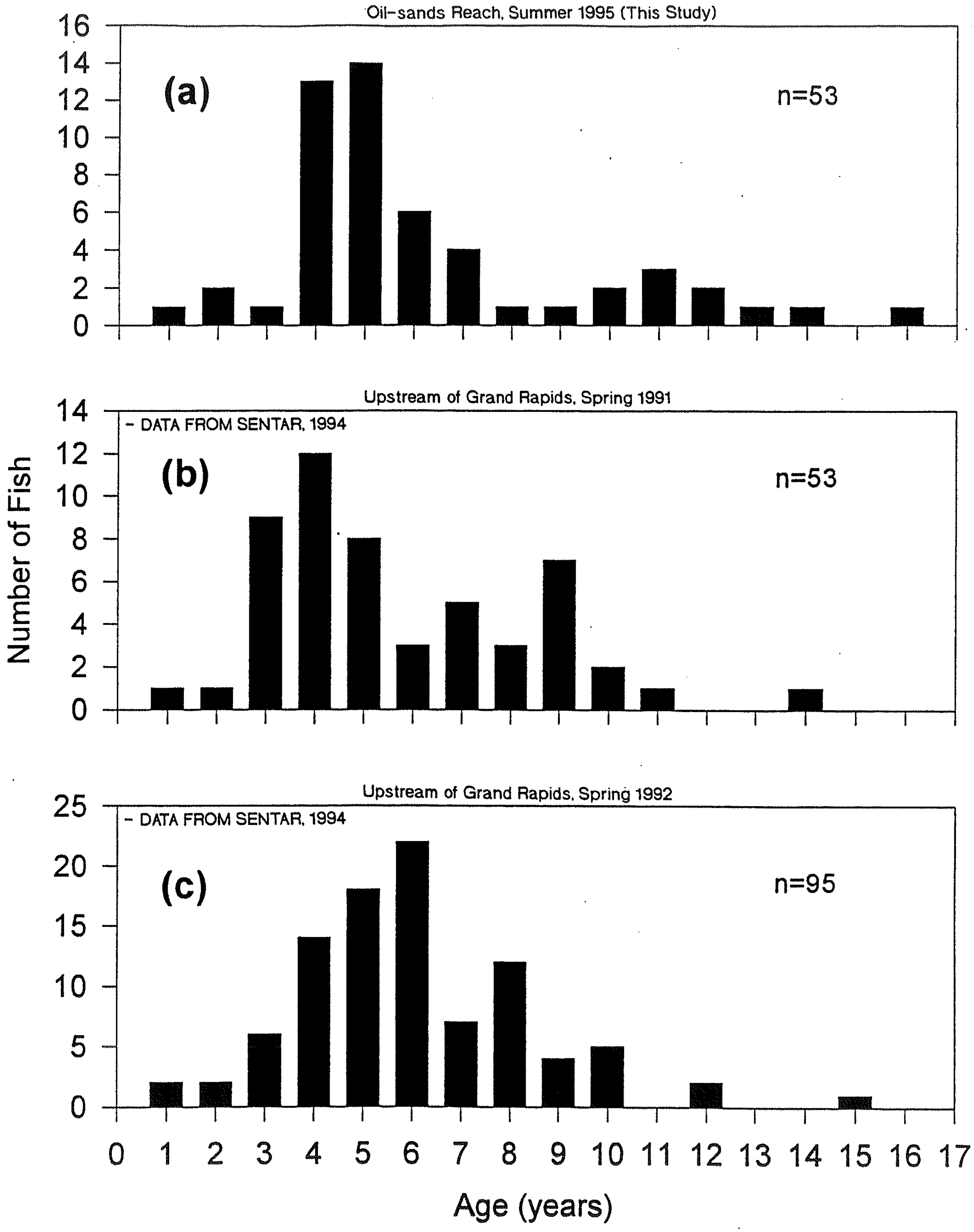
Age-Frequency Distribution for Athabasca River Walleye

Figure 4.3-7

* DATA ARE FROM A SUBSAMPLE OF FISH NON-DESTRUCTIVELY SAMPLED BY ALL COLLECTING METHODS

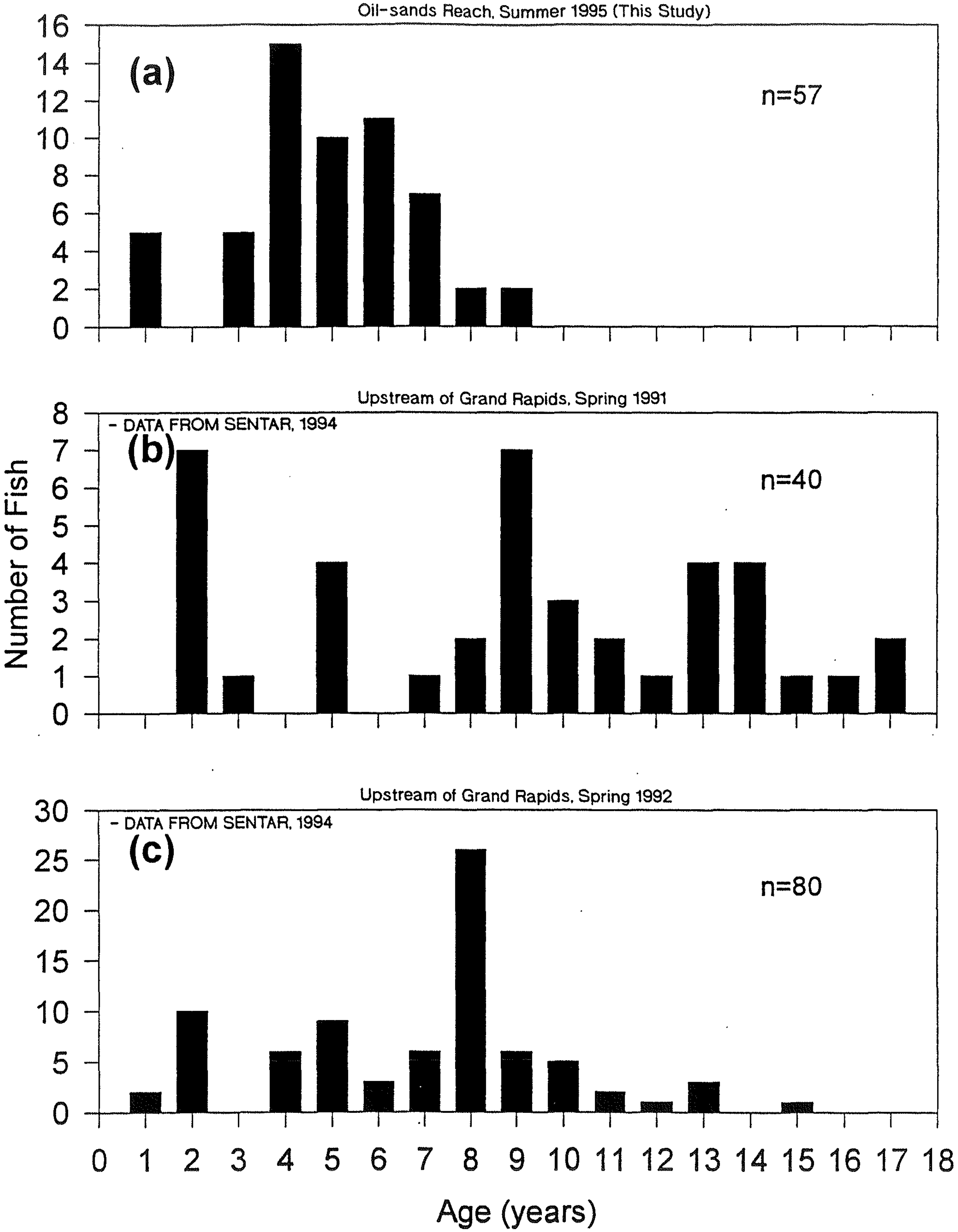


PROJECT 952-2307 DRAWN MVZ REVIEWED DATE 7 FEB 96 952-2307.5140

Age-Frequency Distribution for Athabasca River Goldeye

Figure 4.3-8

* DATA ARE FROM A SUBSAMPLE OF FISH NON-DESTRUCTIVELY SAMPLED BY ALL COLLECTING METHODS



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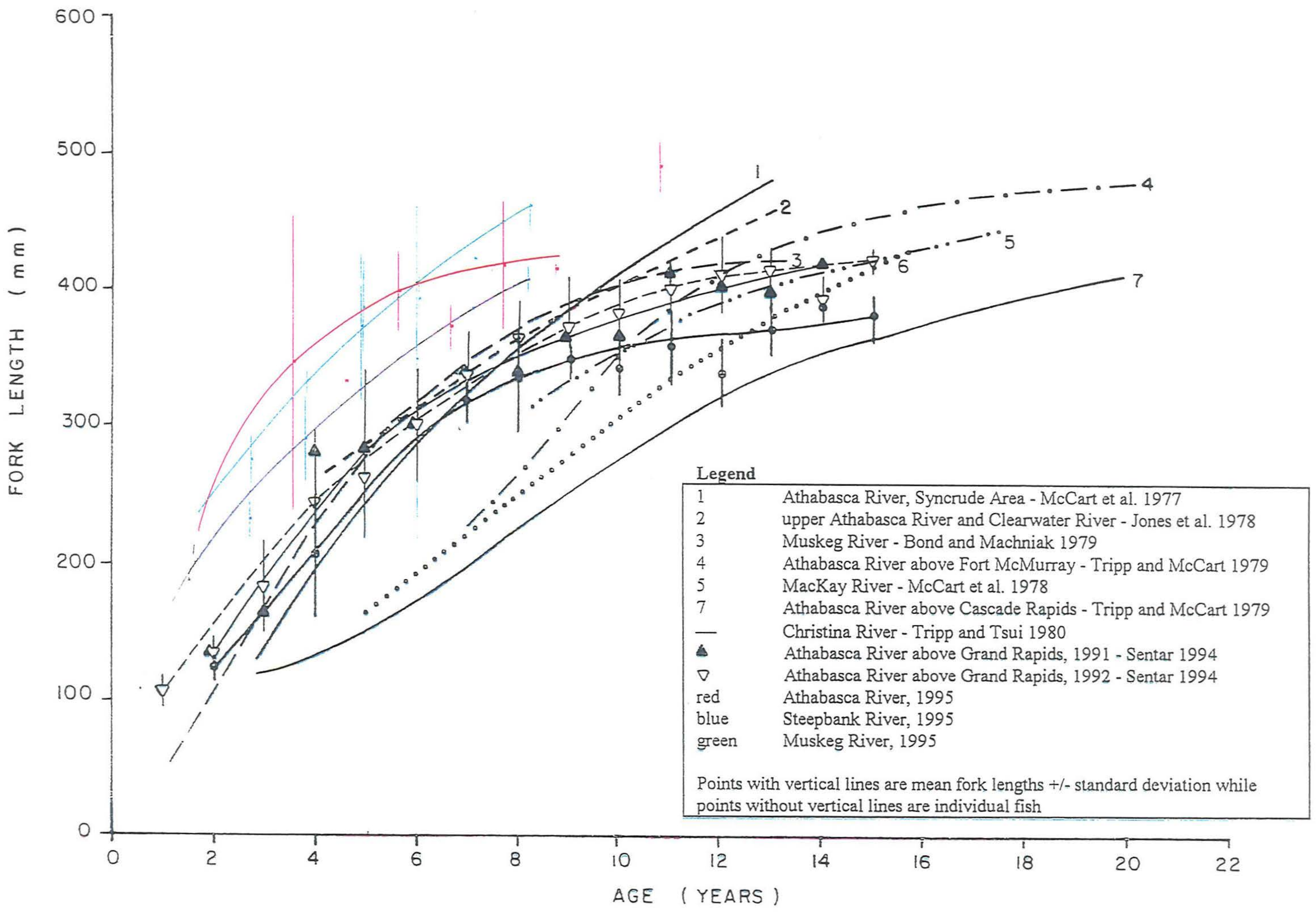

Comparison of Longnose Sucker Length-at-Age from the Present Study with Previous Studies (Adapted from Tripp and Tsui 1980)

Figure 4.3-9

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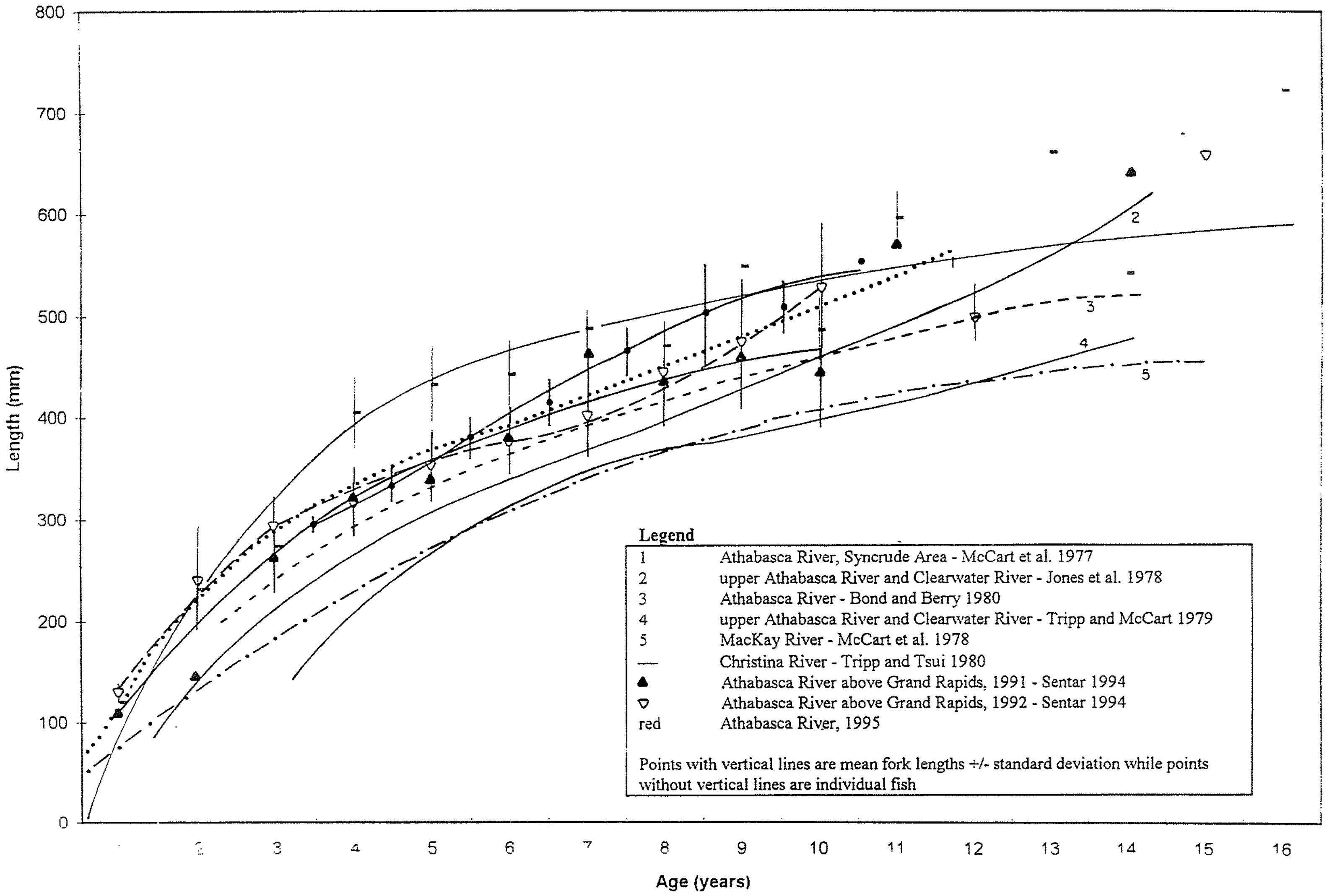

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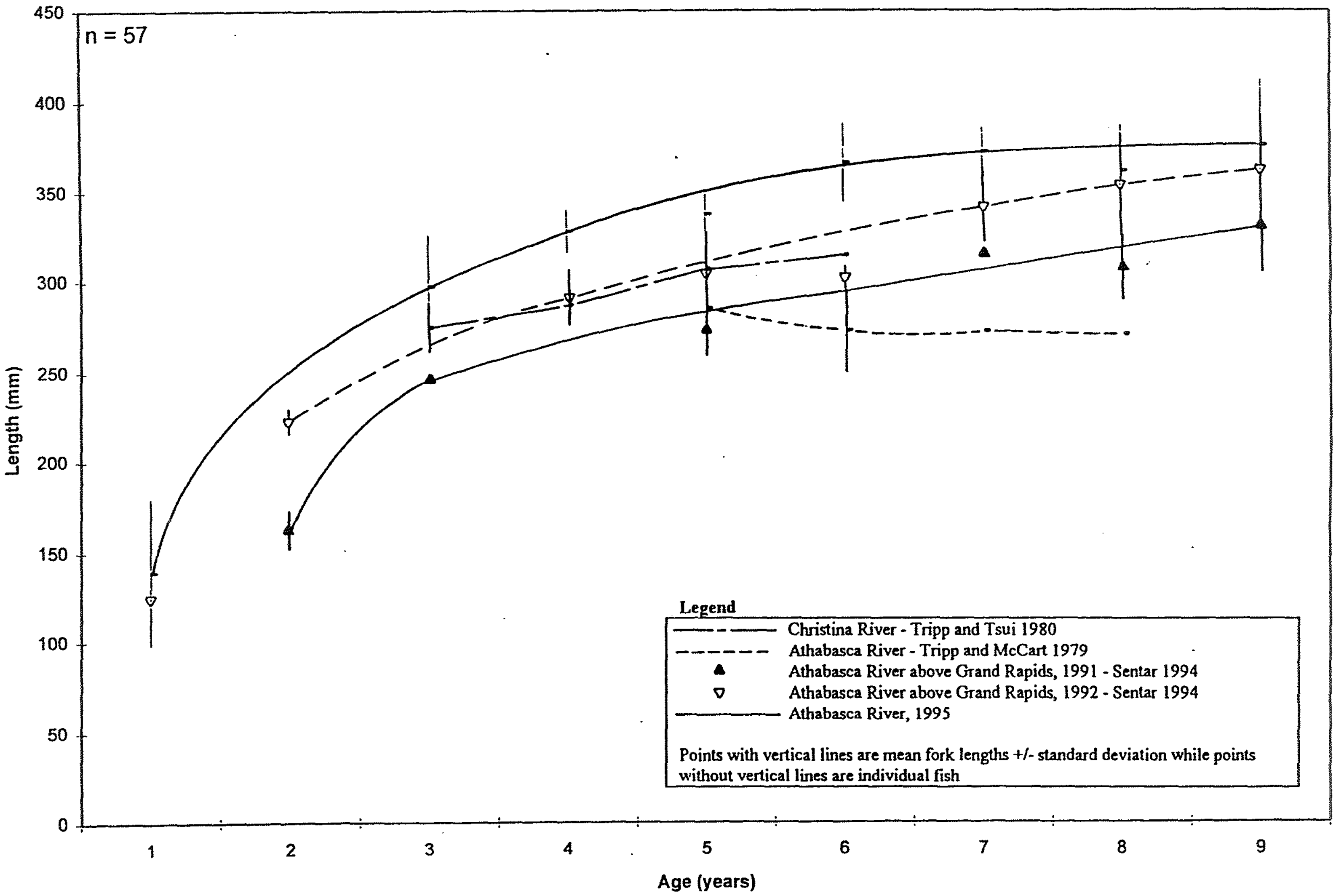
Comparison of Walleye Length-at-Age from the Present Study with Previous Studies (Adapted from Tripp and Tsui 1980)

Figure 4.3-10

PROJECT 952-2307 DRAWN MVZ REVIEWED ______ DATE 7 FEB 96 952-2307.5140



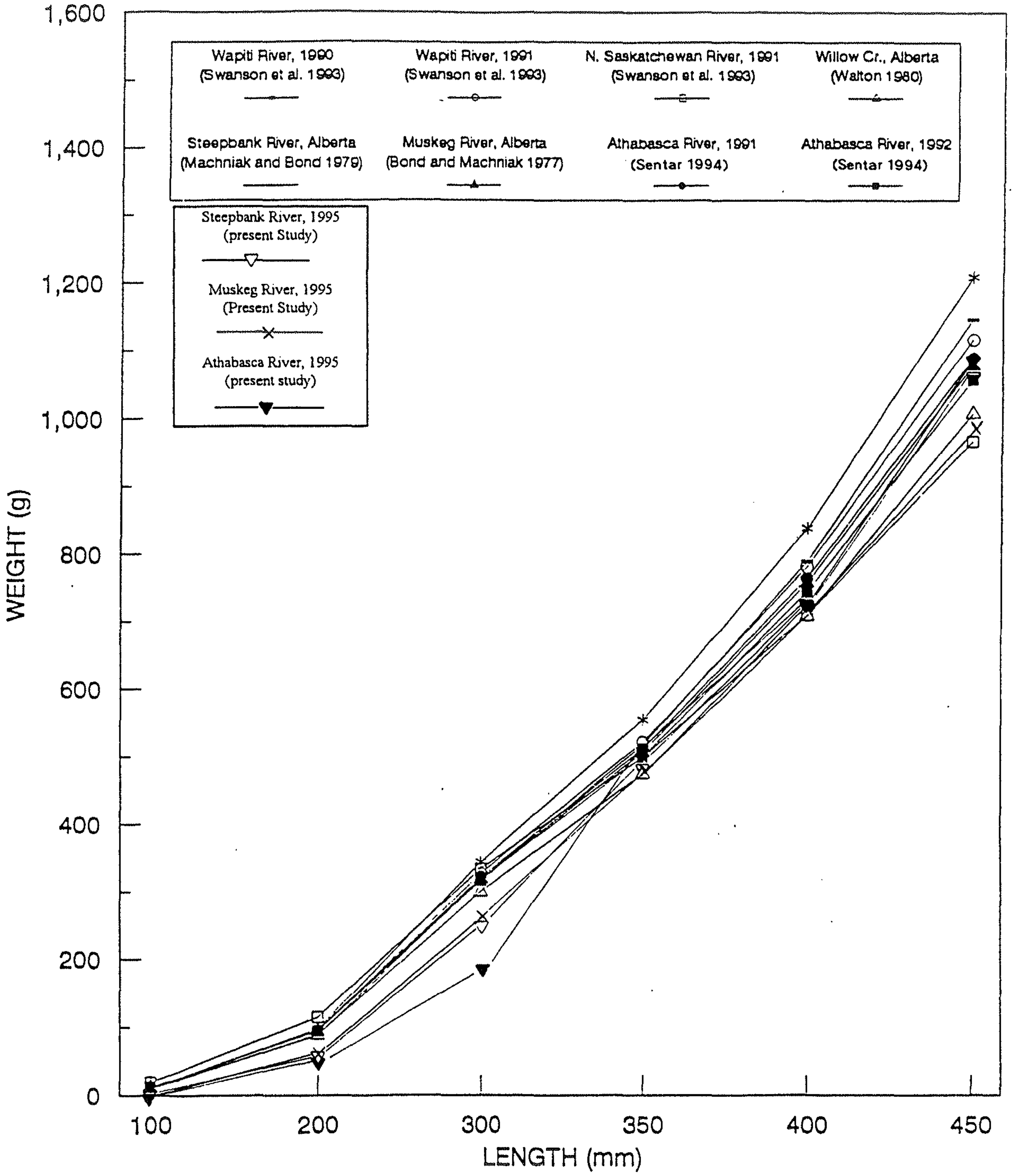
Comparison of Goldeye Length-at-Age from the Present Study and Previous Studies

Figure 4.3-11

Golder Associates

Comparison of Longnose Sucker Length-Weight Relationships from Present and Previous Studies (Adapted from Sentar 1994)

Figure 4.3-12



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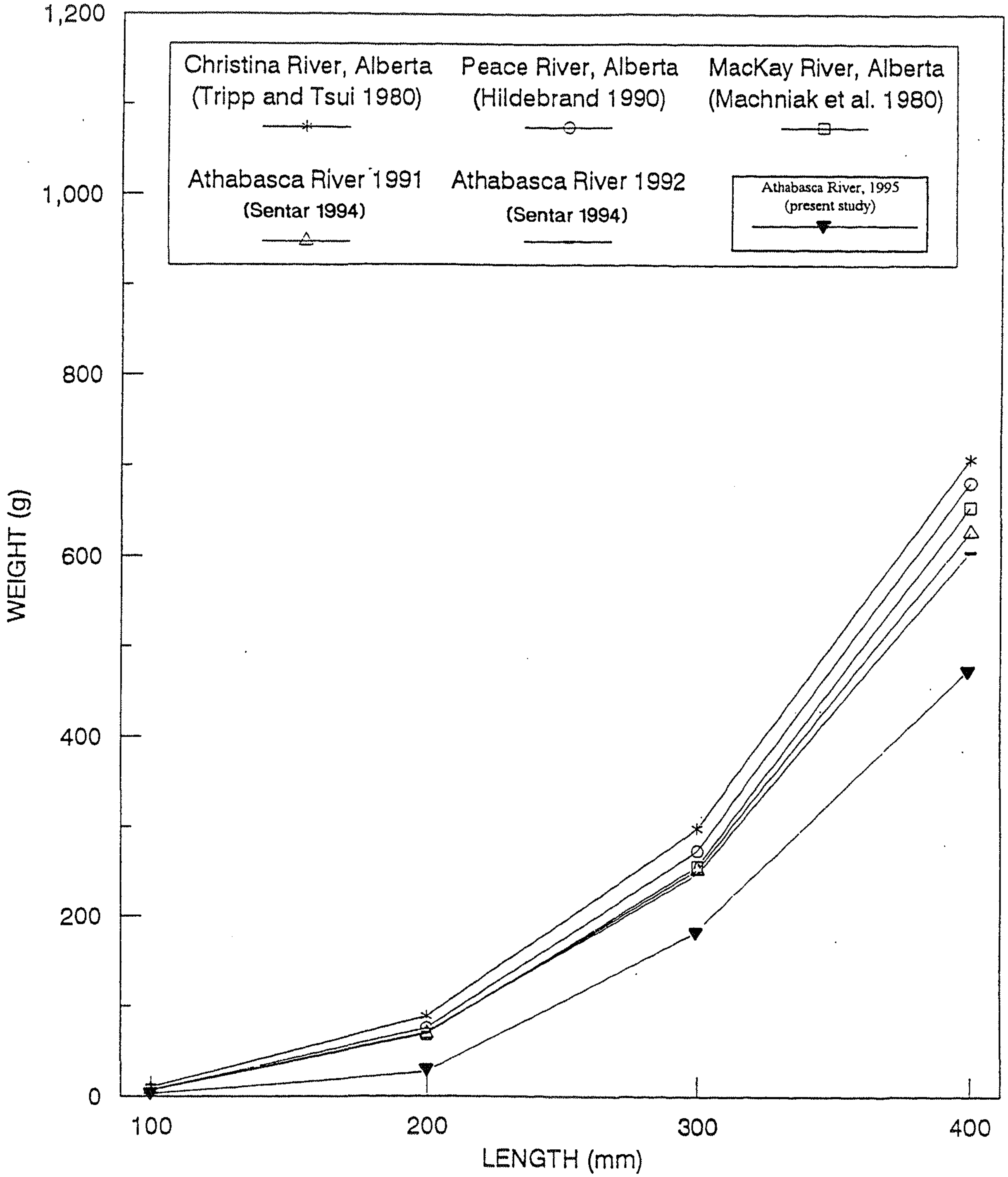
Comparison of Walleye Length-Weight Relationships from Present and Previous Studies (Adapted from Sentar 1994)

Figure 4.3-13

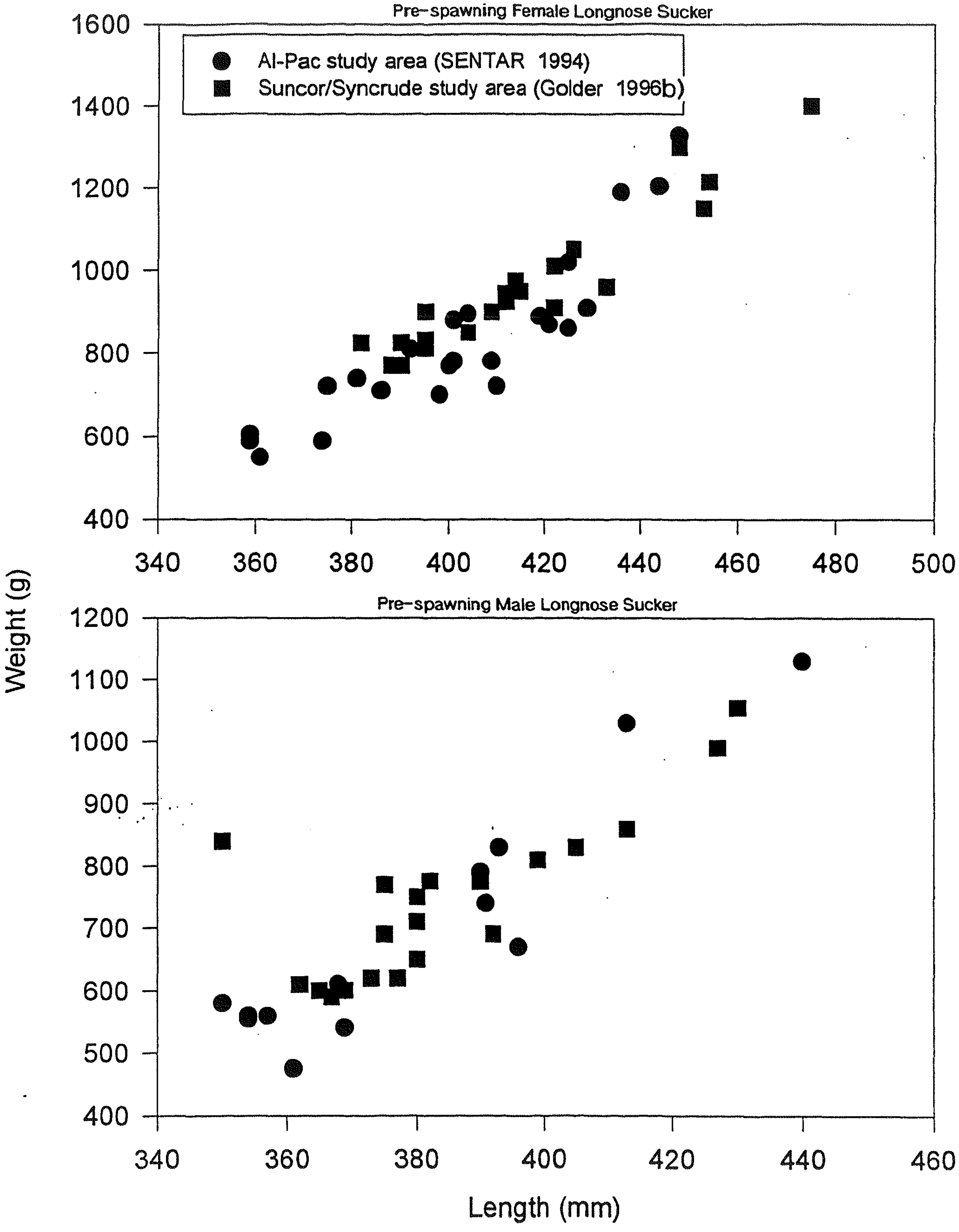


PROJECT 952-2307 DRAWN MVZ REVIEWED ______ DATE 7 FEB 96 952-2307.5140

Comparison of Length-Weight Relationships for Pre-Spawning Longnose Sucker from Al-Pac Mill Baseline Study to Suncor/Syncrude Baseline Data

Figure 4.3-14

* DATA FROM AL PAC MILL BASELINE STUDY PROVIDED BY SENTAR
* DATA ARE FROM FISH USED IN BIOMARKER DETERMINATIONS

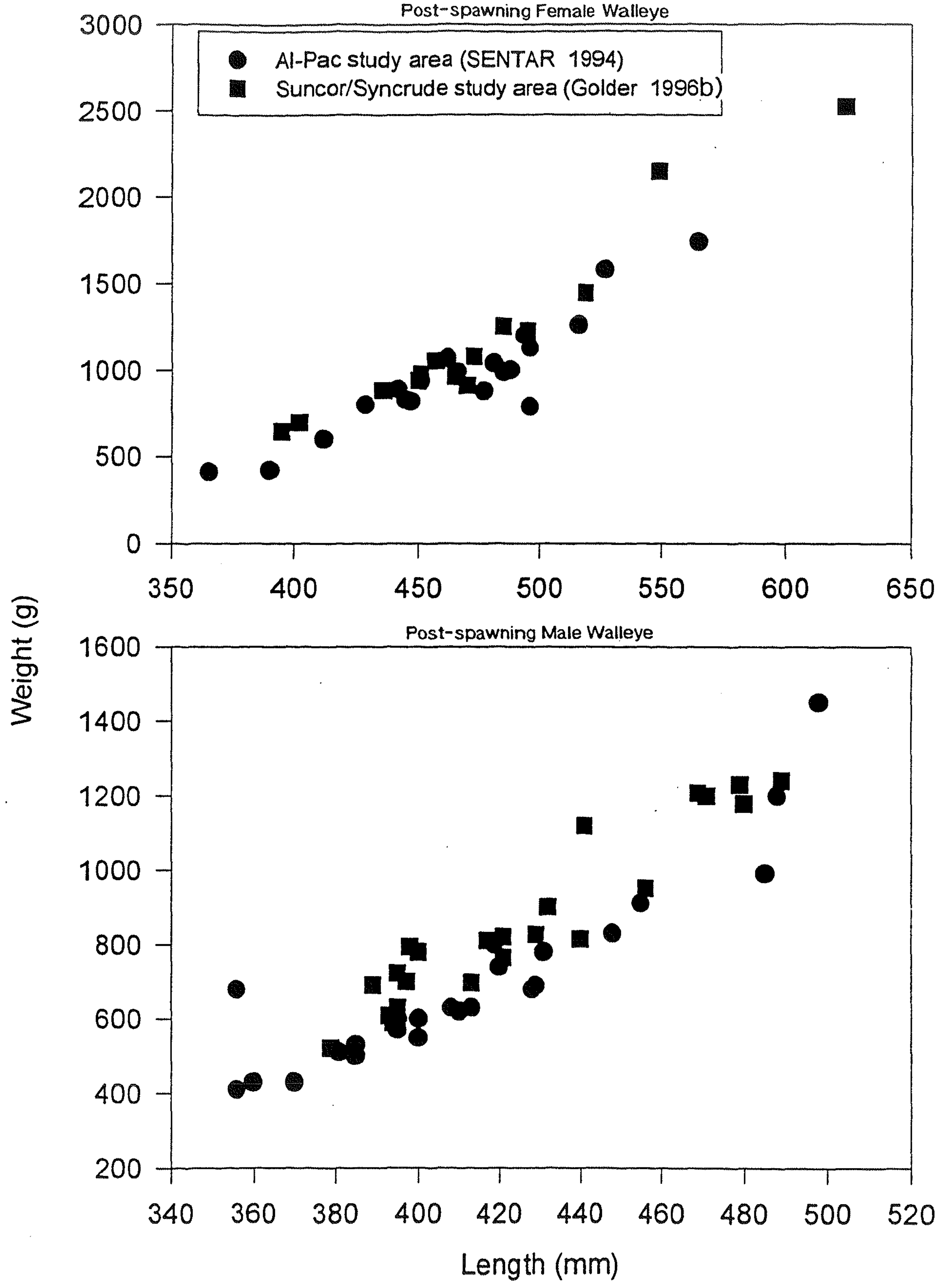


PROJECT 952-2307 DRAWN MVZ REVIEWED ___ DATE 7 FEB 96 952-2307.5140

Comparison of Length-Weight Relationships for Post-Spawning Walleye from Al-Pac Mill Baseline Study to Suncor/Syncrude Baseline Data

Figure 4.3-15

* DATA FROM AL PAC MILL BASELINE STUDY PROVIDED BY SENTAR
* DATA ARE FROM FISH USED IN BIOMARKER DETERMINATIONS



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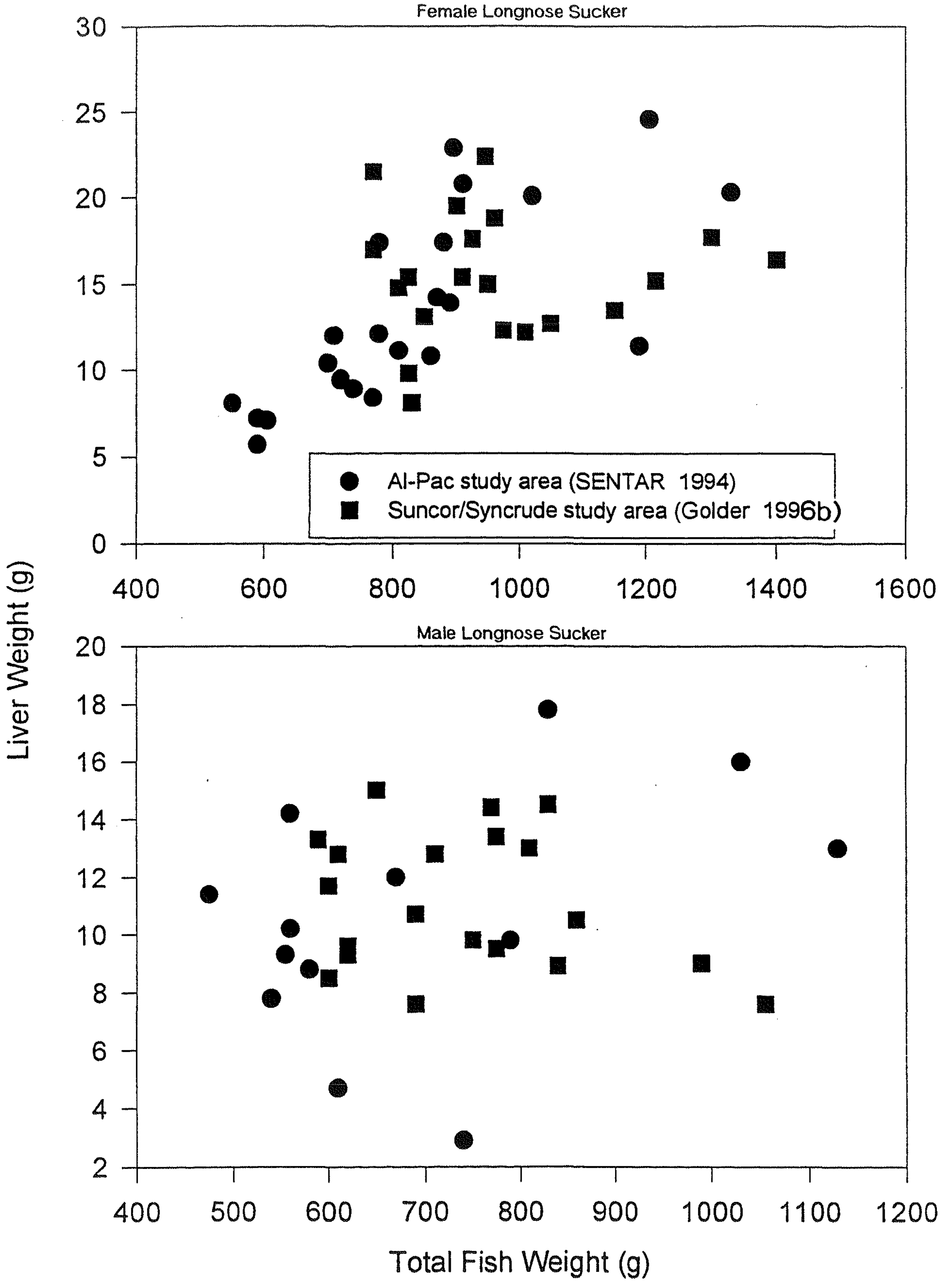
Relationship Between Liver Weight and Total Body Weight for Longnose Sucker from Al-Pac Mill Baseline Study to Suncor/Syncrude Baseline Data

Figure 4.3-16

- DATA FROM AL PAC MILL BASELINE STUDY PROVIDED BY SENTAR
- DATA ARE FROM FISH USED IN BIOMARKER DETERMINATIONS

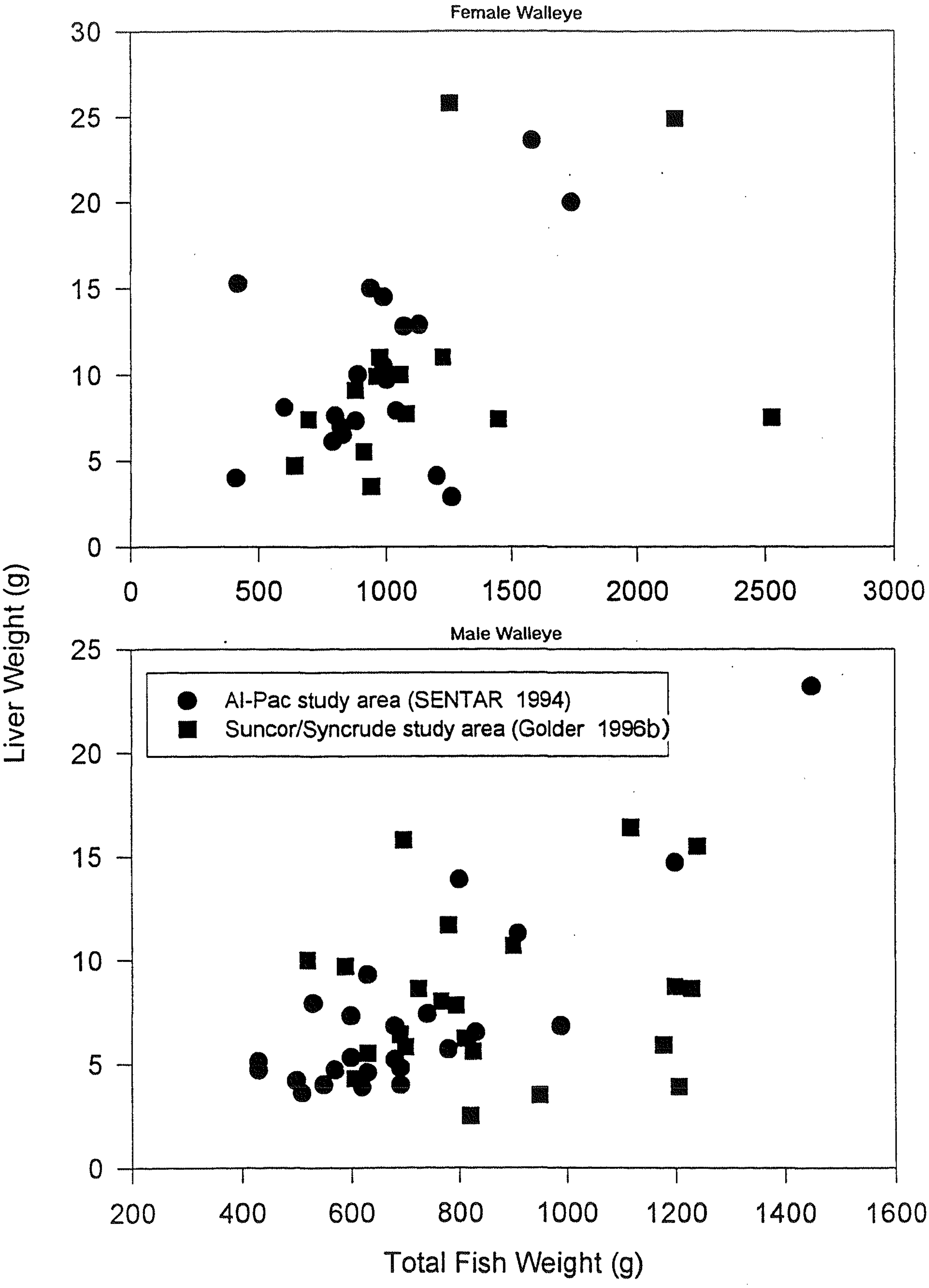


PROJECT 952-2307 DRAWN MVZ REVIEWED ____ DATE 7 FEB 96 952-2307.5140

Relationship Between Liver Weight and Total Body Weight for Walleye from Al-Pac Mill Baseline Study to Suncor/Syncrude Baseline Data

Figure 4.3-17

- DATA FROM AL PAC MILL BASELINE STUDY PROVIDED BY SENTAR
- DATA ARE FROM FISH USED IN BIOMARKER DETERMINATIONS


Female Walleye

Male Walleye

PROJECT 952-2307 DRAWN MVZ REVIEWED ______ DATE 7 FEB 96 952-2307.5140

Relationship Between Gonad Weight and Total Body Weight for Reproductively Mature Longnose Sucker from Al-Pac Mill Baseline Study to Suncor/Syncrude Baseline Data

Figure 4.3-18

* DATA FROM AL PAC MILL BASELINE STUDY PROVIDED BY SENTAR
* DATA ARE FROM FISH USED IN BIOMARKER DETERMINATIONS

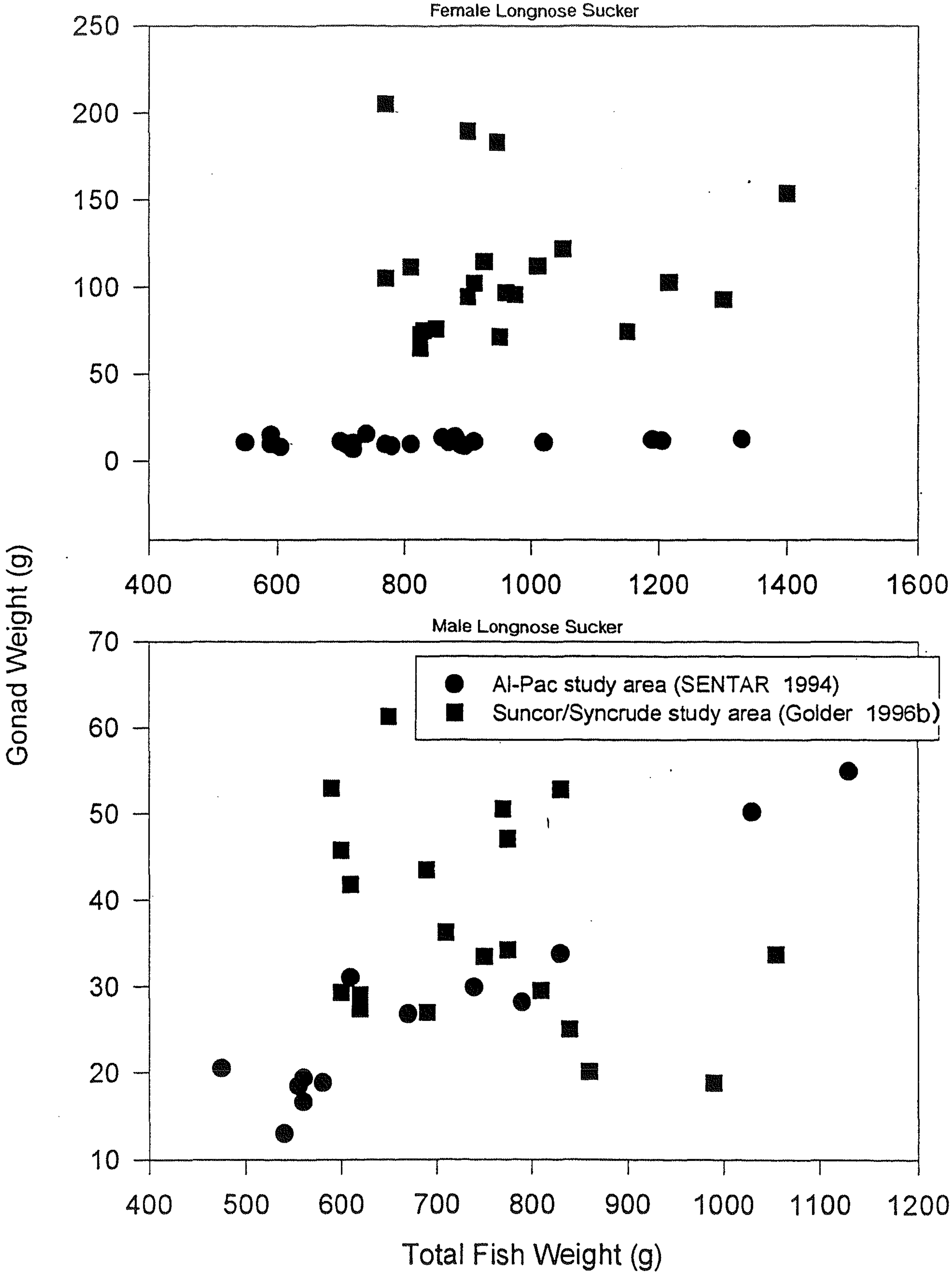


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Figure 4.3-19
Percent Dilution of Suncor Water Releases in the Athabasca River Mean Annual Flow, 1995

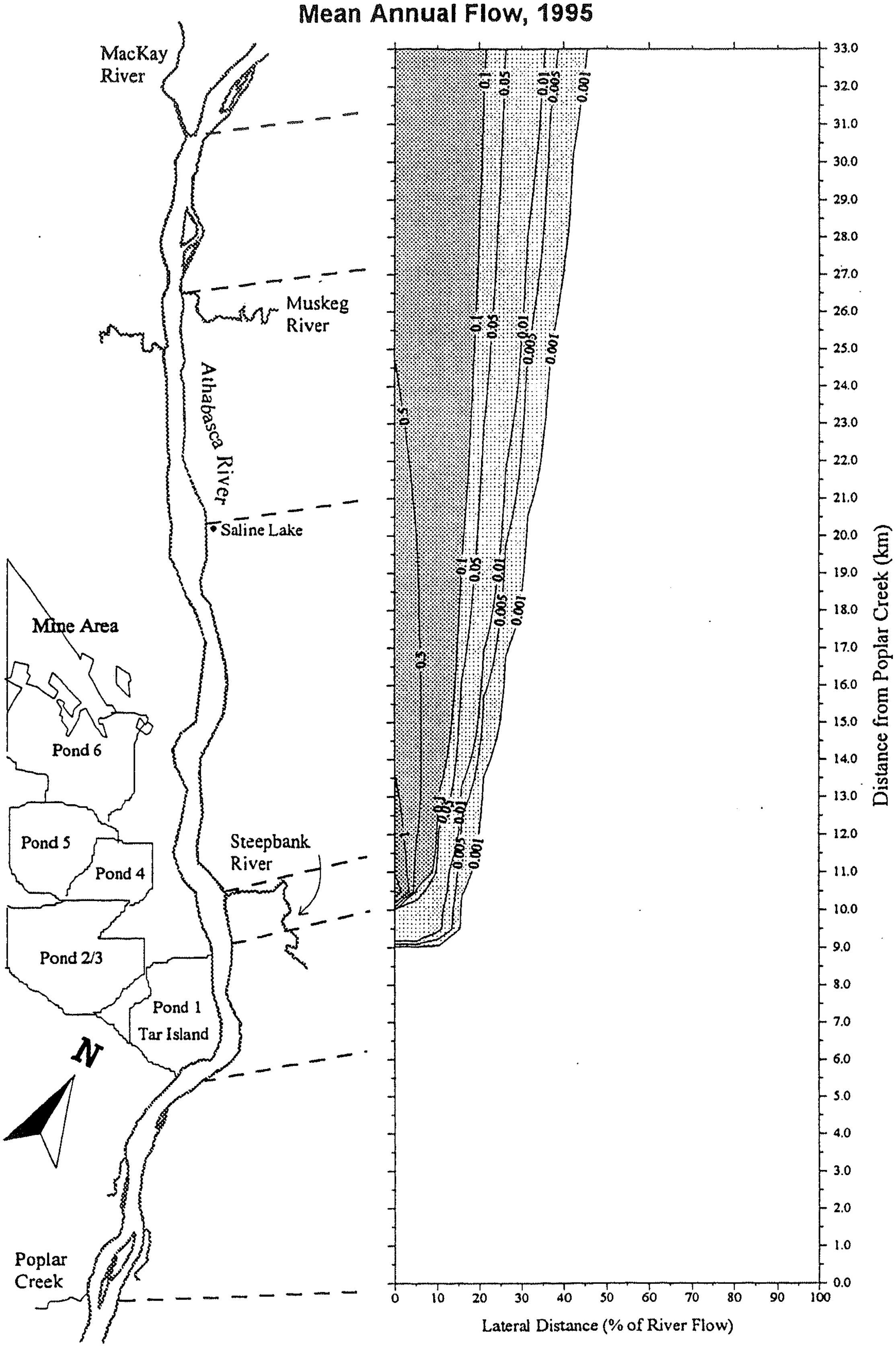

Figure 4.3-20
Percent Dilution of Suncor Water Releases in the Athabasca River
7Q10 Flow, 1995

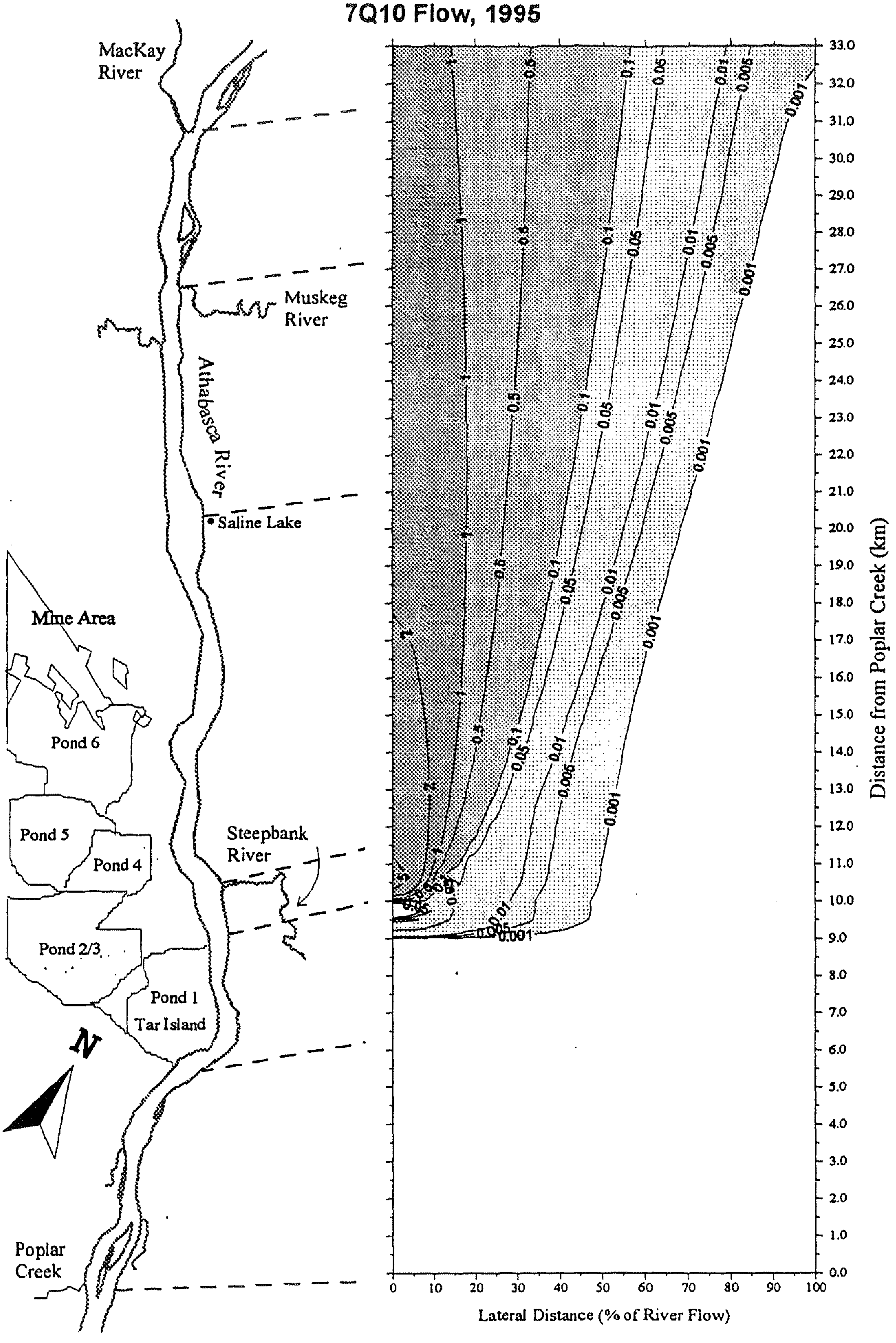

Figure 4.3-21
Percent Dilution of Suncor Water Releases in the Athabasca River Mean Annual Flow, 2001

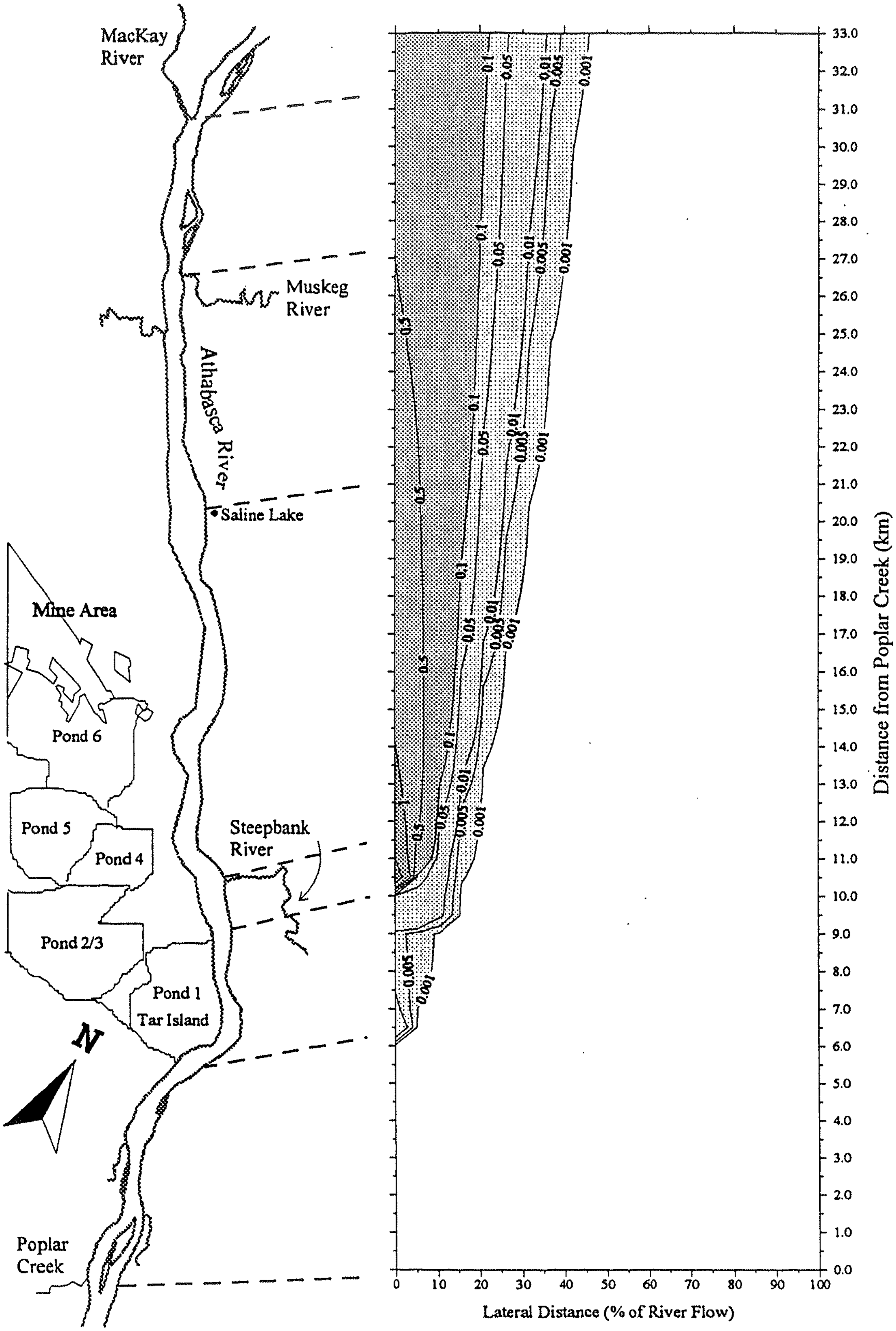

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Figure 4.3-22
Percent Dilution of Suncor Water Releases in the Athabasca River
Mean Annual Flow, 2010

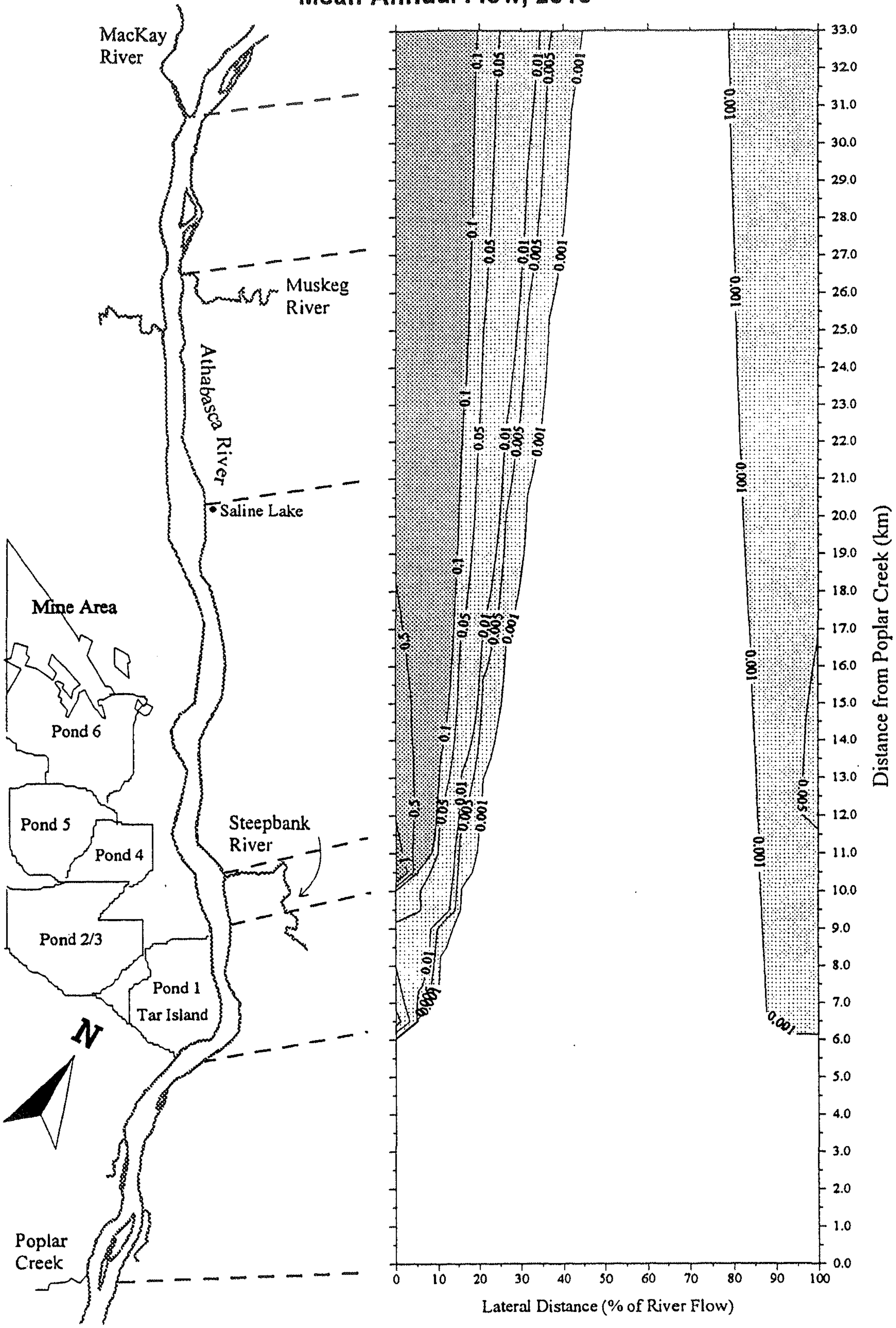

Figure 4.3-23
Percent Dilution of Suncor Water Releases in the Athabasca River
Mean Annual Flow, 2020

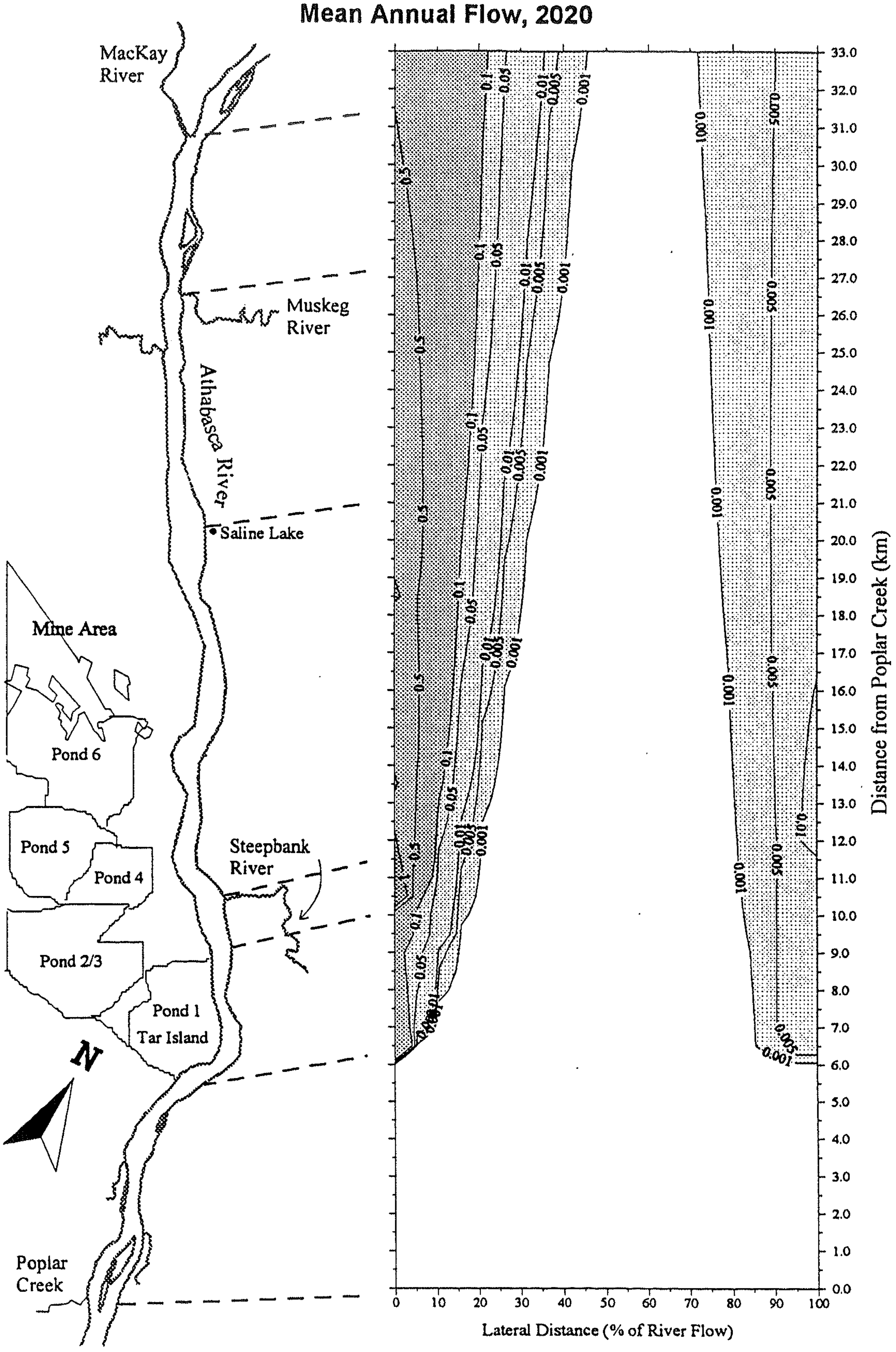

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Figure 4.3-24
Percent Dilution of Suncor Water Releases in the Athabasca River
7Q10 Flow, 2001

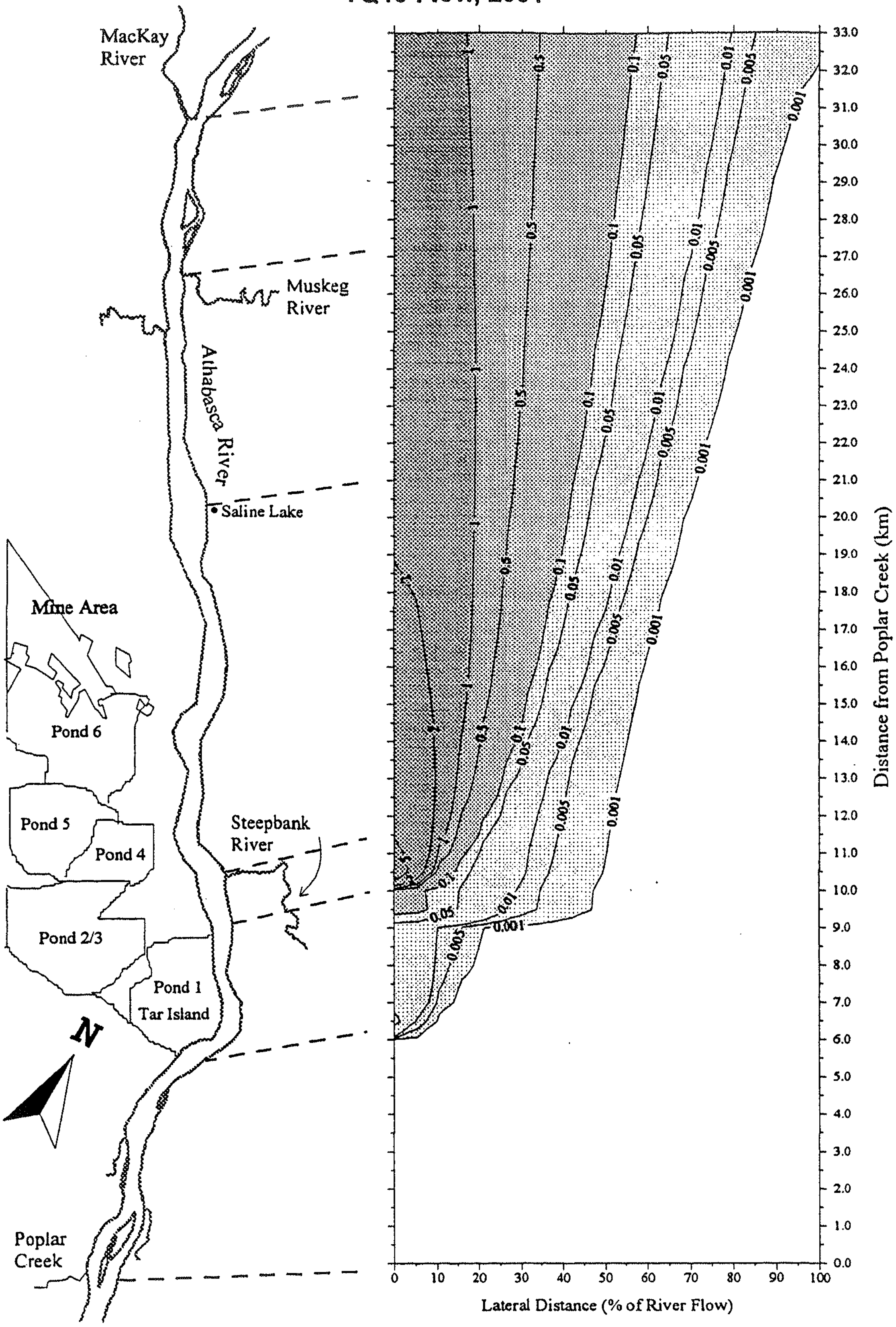


Figure 4.3-25
Percent Dilution of Suncor Water Releases in the Athabasca River
7Q10 Flow, 2010

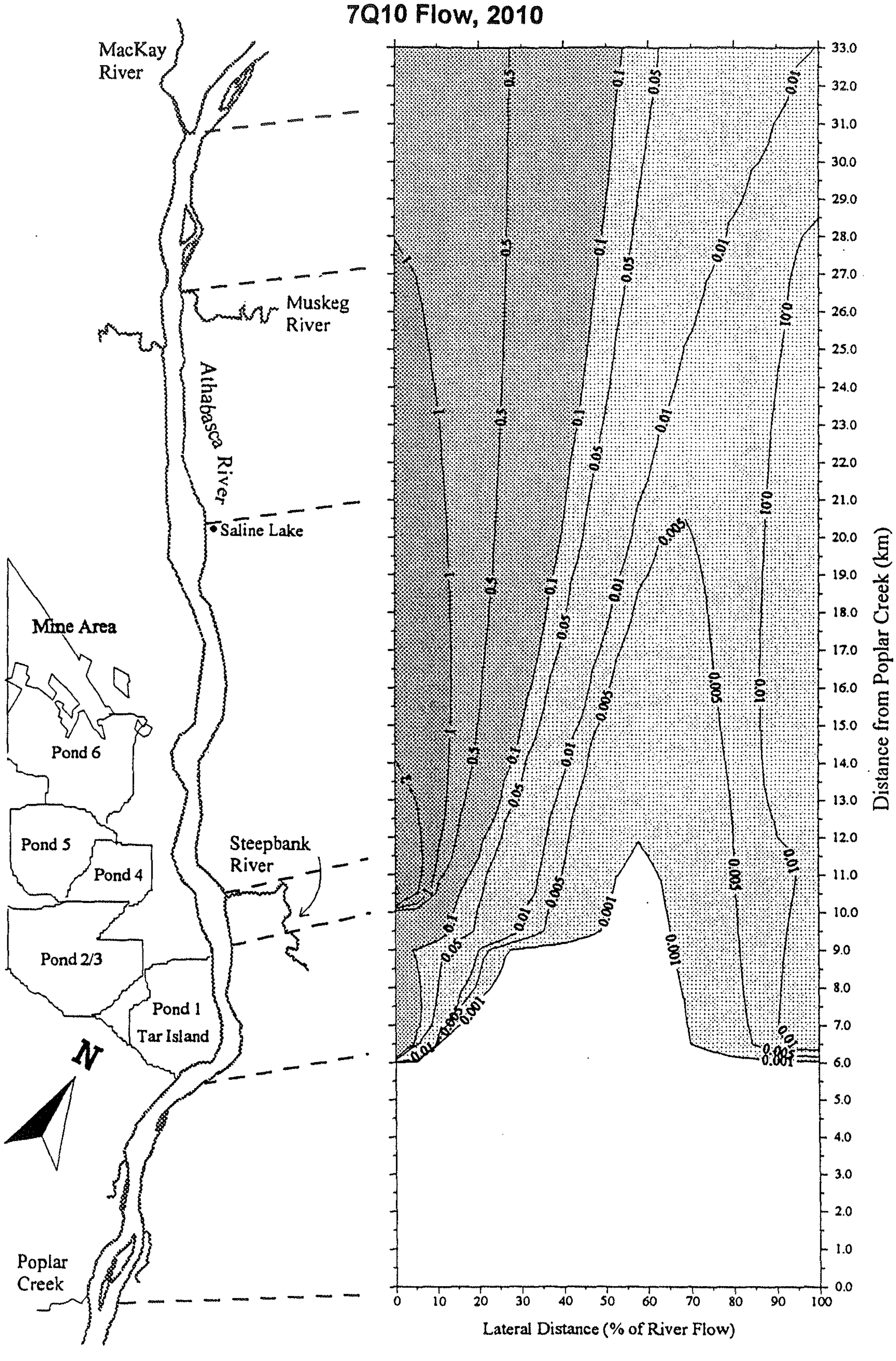


Figure 4.3-26
Percent Dilution of Suncor Water Releases in the Athabasca River
7Q10 Flow, 2020

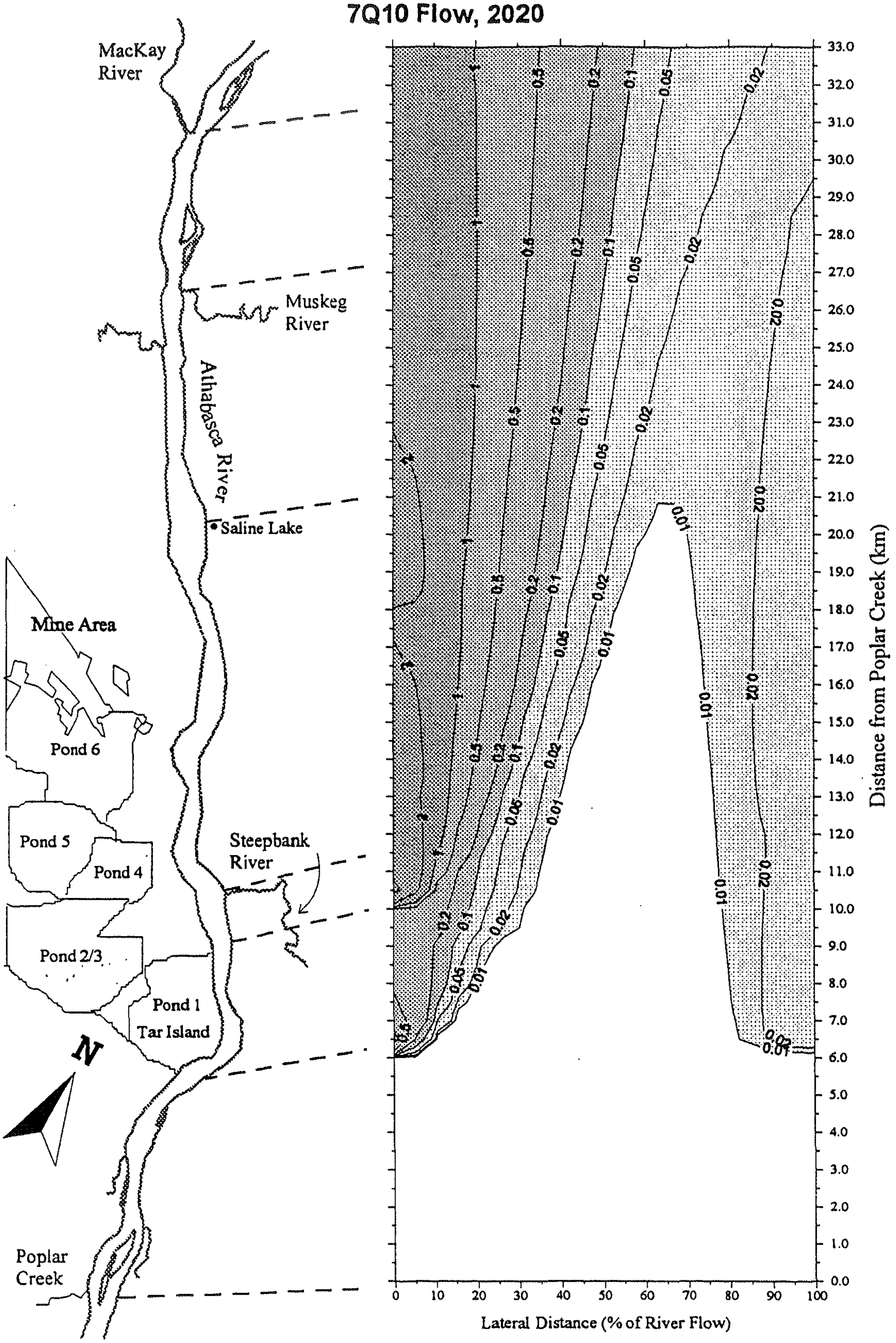


Figure 4.3-27
Percent Dilution of Suncor Water Releases in the Athabasca River Mean Annual Flow, Post-Reclamation

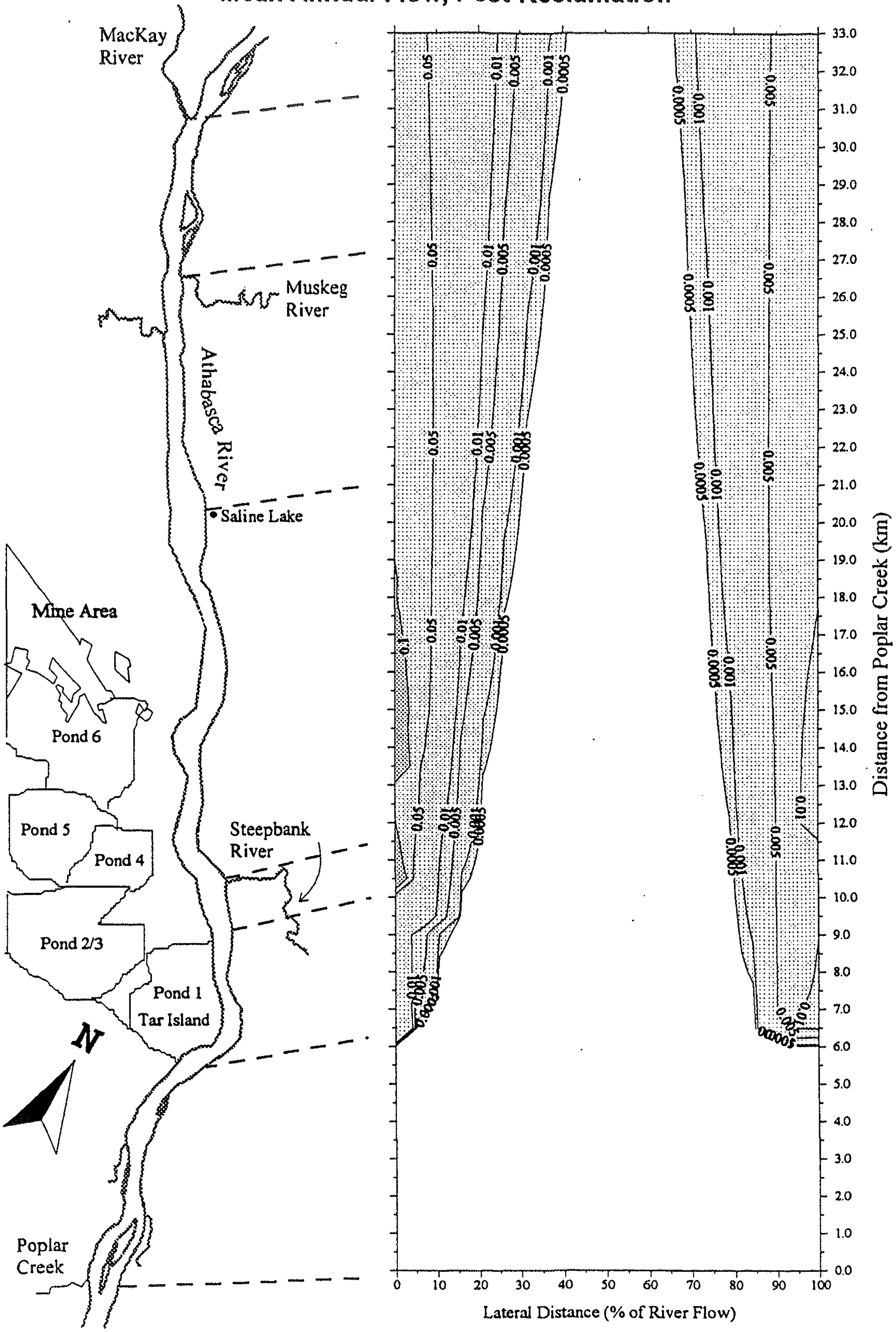


Figure 4.3-28
Percent Dilution of Suncor Water Releases in the Athabasca River
7Q10 Flow, Post-Reclamation

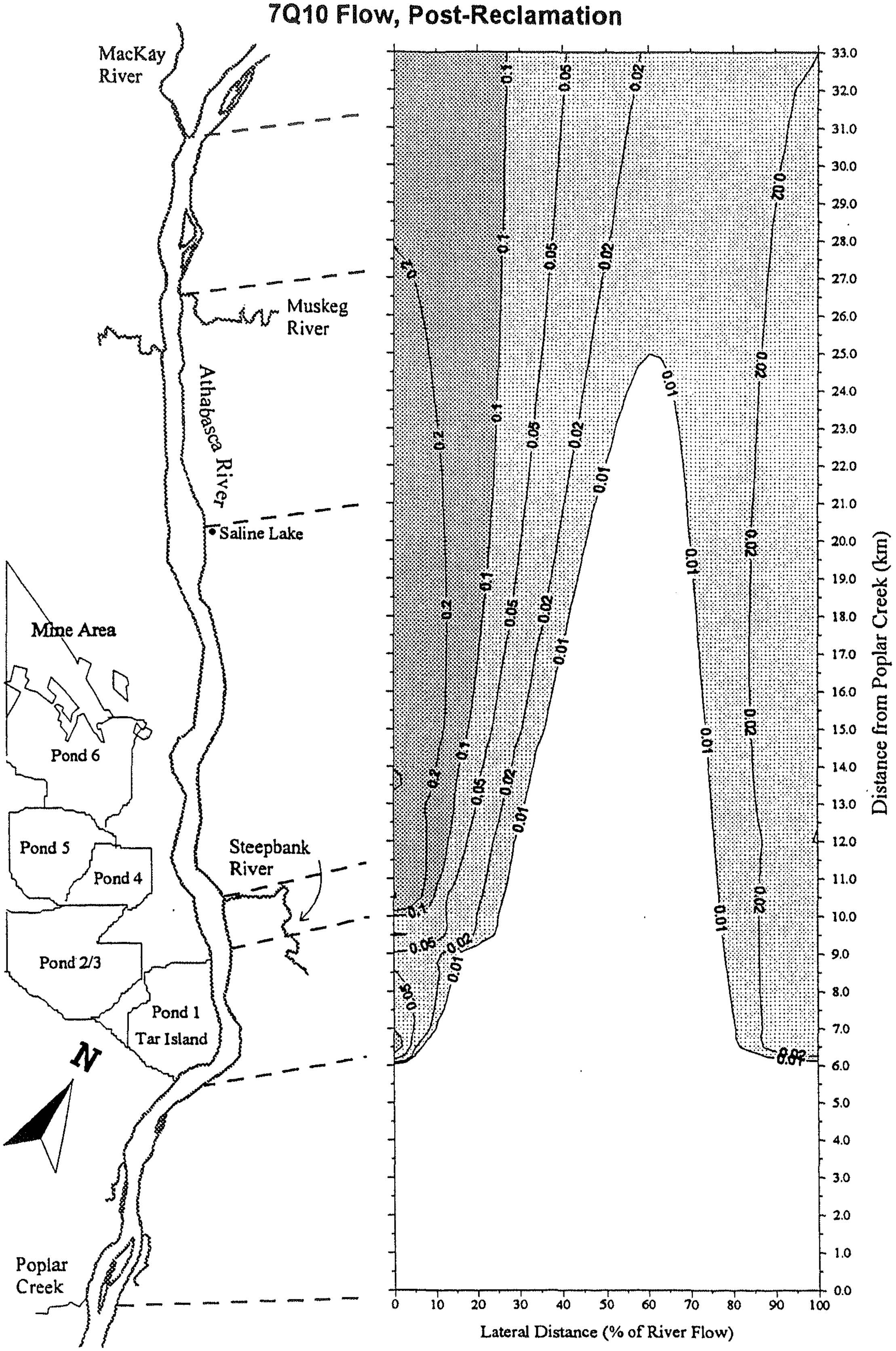


Figure 5.1-1

Problem Formulation

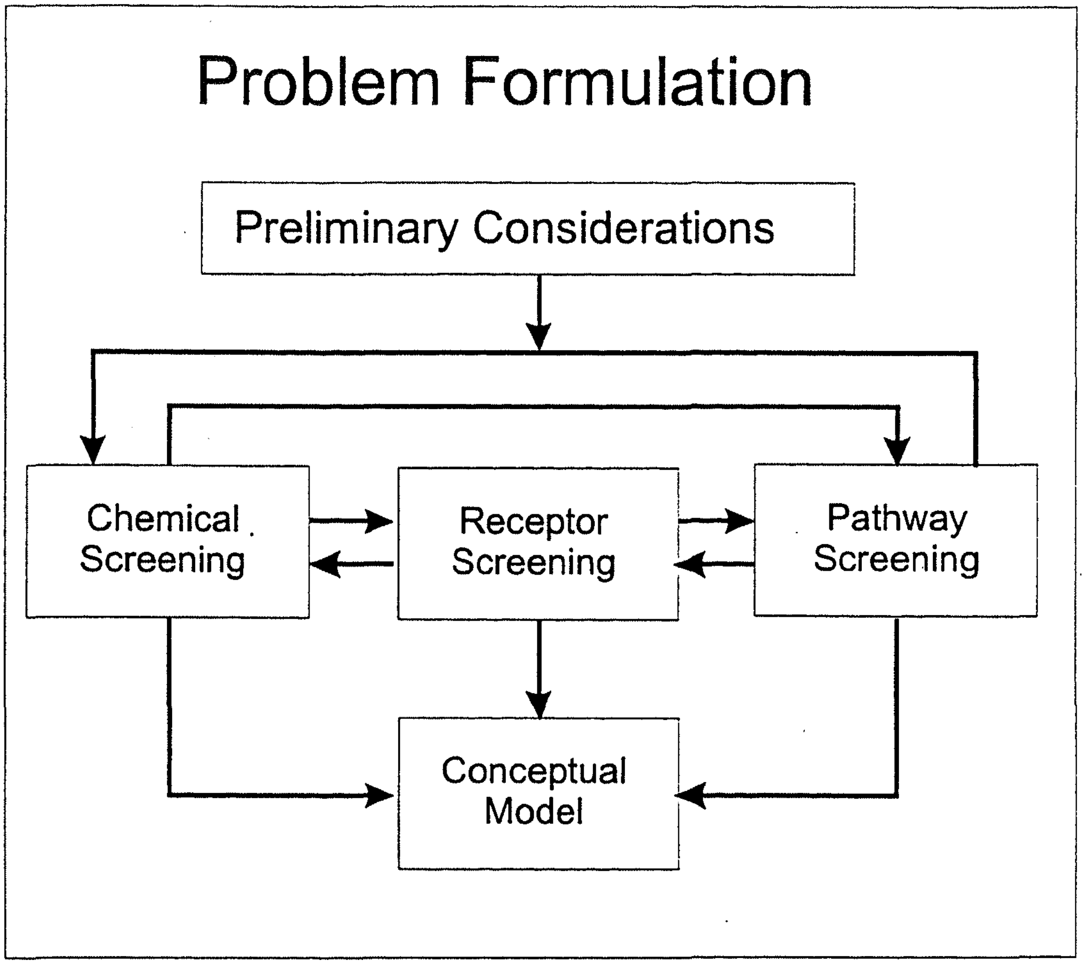


Figure 5.1-2

Risk Components

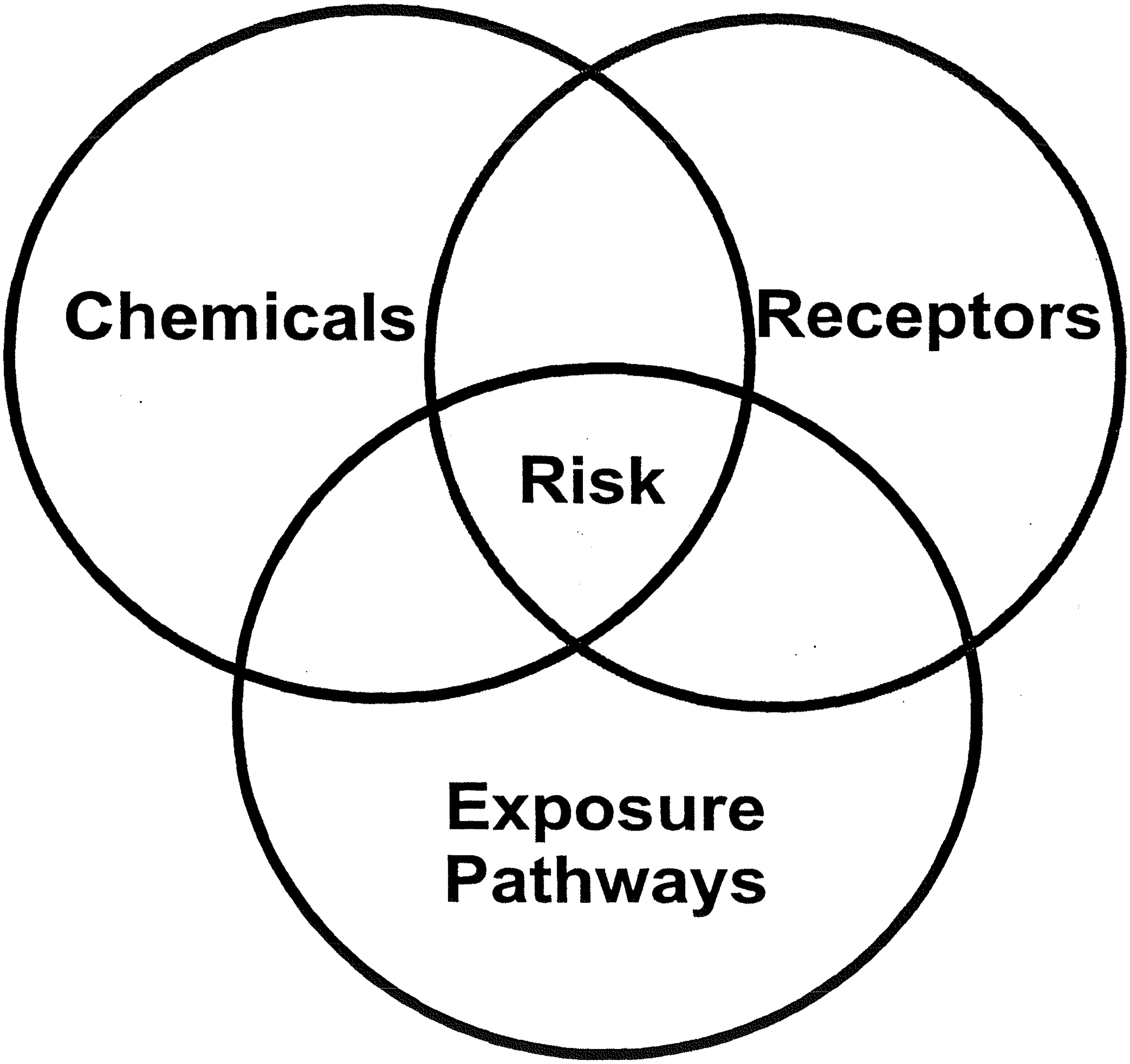


Figure 5.1-3
Process for Chemical Screening

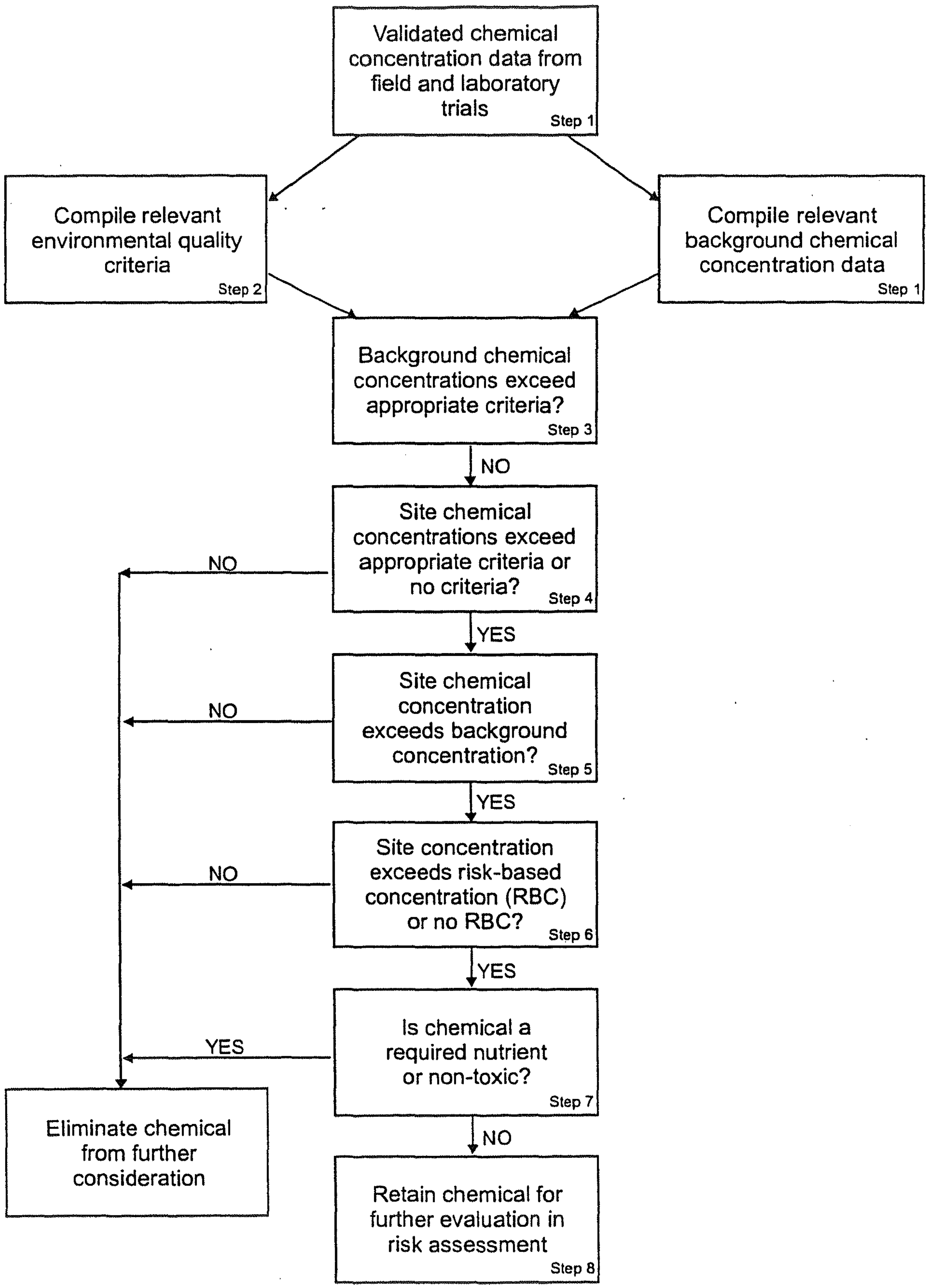
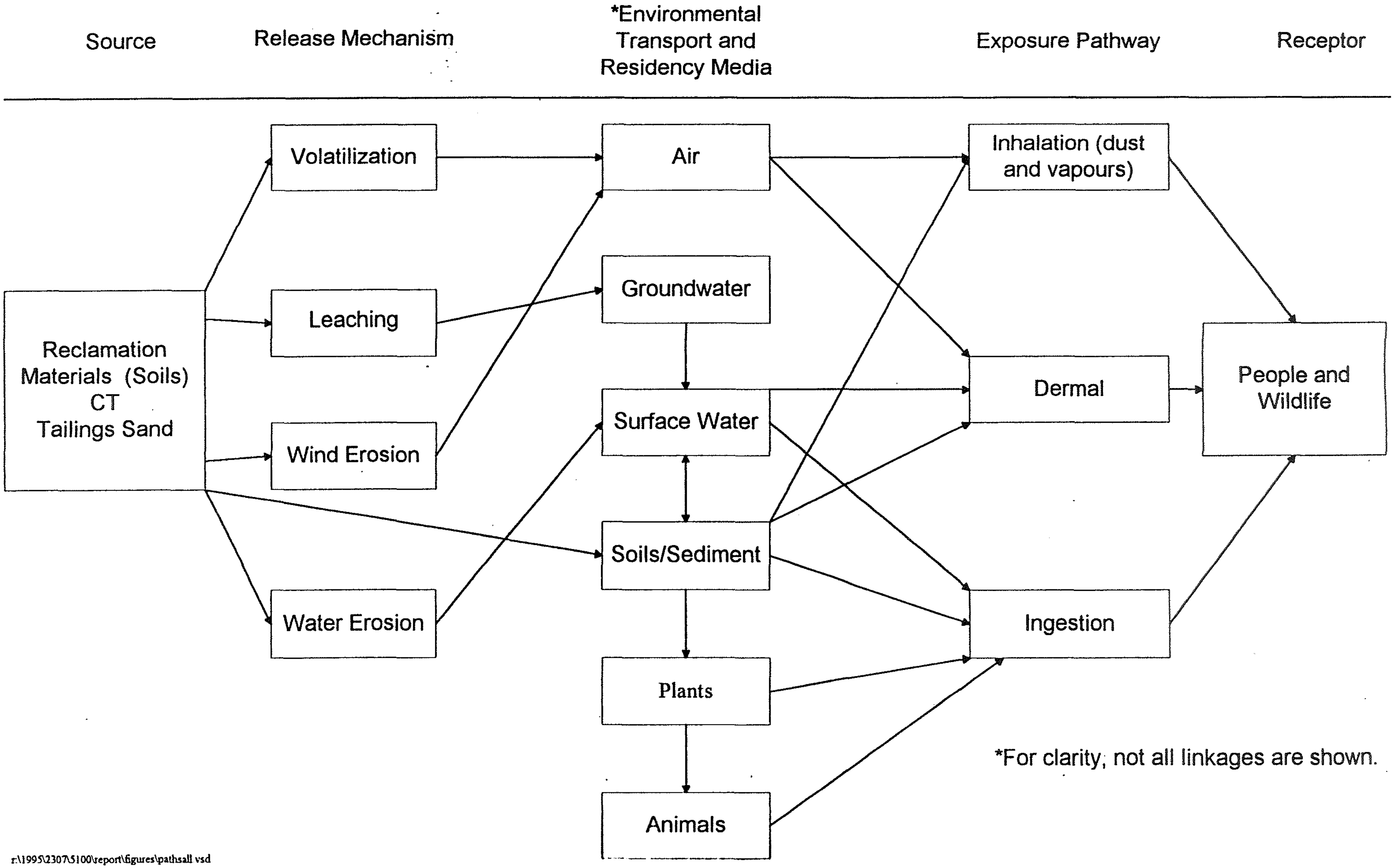


Figure 5.1-4
Potential Pathways For Exposure of People and Wildlife



*For clarity; not all linkages are shown.

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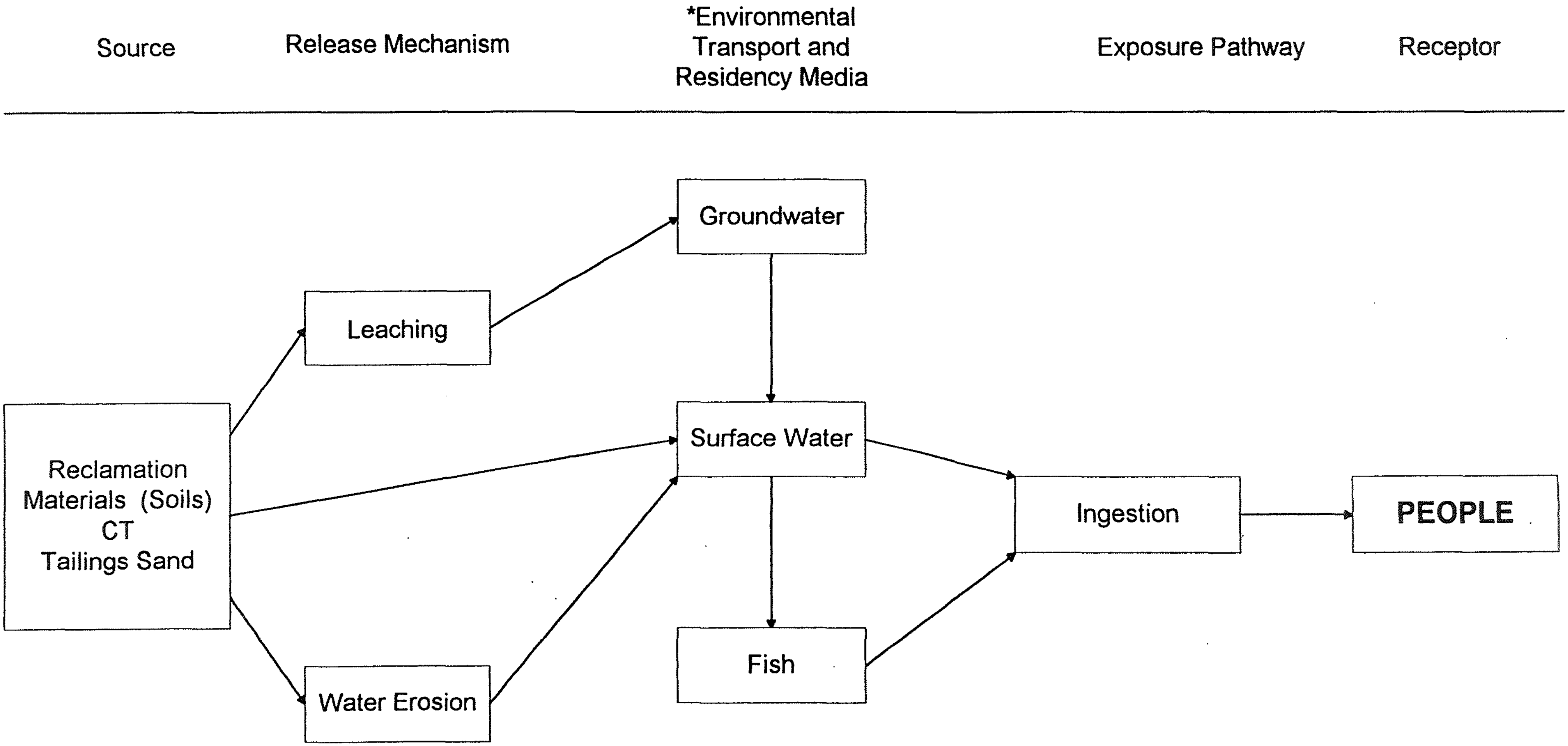
Figure 5.1-5
Conceptual Model For People



*For clarity, not all linkages are shown.

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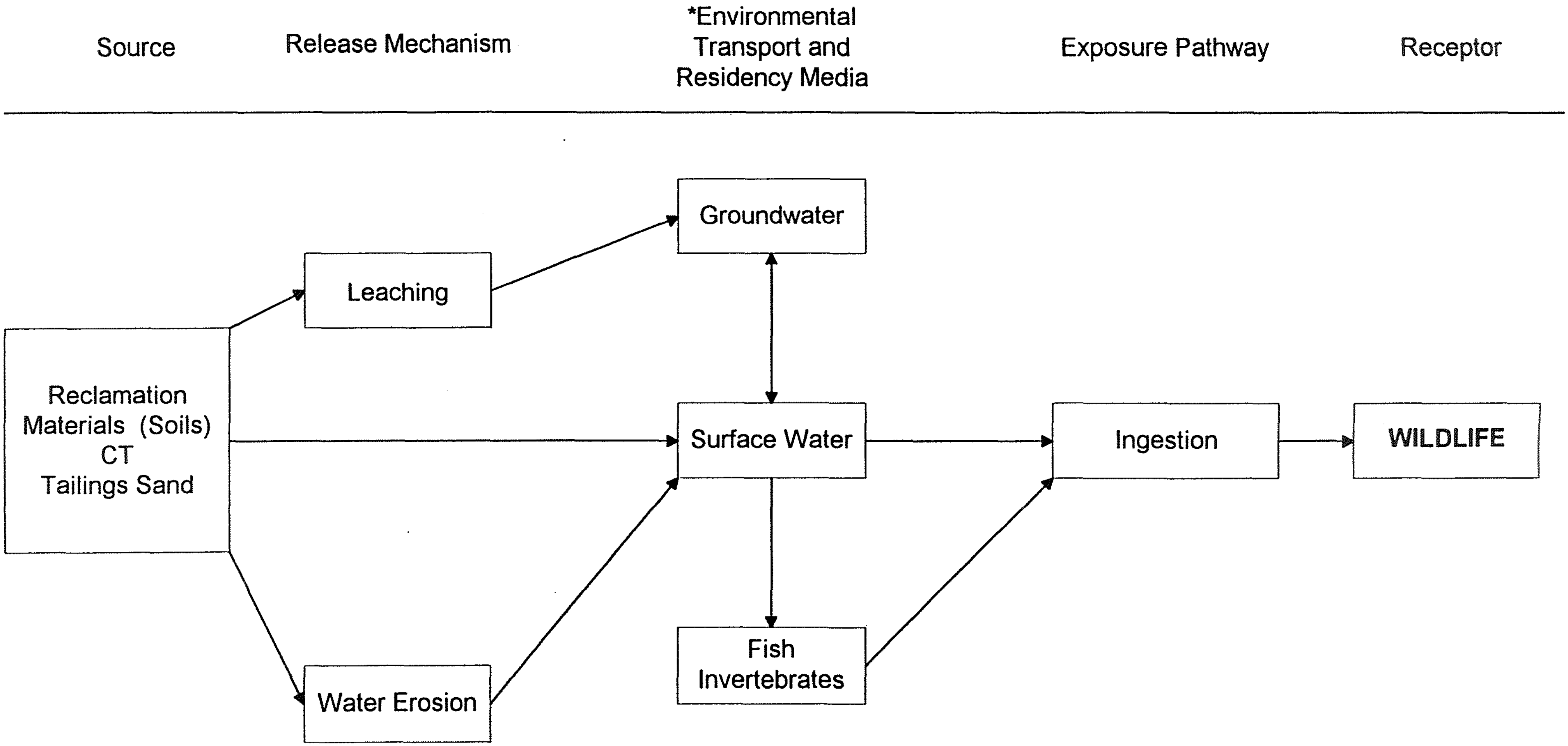
Figure 5.1-6
Conceptual Model For Wildlife



*For clarity, not all linkages are shown.

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APPENDICES

APPENDIX I

RATIONALE FOR CHEMICAL PARAMETER LIST

Naphthenic Acids

Oil sands wastewater and fine tailings originate from extracting bitumen from oil sands, so it is not surprising that the predominant issues identified to date are related to organic compounds. The most important issue with respect to acute toxicity to aquatic organisms is elevated concentrations of naphthenic acids in oil sands tailings recycle and pore waters. Naphthenic acids, which are a complex group of naturally-occurring organic acids/surfactants leached from the oil sands during the hot water extraction process, account for nearly all of the acute toxicity to aquatic organisms of tailings pond water and porewater from Suncor's and Syncrude's wastewater ponds. These compounds naturally detoxify in aerobic environments due to biodegradation, however, it is not known whether significant detoxification occurs within anaerobic groundwater. In addition, these compounds are highly soluble and it is unlikely that they readily partition to solid-phase material. Hence, they are likely persistent and mobile in groundwater, so seepage of naphthenic acids to surface waters is of potential concern.

Benthic invertebrates (small, bottom-dwelling animals) and fish are the primary organisms at risk with respect to exposure to these compounds. The mode of toxicity may be related to adherence of the compounds to organism membranes, thus disrupting oxygen transfer and resulting in suffocation.

Limited naphthenic acids data exists because of the difficulty in measuring naphthenic acid concentrations. However, Syncrude Canada Ltd. has developed a promising method for quantifying total naphthenic acid concentrations using FTIR and absorbance at two wave numbers present in the 1700-1800 cm^{-1} range. Typical naphthenic aids concentrations based on the FTIR method range from 1-2 mg/L in the Athabasca River to over 100 mg/L in fresh tailings water.

Substituted PAHs and PASHs

While concentrations of unsubstituted polycyclic aromatic hydrocarbons (PAHs) are generally low or below detection limits even in tailings pond recycle water, the presence of alkyl-substituted PAHs is an emerging issue. In many oil sands waste samples, concentrations of alkyl-substituted PAHs are considerably higher than the parent compounds. The lower molecular weight PAHs (2-3 rings such as naphthalene and phenanthrene) are generally more acutely toxic to aquatic organisms than the higher molecular weight PAHs. However, the higher weight PAHs have a greater affinity to lipids and therefore bioconcentrate more in animal tissue. Hence, they are a potential issue with respect to food chain biomagnification. Further, alkyl-substituted PAHs are a particular concern because alkyl substituents may enhance both the carcinogenic potency and the persistence of these compounds.

Another issue is the potential for tainting of fish flesh, primarily associated with polycyclic aromatic sulphur heterocycles (PASHs) such as dibenzothiophene and alkyl-substituted dibenzothiophenes. These compounds have been detected in oil sands wastewater and in the Athabasca River downstream of Suncor's lease. PASHs are generally more persistent and more toxic than other PAHs. In addition, they readily bioaccumulate in animal tissues .

PANHs

Polycyclic aromatic nitrogen heterocycles (PANHs) such as quinoline and alkyl-substituted quinolines have been identified in both natural and synthetic crude oils. These compounds have been detected in oil sands wastewater and in the Athabasca River downstream of Suncor's lease. PANHs can be toxic, teratogenic, mutagenic, and/or carcinogenic.

Non-Chlorinated Phenols

Concentrations of phenols and cresols ranging from 25-152 μg/L have been measured in samples from Syncrude's settling pond. A number of simple alkylphenols were also identified in the pond samples. Samples from dyke drainage, groundwaters and surface waters contained <1 μg/L of the simple phenols analyzed and did not contain any of the simple alkylphenols identified in the MLSB samples. A sample of surface water that drained over exposed oil sands contained low concentrations of phenol (4 μg/L) but no detectable concentrations of cresols or simple alkylphenols. Low concentrations of simple phenols are of concern because of the potential for tainting fish flesh.

Volatile Organics

Low molecular weight, non-polar, volatile organic compounds represent another potential issue as they account for up to 20 % of the acute toxicity of Suncor's Pond 1A surface water. The exact compound(s) causing the toxicity have not been identified, however, naphtha, which is used as a dilutant in the bitumen froth treatment, is likely the source of these light-end hydrocarbons.

Oil and Grease/Total Extractable Hydrocarbons

TEH is a parameter that indicates of the quantity of hydrocarbons in a sample. Typically, the bulk of hydrocarbons in process-affected waters are in the C_{15} to C_{28} range, which is consistent with the presence of naphthenic acids. In addition, work on Suncor's constructed wetlands indicates that the GC chromatographs can serve as a useful marker to monitor oil sands wastewater and to assist in identifying the source of hydrocarbons in water. However, since (1) most of the TEH in process-affected waters and in natural waters exposed to bitumen is naphthenic acids and (2) naphthenic acids are being measured on all water samples collected from the site, it would be redundant to measure TEH in water samples. We are, therefore, proposing to measure oil and grease, gravimetrically, following silica gel clean-up. Silica gel removes polar compounds (such as naphthenic acids), thus, the residual represents the non-polar component of the hydrocarbons.

Cyanide and Phenolics

These groups of compounds are associated with oil sands water and are potentially toxic to aquatic life.

Organic Carbon and Particle Size

Organic carbon content and particle size of soils are key parameters to assist in understanding partitioning between water and sediments and are required for modelling contaminant-fate processes.

Nutrients

The nutrients nitrogen and phosphorus are essential elements for growth of plants in aquatic environments. However, high levels of these nutrients can lead to excessive plant growth in lakes and streams. In addition, ammonia-nitrogen is toxic to aquatic life at high concentrations.

Metals and Trace Elements

Metal concentrations in Suncor's process-affected waters are typically within the range observed in background groundwater and surface waters; the only notable exception appears to be arsenic. Arsenic is, however, toxic to aquatic life and wildlife and is classed as a human carcinogen. Lead has also been observed at relatively high concentrations in emergent insects from Suncor's constructed wetlands.

APPENDIX II

GROUPING OF CHEMICALS FOR SCREENING AND THE USE OF TOXICITY SURROGATES

Chemical Groupings

All chemicals detected were classified and grouped for screening purposes according to their structure and physiochemical and toxicological properties.

Closely-related chemicals were combined together 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 1.

Selection of Surrogate Toxicity Values for Screening Purposes

For the purpose of risk-based screening, all the chemicals of a group are 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;
- 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 was available data 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 of these chemical groups and other chemicals are listed in Table II-1.

TABLE II-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[1]
Benzo(ghi)perylene	• benzo(ghi)perylene	pyrene
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
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
Acridine Group	• acridine • methyl acridine	anthracene
Quinoline Group	• quinoline • 7-methyl quinoline • C_2 alkyl substituted quinolines	pyridine

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

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

[3] Based on phenanthrene as there was sufficient laboratory data for ecological receptors.

APPENDIX III

RATIONALE FOR NOAELS AND RISK-BASED CONCENTRATIONS FOR CHEMICAL SCREENING

TABLE III-1

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Soil[2] Ingestion Rate (kg/day)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg soil)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L)
Water Shrew										
Acenaphthylene	2.3	13	6.50E-04	-	0.01235	0.001987	46252	-	2434	15130
Acenaphthene	2.3	13	6.50E-04	-	0.01235	0.001987	46252	-	2434	15130
Benzo(a)anthracene	1.3	13	6.50E-04	-	0.01235	0.001987	26430	-	1391	8646
Benzo(a)pyrene	0.13	13	6.50E-04	-	0.01235	0.001987	2643	-	139	865
Benzo(ghi)perylene	13	13	6.50E-04	-	0.01235	0.001987	264295	-	13910	86458
Biphenyl	6.6	13	6.50E-04	-	0.01235	0.001987	132148	-	6955	43229
Dibenzothiophene	1.0	13	6.50E-04	-	0.01235	0.001987	19822	-	1043	6484
Fluorene	1.7	13	6.50E-04	-	0.01235	0.001987	33037	-	1739	10807
Fluoranthene	1.0	13	6.50E-04	-	0.01235	0.001987	19822	-	1043	6484
Naphthalene	1.8	13	6.50E-04	-	0.01235	0.001987	35151	-	1850	11499
Phenanthrene	0.53	13	6.50E-04	-	0.01235	0.001987	10572	-	556	3458
Pyrene	0.99	13	6.50E-04	-	0.01235	0.001987	19822	-	1043	6484
Acridine	13	13	6.50E-04	-	0.01235	0.001987	264295	-	13910	86458
Quinoline	0.30	13	6.50E-04	-	0.01235	0.001987	5994	-	315	1961
Chloroform	4.5	13	6.50E-04	-	0.01235	0.001987	89914	-	4732	29413
Ethylbenzene	2.9	13	6.50E-04	-	0.01235	0.001987	58205	-	3063	19040
Toluene	3.4	13	6.50E-04	-	0.01235	0.001987	68664	-	3614	22462
Xylenes	0.27	13	6.50E-04	-	0.01235	0.001987	5444	-	287	1781
2,4-Dimethylphenol	0.66	13	6.50E-04	-	0.01235	0.001987	13215	-	696	4323
m-cresol	92	13	6.50E-04	-	0.01235	0.001987	1838956	-	96787	601571
Antimony	0.017	13	6.50E-04	-	0.01235	0.001987	330	-	17	108
Barium	1.6	13	6.50E-04	-	0.01235	0.001987	32611	-	1716	10668
Manganese	26	13	6.50E-04	-	0.01235	0.001987	527498	-	27763	172559
Molybdenum	0.70	13	6.50E-04	-	0.01235	0.001987	14050	-	739	4596
Strontium	79	13	6.50E-04	-	0.01235	0.001987	1576500	-	82974	515715
Tin	0.18	13	6.50E-04	-	0.01235	0.001987	3597	-	189	1177
Uranium	0.40	13	6.50E-04	-	0.01235	0.001987	7929	-	417	2594

TABLE III-1

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Soil[2] Ingestion Rate (kg/day)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg soil)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L)
Vanadium	0.057	13	6.50E-04	-	0.01235	0.001987	1140	-	60	373
Zirconium	0.23	13	6.50E-04	-	0.01235	0.001987	4593	-	242	1503
River Otter										
Acenaphthylene	2.8	7.698	0.30792	-	0.3678	0.6214	69	-	58	34
Acenaphthene	2.8	7.698	0.30792	-	0.3678	0.6214	69	-	58	34
Benzo(a)anthracene	1.6	7.698	0.30792	-	0.3678	0.6214	39	-	33	19
Benzo(a)pyrene	0.16	7.698	0.30792	-	0.3678	0.6214	3.9	-	3.3	1.9
Benzo(ghi)perylene	16	7.698	0.30792	-	0.3678	0.6214	393	-	329	195
Biphenyl	7.9	7.698	0.30792	-	0.3678	0.6214	197	-	165	97
Dibenzothiophene	1.2	7.698	0.30792	-	0.3678	0.6214	30	-	25	15
Fluorene	2.0	7.698	0.30792	-	0.3678	0.6214	49	-	41	24
Fluoranthene	1.2	7.698	0.30792	-	0.3678	0.6214	30	-	25	15
Naphthalene	2.1	7.698	0.30792	-	0.3678	0.6214	52	-	44	26
Phenanthrene	0.63	7.698	0.30792	-	0.3678	0.6214	16	-	13	7.8
Pyrene	1.2	7.698	0.30792	-	0.3678	0.6214	30	-	25	15
Acridine	16	7.698	0.30792	-	0.3678	0.6214	393	-	329	195
Quinoline	0.36	7.698	0.30792	-	0.3678	0.6214	8.9	-	7.5	4.4
Chloroform	5.4	7.698	0.30792	-	0.3678	0.6214	134	-	112	66
Ethylbenzene	3.5	7.698	0.30792	-	0.3678	0.6214	87	-	73	43
Toluene	4.1	7.698	0.30792	-	0.3678	0.6214	102	-	86	51
Xylenes	0.32	7.698	0.30792	-	0.3678	0.6214	8.1	-	6.8	4.0
2,4-Dimethylphenol	0.79	7.698	0.30792	-	0.3678	0.6214	19.7	-	16.5	9.7
m-cresol	109	7.698	0.30792	-	0.3678	0.6214	2737.4	-	2291.7	1356
Antimony	0.020	7.698	0.30792	-	0.3678	0.6214	0.49	-	0.41	0.24
Barium	1.9	7.698	0.30792	-	0.3678	0.6214	49	-	41	24
Copper	5.9	7.698	0.30792	-	0.3678	0.6214	148	-	124	73
Manganese	31	7.698	0.30792	-	0.3678	0.6214	785	-	657	389
Molybdenum	0.84	7.698	0.30792	-	0.3678	0.6214	21	-	18	10

TABLE III-1

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Soil[2] Ingestion Rate (kg/day)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg soil)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L)
Nickel	14	7.698	0.30792	-	0.3678	0.6214	357	-	299	177
Strontium	94	7.698	0.30792	-	0.3678	0.6214	2347	-	1965	1163
Tin	0.21	7.698	0.30792	-	0.3678	0.6214	5.4	-	4.5	2.7
Uranium	0.47	7.698	0.30792	-	0.3678	0.6214	11.8	-	9.9	5.8
Vanadium	0.068	7.698	0.30792	-	0.3678	0.6214	1.7	-	1.4	0.84
Zinc	57	7.698	0.30792	-	0.3678	0.6214	1428	-	1195	707
Zirconium	0.27	7.698	0.30792	-	0.3678	0.6214	6.8	-	5.7	3.4
Killdeer										
Acenaphthylene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Acenaphthene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Benzo(a)anthracene	0.18	0.0989	0.001125	-	0.0154	0.02179	15	-	1.1	0.80
Benzo(a)pyrene	0.018	0.0989	0.001125	-	0.0154	0.02179	1.6	-	0.11	0.081
Benzo(ghi)perylene	1.8	0.0989	0.001125	-	0.0154	0.02179	154	-	11	8.0
Dibenzothiophene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Fluoranthene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Fluorene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Phenanthrene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Pyrene	49	0.0989	0.001125	-	0.0154	0.02179	4287	-	313	221
Acridine	36	0.0989	0.001125	-	0.0154	0.02179	3158	-	231	163
Barium	22	0.0989	0.001125	-	0.0154	0.02179	1975	-	144	102
Manganese	349	0.0989	0.001125	-	0.0154	0.02179	30683	-	2241	1584
Molybdenum	17	0.0989	0.001125	-	0.0154	0.02179	1529	-	112	79
Uranium	37	0.0989	0.001125	-	0.0154	0.02179	3276	-	239	169
Vanadium	26	0.0989	0.001125	-	0.0154	0.02179	2280	-	167	118
Great Blue Heron										
Acenaphthylene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Acenaphthene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Benzo(a)anthracene	0.062	2.204	0.08816	-	0.09757	0.2223	1.6	-	1.4	0.62

TABLE III-1

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

Page 4 of 4

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Soil[2] Ingestion Rate (kg/day)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg soil)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L)
Benzo(a)pyrene	0.0063	2.204	0.08816	-	0.09757	0.2223	0.16	-	0.14	0.063
Benzo(ghi)perylene	0.62	2.204	0.08816	-	0.09757	0.2223	16	-	14	6.2
Dibenzothiophene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Fluoranthene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Fluorene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Phenanthrene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Pyrene	17	2.204	0.08816	-	0.09757	0.2223	433	-	391	172
Acridine	13	2.204	0.08816	-	0.09757	0.2223	319	-	288	127
Barium	8.0	2.204	0.08816	-	0.09757	0.2223	200	-	180	79
Copper	21	2.204	0.08816	-	0.09757	0.2223	518	-	468	205
Manganese	124	2.204	0.08816	-	0.09757	0.2223	3101	-	2802	1230
Molybdenum	6.2	2.204	0.08816	-	0.09757	0.2223	154	-	140	61
Nickel	55	2.204	0.08816	-	0.09757	0.2223	1370	-	1238	543
Uranium	13	2.204	0.08816	-	0.09757	0.2223	331	-	299	131
Vanadium	9.2	2.204	0.08816	-	0.09757	0.2223	230	-	208	91
Zinc	2.3	2.204	0.08816	-	0.09757	0.2223	58	-	52	23

[1] No-Observed Adverse Effect Level (NOAEL) based on the toxicological literature and the method by Opresko et al. 1994. See Appendix II for derivation of values.

[2] Based on literature derived values. See Table III-2.

[3] Risk-Based Concentration (RBC) = (NOAEL x body weight) / (ingestion rate x exposure frequency ratio x bioavailability factor).
Note that for the screening assessment, both exposure frequency and bioavailability factors were set equal to one.

TABLE III-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Page 1 of 4

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Water Shrew							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	13	2.3	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	13	2.3	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	13	13	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	13	1.3	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	13	0.13	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	13	13	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	13	7	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	13	0.99	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	13	1.7	U.S. EPA 1989c.
Fluoranthene	laboratory mice	7.5	kidney effects	0.03	13	0.99	Based on pyrene.
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	13	1.8	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	13	0.53	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	13	0.99	U.S. EPA 1989d.
Acridine	laboratory mice	100	reproduction	0.03	13	13	Based on anthracene.
Quinoline	laboratory rat	1	increased liver weight	0.35	13	0.30	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	13	4.5	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	13	2.9	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	13	3.4	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	13	0.27	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	13	0.66	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	13	92	Based on o-cresol.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	13	0.017	Schroeder et al. 1968.
Barium	laboratory rat	5.1	growth, hypertension	0.435	13	1.6	Perry et al. 1983.
Manganese	laboratory rat	88	reproduction	0.35	13	26	Laskey et al. 1982.
Molybdenum	cattle	0.24	maximum tolerable level	318	13	0.70	NAS 1980.
Strontium	laboratory rat	263	body weight and bone changes	0.35	13	79	Skornya 1981.
Tin	laboratory rat	0.6	kidney and liver effects	0.35	13	0.18	NTP 1982.

TABLE III-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Uranium	laboratory mouse	3.1	reproduction	0.028	13	0.40	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	13	0.057	Domingo et al. 1986.
Zirconium	laboratory mouse	1.7	lifespan; longevity	0.03	13	0.23	Schroeder et al. 1968.
River Otter							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	7.698	2.8	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	7.698	2.8	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	7.698	16	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	7.698	1.6	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	7.698	0.16	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	7.698	16	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	7.698	7.9	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	7.698	1.2	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	7.698	2.0	U.S. EPA 1989c.
Fluoranthene	laboratory mice	7.5	kidney effects	0.03	7.698	1.2	Based on pyrene.
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	7.698	2.1	Shopp et al. 1984.
Phenanthrene	laboratory mice	4.0	mortality, clinical signs	0.03	7.698	0.63	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	7.698	1.2	U.S. EPA 1989d.
Acridine	laboratory mice	100	reproduction	0.03	7.698	16	Based on anthracene.
Quinoline	laboratory rat	1.0	increased liver weight	0.35	7.698	0.36	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	7.698	5.4	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	7.698	3.5	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	7.698	4.1	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	7.698	0.32	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5.0	clinical signs and blood changes	0.03	7.698	0.79	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	7.698	109	Based on o-cresol.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	7.698	0.020	Schroeder et al. 1968.
Barium	laboratory rat	5.1	growth, hypertension	0.435	7.698	1.9	Perry et al. 1983.
Copper	mink	11.7	reproduction	1	7.698	5.9	Aulerich et al. 1982.

TABLE III-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Manganese	laboratory rat	88	reproduction	0.35	7.698	31	Laskey et al. 1982.
Molybdenum	cattle	0.24	maximum tolerable level	318	7.698	0.84	NAS 1980.
Nickel	laboratory rat	40	reproduction	0.35	7.698	14	Ambrose et al. 1976.
Strontium	laboratory rat	263	body weight and bone changes	0.35	7.698	94	Skornya 1981.
Tin	laboratory rat	0.60	kidney and liver effects	0.35	7.698	0.21	NTP 1982.
Uranium	laboratory mouse	3.1	reproduction	0.028	7.698	0.47	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	7.698	0.068	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	7.698	57	Schlicker and Cox 1968.
Zirconium	laboratory mouse	1.7	lifespan; longevity	0.03	7.698	0.27	Schroeder et al. 1968.
Killdeer							
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	36	Peakall et al. 1982.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0989	0.18	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	0.0989	0.018	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	0.0989	1.8	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	0.0989	49	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	36	Based on anthracene.
Barium	day-old chicks	21	mortality	0.121	0.0989	22	Johnson et al. 1960.
Manganese	chicken	138	maximum tolerable level	1.6	0.0989	349	NAS 1980.
Molybdenum	chicken	6.9	maximum tolerable level	1.6	0.0989	17	NAS 1980.
Uranium	black duck	16	mortality, body weight, liver/kidney effects	1.25	0.0989	37	Haseltine and Sileo 1983.
Vanadium	mallard	11	mortality, body weight	1.17	0.0989	26	White and Dieter 1978.
Great Blue Heron							

TABLE III-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	2.204	17	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	2.204	17	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	13	Patton and Dieter 1980.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	2.204	0.062	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	2.204	0.0063	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	2.204	0.62	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	2.204	17	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	2.204	17	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	2.204	17	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	2.204	17	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	2.204	17	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	13	Based on anthracene.
Barium	day-old chicks	21	mortality	0.121	2.204	8.0	Johnson et al. 1960.
Copper	day-old chicks	33	growth	0.534	2.204	21	Mehring et al. 1960.
Manganese	chicken	138	maximum tolerable level	1.6	2.204	124	NAS 1980.
Molybdenum	chicken	6.9	maximum tolerable level	1.6	2.204	6.2	NAS 1980.
Nickel	mallard duckling	77	mortality, growth, behaviour	0.782	2.204	55	Cain and Pafford 1981.
Uranium	black duck	16	mortality, body weight, liver/kidney effects	1.25	2.204	13	Haseltine and Sileo 1983.
Vanadium	mallard	11	mortality, body weight	1.17	2.204	9.2	White and Dieter 1978.
Zinc	mallard	3.0	mortality, body weight	1	2.204	2.3	Gasaway and Buss 1972.

[1] No-Observed Adverse Effect Level (NOAEL) based on the toxicological literature.

[2] Based on literature derived values. Please see Appendix IV.

[3] Estimated Wildlife NOAEL = $NOAEL_{test}$ $(\text{body weight}_{test} / \text{body weight}_{wildlife})^{1/3}$. Based on method by Opresko et al. (1994).

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APPENDIX IV

WILDLIFE EXPOSURE FACTORS

B1. ECOLOGICAL AND PHYSIOLOGICAL ASSUMPTIONS FOR WATER SHREWS (*Sorex palustris*)

Body Weight:

Mean body mass kg[1]	0.013
standard deviation (SD)	0.00291
coefficient of variation (CV)	0.224
sample size (# studies)	4

Distribution: **Normal**

Deterministic value for body mass (minimum body mass; mean - 2SD)	0.00718

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[1] 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).

Therefore,

Food ingestion rate[2] **(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)[3]	0.0028

Distribution: **Normal (based on the fact that FI is dependent on body mass which is normally distributed.**[4]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD)

for shrew with mean mass (0.013 kg)	0.0179
for shrew with minimum mass (0.00718 kg)	0.01235

---

[2] Food ingestion rate calculated as a function of body mass based on data from Conoway (1952).

[3] 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).

[4] 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:

Mean home range[5] (m)	75-200
standard deviation (SD)	
coefficient of variation (CV)	
sample size (n)	

Distribution: **not normal**

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[5] Home range sizes are likely linear as water shrews inhabit streamside or waterside habitats. Home range length estimated (pers. comm., M. Raine).

Fraction of Food Derived From Site:

Water Ingestion Rate:

Water ingestion rate[6] (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)[7]	0.0005

Distribution: Normal[8]

Deterministic value for water ingestion rate, L/day (maximum WI rate; mean + 2SD):	
for shrew with mean mass (0.013 kg)	0.0029
for shrew with minimum mass (0.00718 kg)	0.0021

---

[6] Water ingestion rate estimated based on one allometric equation, Calder and Braun (1983).

[7] 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).

[8] Assumed to be the same as for body mass.

Fraction of Water Derived From Site:

Soil Ingestion Rate: Estimate soil ingestion at 5% of the animal's body mass per day.

Soil ingestion rate[9] (SI rate) (kg/day):	
for shrew with mean mass (0.013 kg)	0.00065
for shrew with minimum mass (0.00718 kg)	0.00036
standard deviation (SD)[10]	0.00015

Distribution: Normal[11]

Deterministic value for soil ingestion rate, kg/day (maximum SI rate; mean + 2SD):	
for shrew with mean mass (0.013 kg)	0.00094
for shrew with minimum mass (0.00718 kg)	0.00065

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[9] Soil ingestion rate estimated.

[10] Standard deviation for soil ingestion based on the coefficient of variation for body mass as SI is correlated to body mass (standard deviation = cv x SI rate for mean mass shrew).

[11] 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).

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).

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B2. ECOLOGICAL AND PHYSIOLOGICAL ASSUMPTIONS FOR KILLDEER (*Charadrius vociferus*)

Body Weight:

Mean body mass[12]	0.0989
standard deviation (SD)	0.005
coefficient of variation (CV)	0.05
sample size (# studies)	2

Distribution: **Normal**

Deterministic value for body mass (minimum mean body mass; mean - 2SD)	0.0889

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[12] 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 1993). We assume a diet of 100% invertebrate prey.

Food ingestion rate[13] **(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)[14]	0.0008

Distribution: **Normal (based on the fact that FI is dependent on body mass which is normally distributed.**[15]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD):	
for birds with mean mass (0.0989 kg)	0.017
for birds with minimum mass (0.0889 kg)	0.016

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[13] 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).

[14] 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).

[15] Assumed to be the same as for body mass.

Foraging Home Range Size:

Mean home range size[16] (ha)
standard deviation (SD)
coefficient of variation (CV)
sample size (n)

Distribution: Normal

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[16] Mean foraging home range size calculated from data given in.

Fraction of Food Derived From Site:

Water Ingestion Rate:

Water ingestion rate[17] (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)[18]	0.0011

Distribution: Given mean and standard deviation, MEI is a normal distribution.[19]

Deterministic value for food ingestion rate (mean WI rate; mean + 2SD):	
for birds with mean mass (0.0989 kg)	0.024
for birds with minimum mass (0.0889 kg)	0.022

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[17] 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)$^{0.75}$.

[18] 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).

[19] Assumed to be the same as for body mass.

Fraction of Water Derived From Site:

Soil Ingestion Rate: Based on the soil ingestion rate of 7.3% calculated by Beyer et al. (1994) for an ecologically similar species (the Least Sandpiper, *Caladris minutilla*), we estimate that soil ingestion for Killdeer amounts to 7.3% of the diet (dry weight).

Soil ingestion rate[20] (SI rate) (kg/day):	
for birds with mean mass (0.0989 kg)	0.00113
for birds with minimum mass (0.0889 kg)	0.00104
standard deviation (SD)[21]	0.00006

Distribution: Normal[22]

Deterministic value for soil ingestion rate, kg/day (maximum SI rate; mean + 2SD):	
for birds with mean mass (0.0989 kg)	0.00124
for birds with minimum mass (0.0889 kg)	0.00115

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[20] Soil ingestion rate estimated based on ingestion rates given for Least Sandpipers by Beyer et al. (1994).

[21] Standard deviation for soil ingestion based on the coefficient of variation for body mass as SI is correlated to body mass (standard deviation = cv x SI rate for mean mass bird).

[22] Assumed to be the same as for body mass.

Fraction of Soil Derived From Site:

Time Spent in Area Killdeer arrive in northern Alberta in mid-April and leave sometime between late November or early December (Semenchuk 1993, 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).

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B3. ECOLOGICAL AND PHYSIOLOGICAL ASSUMPTIONS FOR RIVER OTTER (*Lutra canadensis*)

Body Weight:

Mean body mass (kg)[23]	7.698
standard deviation (SD)	0.891
coefficient of variation (CV)	0.12
sample size (# studies)	5

Distribution: Normal

Deterministic value for body mass (kg) **(minimum body mass; mean - 2SD)**	5.92

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[23] 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, USEPA 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[24] **(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)[25]	0.043

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[26]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD)

for an otter with mean mass (7.698 kg):	0.453
for an otter with minimum mass (5.92 kg)	0.381

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[24] 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).

[25] 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).

[26] Assumed to be the same as for body mass.

Home Range:

Mean home range[27] (km)	31
standard deviation (SD)	9.2
coefficient of variation (CV)	
sample size (n)	

Distribution: not normal

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[27] 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).

Fraction of Food Derived From Site:

Water Ingestion Rate:

Water ingestion rate[28] (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)[29]	0.072

Distribution: Normal[30]

Deterministic value for water ingestion rate (L/day) (maximum WI rate; mean + 2SD):	
for an otter with mean mass (7.698 kg):	0.765
for an otter with minimum mass (5.92 kg)	0.634

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[28] 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).

[29] 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).

[30] Assumed to be the same as for body weight.

Fraction of Water Derived From Site:

Soil Ingestion Rate: Otters potentially could ingest soil as they will roost around the bottom of ponds to dig out frogs in winter (Liers 1951). Otters will also root in a similar manner on shallow sand bars in swift streams for turtles or invertebrates (Liers 1951).

Soil ingestion rate likely varies depending on activity and type of food ingested. High soil ingestion would be expected when otters are digging bank burrows, canals, and when foraging. Proportion of soil ingested in the diet likely ranges between 3-4% of the animal's body mass. To be conservative we will use an estimated soil ingestion rate of 4% of the animal's body mass.

Soil ingestion rate[31] (SI rate) (kg/day):	
for an otter with mean mass (7.698 kg):	0.308
for an otter with minimum mass (5.92 kg)	0.237
standard deviation (SD)[32]	0.036

Distribution: Normal[33]

Deterministic value for soil ingestion rate, kg/day (maximum SI rate; mean + 2SD):	
for an otter with mean mass (7.698 kg):	0.379
for an otter with minimum mass (5.92 kg)	0.308

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[31] Soil ingestion rate estimated.

[32] Standard deviation for soil ingestion based on the coefficient of variation for body mass as SI is correlated to body mass (standard deviation = cv x SI rate for mean mass otter).

[33] Assumed to be the same as for body mass.

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).

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B4. ECOLOGICAL AND PHYSIOLOGICAL ASSUMPTIONS FOR GREAT BLUE HERONS (*Ardea herodias*)

Body Weight:

Mean body mass adult female (kg)[34]	2.204
standard deviation (SD)	0.337
coefficient of variation (CV)	0.153
sample size	15

Distribution: Normal

Deterministic value for body mass (minimum mean body mass; mean - 2SD)	1.530 kg

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[34] 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[35] **(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)[36]	0.0149

Distribution: Normal (based on the fact that FI is dependent on body mass which is normally distributed.[37]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD):	kg/day
for birds with mean mass (2.204 kg)	0.127
for birds with minimum mass (1.53 kg)	0.104

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[35] Food ingestion rates estimate based on an allometric equation for non-passerines (Nagy 1987): FI (g dry weight /day) = 0.301 (Body weight g)$^{0.751}$.

[36] 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).

[37] Assumed to be the same as for body mass.

Foraging Home Range Size:

Mean home range size[38] (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[39] (km)	5.3
standard deviation (SD)	3.11
coefficient of variation (CV)	0.59
sample size (n)	2

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[38] Mean foraging home range size calculated from data given in Bayer (1978).

[39] Mean foraging distance from colony calculated from data given in Parnell and Soots (1978) and in Dowd and Flake (1985).

Fraction of Food Derived From Site: Great Blue Herons are likely in this area for a maximum of 213 days per year (Semenchuk 1992). Assuming that birds spend 100% of their time on site while in Canada, the maximum fraction of food from the contaminated sites would be 213/365 = 0.58 of their annual food requirements.

Water Ingestion Rate:

Water ingestion rate[40] (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)[41]	0.034

Distribution: **Given mean and standard deviation, MEI is a normal distribution.**[42]

Deterministic value for water ingestion rate (mean WI rate; mean + 2SD):	
for birds with mean mass (2.204 kg)	0.291 L/day
for birds with minimum mass (1.53 kg)	0.238 L/day

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[40] 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)$^{0.75}$.

[41] 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).

[42] Assumed to be the same as for body mass.

Fraction of Water Derived From Site: Great Blue Herons are likely in this area for a maximum of 213 days per year (Semenchuk 1992). Assuming that birds spend 100% of their time on site while in Canada, the maximum fraction of water from the contaminated sites would be 213/365 = 0.58 of their annual water requirements.

Soil Ingestion Rate: We make a conservative estimate of soil in the diet of Great Blue Herons to be represented by 5% of the bird's body mass. Soil ingestion for this species may be relatively high as a result of feeding on small vertebrates and larger invertebrates in shallow waters and in sediments.

Soil ingestion rate[43] (SI rate) (kg/day):	
for birds with mean mass (2.204 kg)	0.110
for birds with minimum mass (1.53 kg)	0.0765
standard deviation (SD)[44]	0.01685
Distribution: Normal[45]	
Deterministic value for soil ingestion rate, kg/day (maximum SI rate; mean + 2SD):	
for birds with mean mass (2.204 kg)	0.144
for birds with minimum mass (1.53 kg)	0.110

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[43] Soil ingestion rate estimated.

[44] Standard deviation for soil ingestion based on the coefficient of variation for body mass as SI is correlated to body mass (standard deviation = cv x SI rate for mean mass heron).

[45] Assumed to be the same as for body mass.

Fraction of Soil Derived From Site: Great Blue Herons are likely in this area for a maximum of 213 days per year (Semenchuk 1992). Assuming that birds spend 100% of their time on site while in Canada, the maximum fraction of soil from the contaminated sites would be 213/365 = 0.58 of their annual soil ingestion.

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.

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).

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APPENDIX V

TOXICITY PROFILE FOR NAPHTHENIC ACIDS

Naphthenic Acids

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 and Subchronic 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. 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).

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.

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 less 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.

Human Health Criteria

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

The table below compares the doses that cause 50% mortality in various species:

Chemical	LD_{50} rat	LD_{50} mice	TDLo rabbit	Reference
naphthenic acids	3,000 mg/kg	3550 mg/kg	NA	Rockhold 1955, Pennisi & dePaul Lynch 1977
calcium naphthenate	>6,000 mg/kg	NA	NA	Rockhold 1955
cobalt naphthenate	3,900 mg/kg	NA	NA	Rockhold 1955
copper naphthenate	>6,000 mg/kg	NA	NA	Rockhold 1955
lead naphthenate	5,100 mg/kg	NA	NA	Rockhold 1955
phenyl mercury naphthenate	390 mg/kg	NA	NA	Rockhold 1955
manganese naphthenate	>6000 mg/kg	NA	NA	Rockhold 1955
zinc naphthenate	>6000 mg/kg	NA	NA	Rockhold 1955

References

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APPENDIX VI

WASTELOAD ALLOCATION PROTOCOL

1 INTRODUCTION

In late 1995, Alberta Environmental Protection established procedures to help derive limits for wastewater effluents based on the assimilative capacity of the receiving water body (AEP 1995). This protocol is shown schematically in Figure VI-1. Effectively, this approach is based on estimating, on a chemical-by-chemical basis, the maximum load or effluent concentration that could be discharged to the Athabasca River without exceeding established in-stream water quality guidelines for protection of aquatic biota and human health. If the in-stream guidelines are predicted to be exceeded, based on a protective, low-flow river condition, then the reasons for the exceedance are investigated.

The wasteload allocation protocol was developed to assist in setting water quality based effluent limits for a single effluent discharge. That protocol was followed initially to examine Suncor's wastewater and cooling water effluent with respect to changes associated with plant expansion, i.e., increase in production rate from 79,500 bbl/cd in 1995 to 107,000 bbl/cd by 1999. The results of that assessment are presented in Section VI.2 and summarized in Suncor's Fixed Plant Expansion Project Application dated March 1996. The protocol was then modified to account for the cumulative effects from the multiple sources of release waters associated with all of Suncor's existing and future reclamation and operational release waters operations, including the wastewater and cooling water effluent. Details of the cumulative assessment are presented in Section VI.3.

2 REFINERY WASTEWATER ASSESSMENT

Suncor's Pond E cooling water and refinery wastewater discharges were evaluated according to Alberta Environmental Protection's (AEP) recently published a procedures manual for determining limits that can be placed on an effluent discharge. The assessment utilizes a statistical approach whereby the intent is to establish an effluent limit such that the resulting concentrations in the Athabasca River will not exceed established aquatic and human health guidelines more frequently than one day in three years. In other words, there will be a 99.9% probability that water quality guidelines will be met. It also allows the extensive range of chemical and toxicological parameters measured in a wastewater discharge to be reduced to a few, which, based upon historical observations, have a reasonable potential to be exceeded in the Athabasca River as a result of the discharge. This more focused list can then be reviewed with respect to possible effluent limits and the capability of the wastewater treatment system achieving these derived limits. The following describes the assessment methods, data requirements and results.

2.1 Approach

Detailed methods are described in AEP (1995). In summary, the approach is to:

- Calculate the maximum load and maximum effluent concentrations that could be discharged to the Athabasca River and not cause an exceedance of water quality guidelines.
- Compare these calculated maximum loads and concentrations against maximum historical values.
- Further evaluate these parameters, with respect to actual year(s) and frequency of exceedance, where maximum historical effluent values exceeded the calculated maximums that could be discharged.

The calculation of the maximum allowable load is:

$$L_{max}=[(IWQG\times Q_s\times ff)-(Q_s\times ff\times C_s)]\times 86.4$$

where:

L_{max}	is the maximum load (kg/d) that can be discharged to the river and not *IWQG*
IWQG	is the instream water quality guideline (mg/L)
Q_s	is the design river flow (m^3/s)
ff	is the fraction of the design flow which can be utilized for dilution
C_s	is the background river concentration (mg/L)
86.4	is a factor that converts units of g/s to kg/d.

The following describes the values of *IWQG*, Q_s, *ff* and C_s used to calculate L_{max} for each of the selected water quality parameters.

Instream Water Quality Guidelines (*IWQG*)

Appendix 8 of AEP (1995) provides a composite list of instream water quality guidelines established by Alberta Environment (1977), Canadian Council of Resource and Environment Ministers (CCREM 1987), and the United States Environmental Protection Agency (U.S. EPA 1986 and 1992). This list was further enhanced with the inclusion of guidelines established by Ontario (1992). The resulting database of multi-jurisdictional guidelines were the basis for assessment. Unfortunately each jurisdiction followed a different procedure in establishing their guidelines, therefore use of any one values must take into consideration how the guidelines were established. U.S. EPA guidelines were developed in conjunction with a water quality assessment technique that was also the basis for the Alberta procedures (U.S. EPA 1991). Therefore the U.S. EPA criteria are given a higher weighting when reviewing the significance of a result.

There are several types of instream water quality guidelines, including aquatic life (acute and chronic), human health (carcinogens and non-carcinogens) and guidelines related to aesthetics of water (e.g., color, eutrophication). The AEP (1995) approach is best suited to protection of aquatic life and least suited to aesthetic parameters. Correspondingly this assessment focused on chemical and toxicological parameters which could affect aquatic life. Human health parameters were considered, but a more complete evaluation of human health issues is included in the health risk component of this report (Section 5). Aesthetic parameters were not considered in this assessment.

Instream water quality guidelines are available for numerous parameters. To reduce this list to a manageable number, a list of the chemical and toxicological characteristics of the two primary operational effluent streams was compiled (wastewater and cooling pond water). First, the list was reduced to only those chemicals that have been measured at or above the analytical detection limit. This list was then compared to the list of instream water quality objectives. Parameters were included in this assessment if there was both a detectable quantity in the effluent and an established criterion. Table VI-1 lists the parameters and criteria that were included in this assessment.

As mentioned previously, the multi-jurisdictional water quality guidelines were developed using different procedures and assumptions. Instead of reviewing each guideline from each jurisdiction and adjusting the numeric value to ensure consistency for the evaluation, instream guidelines were only reviewed for those parameters in which (1) concentrations in the background Athabasca River were greater than the guideline, and/or (2) maximum historical concentrations/loads from the combined wastewater system were greater than the calculated maximum allowable levels. This is discussed in the following sections.

Background Water Quality (C_s)

Athabasca River water quality upstream of the Suncor discharge were defined using AEP's NAQUADAT data collected from 1980-1995 supplemented with water quality data collected as part of the Steepbank EIA. All available historical and 1995 water quality data were summarized by season and are presented in Table VI-2. Seasons were defined as:

Spring	March, April, May, June
Summer	July, August
Fall	September, October
Winter	November, December, January, February

These historical data are described in detail in the Aquatics Baseline Report for the Steepbank Mine EIA (Golder 1996). For the purpose of this evaluation, background river water quality (C_s) was represented by the median winter concentration. Winter was selected as it is the time when river flows are lowest and therefore the effluent discharge would result in the maximum possible change in river water chemistry. For several parameters, winter concentrations have never been measured at or above the analytical detection limit. Background concentrations for these parameters were assumed to equal zero.

Background concentrations were compared with the multi-jurisdictional instream water quality guidelines. For some parameters the background concentrations exceeded the lowest of the multi-jurisdictional guidelines. As discussed above, these guidelines were then reviewed to determine the development method. Parameters where background levels exceeded guidelines are:

arsenic	(human health criteria - U.S. EPA)
cobalt	(aquatic life - OME)
strontium	(aquatic life - OME)

The OME guidelines for cobalt and strontium were developed with uncertainty factors. Using these factors can result in overly conservative maximum allowable loadings and inconsistencies with other guidelines (e.g., U.S. EPA). The uncertainty factors used by OME are 10 and 23 for cobalt and strontium, respectively. Removing these factors results in guidelines of 0.009 mg/L for cobalt and 0.16 mg/L for strontium. With these revised guidelines, background cobalt concentrations no longer exceeded the guidelines; however, background strontium levels remained greater than the guideline. No uncertainty factors were used in developing the arsenic guideline, therefore, that criterion was not modified.

Athabasca River Design Flows ($Q_s\ ff$)

Design flows describe the amount of dilution available before instream water quality guidelines apply. AEP (1995) guidance suggests evaluations should be conducted assuming minimal available dilution as a means to screen potential concerns. Specifically they recommend:

Acute Aquatic Life:	Guidelines should be screened against effluent concentrations prior to any dilution with river water.
Chronic Aquatic Life:	Guidelines should be applied after effluent mixing with 10% of the 7 day annual flow that occurs 1 in 10 years (7Q10).
Human Health - Carcinogens:	Guidelines should be compared after dilution with 100% of the 30 day annual low flow that occurs 1 in 5 years (30Q5).
Human Health - Non Carcinogen:	Guidelines should be compared after dilution with 100% of the harmonic mean flow (reciprocal of the arithmetic mean of reciprocals).

These recommendations have been used exclusively in this evaluation. The value of each of these river flows used in the evaluation are:

7Q10	115 m^3/s
30Q5	120 m^3/s
Harmonic Mean	306 m^3/s

While AEP (1995) provides specific guidance for screening, they also state that larger chronic and acute mixing zones can be considered if it can be demonstrated that it would not adversely impact water uses. In this evaluation it was not necessary to go beyond the screening level, and therefore no other design flows or mixing zone sizes were evaluated.

Pond E and Wastewater Characteristics

Quality characteristics for Suncor's wastewater and cooling water were determined from measurements made both by AEP and by Suncor. Summary statistics for the parameters considered in this evaluation are included in Table VI-3.

For the screening evaluation, maximum recorded effluent concentrations were used to represent the chemical or toxicological composition of each wastewater stream (Table VI-3). Combined effluent concentrations were determined based upon representative flows. For the evaluation of future loading conditions, the maximum effluent concentrations and three flow rate scenarios, representing different levels of expansion, were used:

Scenarios	Wastewater System	Ponds E
79.5K Case	0.334 m^3/s	0.61 m^3/s
87.0K Case	0.325 m^3/s	0.184 m^3/s
107.0K Case	0.253 m^3/s	0.184 m^3/s

2.2 Results

2.2.1 Aquatic Life

An initial screening step was completed in which maximum effluent loading rates were compared to maximum allowable loading rates. For several parameters, the maximum predicted effluent loading rate was greater than the maximum allowable loading rate. For those parameters, the multi-jurisdictional guidelines were reviewed to determine if they were developed in a manner consistent with other criteria. Vanadium and molybdenum guidelines developed by OME were determined to have uncertainty factors of 23 and 29, respectively. Modified guidelines with the uncertainty factors removed resulted in values equal to 0.16 mg/L and 0.73 mg/L for vanadium and molybdenum, respectively. Those adjusted values were than applied and maximum allowable loading rates re-calculated. Guideline values for other parameters were not adjusted.

Table VI-4 gives the list of chemical specific and whole effluent toxicity parameter that were included in the aquatic-life based assessment:

- Column 2 lists, along with each parameter, the calculated maximum loads that could be discharged from the wastewater system to maintain concentrations in the Athabasca River below the chronic water quality guidelines.

- Column 3 shows the maximum current (1995) load from the combined effluents. This is the worst-case condition since future loads will be reduced as a result of decreases in flows and other changes to the wastewater system.

- Column 4 and 5 show component (cooling Pond and wastewater) loads.

- Column 6 shows the maximum concentrations in the final combined effluent necessary to remain below acute aquatic life criteria.

- Column 7 shows the current maximum concentrations for the combined effluents.

- Column 8 and 9 show the current maximum concentrations for the cooling Pond and wastewater effluents.

Column 2 and 3 highlight parameters where the historical maximum discharge load may result in exceedances of in-stream guidelines under low flow river condition (i.e., exceedance of chronic aquatic life guideline). Column 6 and 7 highlight parameters where the historical maximum effluent concentration exceeds the acute aquatic life guideline.

Aluminum, while shown in Table VI-4 potentially exceeding the instream guideline, is only of concern because of high background levels in the river. The background loading of aluminum ranges from 300 to 30,000 kg/d as compared with the maximum effluent loading of 335 kg/d. Most of the aluminum in the river is associated with particulate material and, consequently, is not physiologically assimilated by aquatic life. If only the bioavailable amount were considered, then aluminum would not identified as a chemical of concern for aquatic biota.

The maximum concentration of strontium in the combined effluent (0.253 mg/L) is less than the river concentration (0.34 mg/L). It is, therefore, impossible for this release water to increase river concentrations above ambient levels. Hence, this chemical was excluded from further investigation.

The following chemicals could potentially result in exceedances of either the acute or chronic aquatic life guidelines, based upon the current combined effluent discharge:

- chromium (acute)
- copper (acute)
- mercury (chronic)

Based upon historical water chemistry data and given proposed future effluent flow rates, Table VI-5 shows how frequently the following might be exceeded:

- the maximum allowable loading of mercury
- the maximum allowable concentrations of copper and chromium

Guidelines for copper and chromium are set at levels that might have acute effects on sensitive aquatic species. Concentrations in the effluents should be below these guidelines prior to release to the Athabasca River (AEP 1995). These guidelines have been exceeded at a very low frequency in the wastewater system effluent. However, copper and chromium pose no risk of acute toxicity to aquatic life in the Athabasca River because of:

- low frequencies of exceedance
- almost instantaneous dilution with Athabasca River water immediately below the outfall
- lack of acute toxicity observed in wastewater samples

In addition, these metals are not expected to contribute to chronic toxicity of sensitive aquatic life in the Athabasca River, even under worst-case conditions. Therefore, copper and chromium are parameters that should continue to be monitored but are unlikely to adversely affect aquatic life in the river.

The mercury guideline might be exceeded infrequently under low flow conditions. However, considering the low frequency of exceedance, (9% in 107,000 bbl/cd case) coupled with the low frequency of the design river flow (7Q10 flows by definition occur only once every ten years), the likelihood of these two events occurring simultaneously is low, only about once every 100 years. Therefore, it is unlikely that mercury from Suncor's wastewater system is contributing to any measurable impacts on aquatic biota in the river. This conclusion is consistent with that from Golder's (1996) baseline study.

2.2.2 Human Health

Table VI-6 lists the chemical specific parameters that were reviewed from the perspective of possible human health impacts. Arsenic was the only chemical identified for which Suncor's wastewater might increase river concentration above human health drinking water guidelines. Arsenic was identified as a result of the extremely low criteria (0.000018 mg/L) set forth by the U.S. EPA, because of its potential for bioaccumulation in fish. The criterion for arsenic is naturally exceeded in the Athabasca River at sites upstream of Suncor. For example, the median winter value at Fort McMurray is 0.00052 mg/L. However, there is no evidence of arsenic accumulating in tissues of any of the fish from the Athabasca River analyzed during the 1995 field studies (Golder 1996), nor any evidence that exposure to process-affected waters results in elevated arsenic levels in fish tissues (HydroQual 1996). Further, if the drinking water criterion was used (0.05 mg/L), arsenic would not have been identified as a chemical of concern. A comprehensive laboratory study has been initiated to confirm that arsenic from Suncor's refinery wastewater does not significantly bioaccumulate in fish tissues.

3 CUMULATIVE ASSESSMENT

3.1 Approach

The approach followed for this assessment was to first calculate, on a chemical-specific basis, the total load that might be discharged to the Athabasca River from all of Suncor's release waters. These total loads were calculated based on the maximum effluent concentration and average flows for each time snapshot under investigation: 1995, 2001, 2010, 2020, and post-reclamation. All existing and proposed operational and reclamation waters were incorporated into this assessment, including the hypothetical release of untreated CT water. The predicted chemical concentrations within the mixing zone of the river were then compared to chronic aquatic life and human health guidelines. In addition, to evaluating in-stream concentrations, "end-of-pipe" concentrations associated with the various releases waters were also investigated by comparing maximum reported concentrations to acute aquatic life guidelines. Chemicals that do not exceed either the acute or chronic guidelines clearly pose no risk to aquatic biota in the Athabasca River and can be safely eliminated from further investigation. Chemicals that exceed either the acute of chronic guideline do not necessarily pose a risk but require further investigation.

The approach was therefore conservative ensuring that chemical and toxicological parameters could be safely excluded from further evaluation if the resulting river concentrations remained below guideline values. However, if the resulting river concentrations exceed guidelines, this only indicates that these parameters should be evaluated more completely.

The methods were identical to those presented in Section VI.2.1 with the following additions or changes:

- Locations of water release discharges are shown in Figure VI-2;
- Flow rates are summarized in Table VI-7;

- Release water chemistry is summarized in Table VI-3; and
- The focus of the detailed evaluation was directed towards the 2020 scenario, since this represents the largest cumulative loading to the river. (Tables VI-8 and VI-9).

3.2 Results

3.2.1 Aquatic Life

Figures VI-2 to VI-56 show isopleths of predicted concentrations in the Athabasca River for the 115 m3/s river flow. These concentrations are "worst case" concentrations as they represent simultaneous maximum loadings coincident with 1 in 10 year low river flow conditions.

Chronic aquatic life guidelines were compared against these simulated Athabasca River concentrations. AEP (1995) guidance suggests that at the screening level receiving water quality should not exceed chronic guidelines after mixing with 10% of the 7Q10 river flow. As there are water releases on both banks, this evaluation was done by comparing the maximum river concentration after mixing with 10% of the river flow, for each side of the river, to the chronic guideline.

Table VI-10 lists the maximum predicted concentrations along either bank, as determined from Figures VI-3 to VI-56. Listed beside the maximum river values are the chronic guidelines. The shaded rows highlight parameters where the predicted maximum river concentration is greater than the guideline.

Acute aquatic life guidelines were compared against the undiluted water release concentrations. Again these are the maximum observed concentrations for any of the water sources. Table VI-11 lists maximum concentrations measured for any of the release waters, and compares these values with acute water quality criteria. Shaded rows show parameters for which the maximum measured concentration is greater than its criterion.

Four chemicals were identified for which maximum concentrations in one or more release waters are greater than acute aquatic life guidelines - ammonia, copper, chromium, and cyanide:

Ammonia - The refinery wastewater is the only release water for which the maximum concentration exceeded the acute guideline of 8 mg/L. This exceedance is an artifact of the use of the historical maximum value rather than more recent values. For instance, during 1980 and 1981 ammonia concentrations ranged from 20 to 25 mg/L. However, the maximum ammonia concentration have been reduced substantially as a result of improvements in the wastewater system; since 1983 the maximum concentration recorded is only 3 mg/L. Thus, this chemical is no longer a concern with respect to acute toxicity.

Chromium - The refinery wastewater is the only operational water for which the maximum concentration exceeded the acute guideline for Cr^{+6} of 0.016 mg/L. Historically, this guideline has been exceeded at a frequency of only 1% of all samples analyzed. Given this low frequency of exceedance, the assumption that all chromium in wastewater would be present as Cr^{+6}, plus the nearly instantaneous dilution with Athabasca River water immediately below the outfall, the resulting chromium concentrations within the Athabasca River pose no risk of acute toxicity to aquatic biota in the river.

Copper - The refinery wastewater is the only release water for which the maximum concentration exceeded the acute guideline of 0.03 mg/L. Historically, this guideline has been exceeded at a frequency of less than 4 % of all samples analyzed. Given this low frequency of exceedance coupled with the nearly instantaneous dilution with Athabasca River water immediately below the outfall, the resulting copper concentrations within the Athabasca River pose no risk of acute toxicity to aquatic biota in the river.

Cyanide - Elevated cyanide levels (maximum 0.055 mg/L) have been measured in CT water, although most concentrations are less than 0.002 mg/L. Additional data are necessary to confirm whether untreated CT release waters will in fact exceed the 0.022 mg/L criterion. Note also that CT water would by treated prior to release to the river.

Four chemicals were identified for which the predicted river concentrations might exceed chronic aquatic life guidelines - aluminum, mercury, phenols, and strontium:

Aluminum - Aluminum was identified only because concentrations in the Athabasca River (<0.1 to 8.64 mg/L) naturally exceed the chronic guideline of 0.1 mg/L. Concentrations in Suncor's release waters are within the range of that reported for the Athabasca River and, thus, will not results in any further increase of aluminum concentrations in the river. In any case, these concentrations of aluminum are not toxic under the conditions prevalent in the river since virtually all of the aluminum would be associated with particulate material and would not be bioavailable.

Mercury - The cumulative loads of mercury associated with Suncor's water releases might result in mercury concentrations in the Athabasca River that slightly exceed the chronic guideline, under the low flow conditions examined here. The largest single source of mercury is from the wastewater/cooling pond discharge, which represents about 75% of the total mercury loadings from all release waters (2020 scenario). However, the expected frequency at which mercury in-stream levels might exceed the chronic guideline is only about 10%. Hence, given the conservative nature of the assessment and the low frequency of exceedance, it is unlikely that mercury associated with Suncor's water releases will affect aquatic biota in the Athabasca River.

Phenols - Phenol concentrations above the 0.001 mg/L chronic guideline have been recorded in most of Suncor's release waters, and the background concentration in the Athabasca River is equal to the 0.001 mg/L guideline. This guideline is also regularly exceeded in many natural surface water bodies. The total contribution from Suncor's release waters, under worst-case conditions of maximum effluent concentration and low river flows would only contribute to an increase of phenols of 0.0005 mg/L beyond the 10% river mixing zone. Hence, under worst-case conditions, river concentrations would only increase from 0.001 to 0.0015 mg/L. The guideline for phenols is for a group of chemicals but is based upon effects due to specific chlorinated forms, none of which have not been measured in any of Suncor's release waters. Hence, it is exceedingly unlikely that the phenols in Suncor's release water would affect aquatic biota in the Athabasca River.

Strontium - Like aluminum, strontium was identified only because concentrations in the Athabasca River (0.18-0.36 mg/L) naturally exceed the chronic guideline of 0.16 mg/L. Concentrations of strontium in most of the release waters are comparable to, or less than, those in the Athabasca River. One exception to this is the CT water, where concentrations have ranged from 0.75 to 2.12 mg/L. Even so, under worst-case conditions of maximum effluent concentration and low river flows, river concentrations would only increase by 0.02 mg/L beyond the 10% mixing zone. Hence, it is exceedingly unlikely that strontium concentrations would affect aquatic biota in the Athabasca River.

In addition, one parameter, molybdenum, exceeded a guideline intended for protection of irrigation water quality. The primary sources of molybdenum are the wastewater system and CT release waters. The molybdenum guideline is unique to CCME, and was intended as an irrigation water guideline. Specifically it was to protect livestock from grazing on irrigated crops with elevated molybdenum levels. It is unlikely that the concentrations of molybdenum predicted for the Athabasca River would ever be realized in an irrigation water.

3.2.2 Human Health

Parameters which exceed human health (carcinogen) criteria include (Table VI-12:

Benzo(a)anthracene - Detectable levels have only been measured in the wastewater system (1µg/L), CT waters (0.27 µg/L) and Plant 4 seepage (0.1 µg/L). Calculated maximum river concentration at the point for comparison is 0.0029 µg/L compared with the criterion of 0.0028 µg/L. This chemical is evaluated more completely as part of the human health risk assessment presented in Section 5.

Total PAH's - PAH's have been detected in TID Seepage water, Sewage Effluent, Pond 1/1A and CT Waters. Highest concentrations are in the CT Waters. Highest loading in the Year 2020 Scenario is associated with potential seepage from Pond 6, which represents 50% of the total water release loadings. PAH's are evaluated more completely in Section 5.

Parameters which exceed human health (non-carcinogen) criteria include (Table VI-12):

Arsenic - The primary source of the arsenic is the wastewater/cooling pond discharge, which contributes 97% of the arsenic loading based upon maximum measured concentrations. Arsenic is also discussed in more detail in Section 5.

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TABLE VI-1 MULTI-JURISDICTIONAL INSTREAM WATER QUALITY GUIDELINES

PARAMETER	UNIT	FRESHWATER AQUATIC LIFE										HUMAN HEALTH			
		ASWQO	1	CCREM	2	Ontario	3	U.S. EPA Chronic	4	U.S. EPA Acute	4	H&W	5	U.S. EPA	6
GENERAL															
Ammonia	mg/L	-		1.53	7	-		1.53	7	8.0		-		-	
Cyanide (Total)	mg/L	0.01		0.005		-		0.0052		0.022		0.2		0.2	
Phenolics	mg/L	0.005		0.001		0.001		2.56		5.8		-		-	
METALS															
Aluminum	mg/L	-		0.1		0.075		-		-		-		-	
Arsenic	mg/L	0.01		0.05		0.1		0.19		0.36		0.025		2.2E-06	
Barium	mg/L	1		-		-		-		-		1		1	
Beryllium	mg/L	-		-		-		0.0053	10	0.13	10	-		6.8E-06	
Cadmium	mg/L	0.01		0.0013	8	0.00045	8	0.0018	8	0.0074	8	0.005		0.01	
Chromium	mg/L	0.05		0.02		0.10		0.011	8	0.016	8	0.05		0.05	
Cobalt	mg/L	-		-		0.0004		-		-		-		-	
Copper	mg/L	0.02		0.003		0.005		0.019	8	0.030	8	1		1	
Iron	mg/L	0.3		0.3		0.3		1		-		0.3		0.3	
Lead	mg/L	0.05		0.004	8	0.005		0.007	8	0.166	8	0.01		0.05	
Mercury	mg/L	0.0001		0.0001		0.0002		0.000012		0.0024		0.001		0.00014	
Molybdenum	mg/L	-		-		0.01		-		-		-		-	
Nickel	mg/L	-		0.11	8	0.025		0.25	8	2.28	8	-		0.0134	
Selenium	mg/L	0.01		0.001		0.1		0.035		0.26		0.01		0.01	
Strontium	mg/L	-		-		0.007		-		-		-		-	
Vanadium	mg/L	-		-		0.007		-		-		-		-	
Zinc	mg/L	0.05		0.03		0.03		0.170	8	0.188	8	5		-	
TRACE ORGANICS															
Volatiles															
Benzene	mg/L			0.3										0.0012	
Bis(2-Ethyl-hexyl)Phthalate	mg/L													15	
Butylbenzyl-Phthalate	mg/L													5.2	
Carbon tetrachloride	mg/L													0.00025	
chloroform	mg/L	-		-		-		1.24		28.9		-		0.0057	
Dibutyl-Phthalate	mg/L													2.7	
Diethyl-Phthalate	mg/L													23	
Ethylbenzene	mg/L	-		0.7		0.008		-		32		0.0024		1.4	
Isophorone	mg/L													0.0084	
Methylene chloride	mg/L													0.0047	
Toluene	mg/L									17.5				6.8	
m,p-Xylene	mg/L	-		-		0.03		-		-		-		-	
o-Xylene	mg/L	-		-		0.002		-		-		-		-	
Polycyclic Aromatic Hydrocarbons															
Benzo(a)anthracene	mg/L	-		-		-		-		-		-		2.8E-06	
Pyrene	mg/L													0.96	
Phenols															
2,4-Dichlorophenol	mg/L			0.0002				0.97		2.02				0.093	
2,4-Dimethylphenol	mg/L									2.12					
2,4,6-Trichlorophenol	mg/L														
Others															
toxicity - acute	TUa	-		-		-		-		0.3		-		-	
toxicity - chronic	TUc	-		-		-		1		-		-		-	

- No guideline or objective

1 Alberta Environment (1977) -- pertaining to protection of aquatic life.

2 CCREM (1987): Freshwater Aquatic Life unless noted otherwise.

3 Ontario (1992).

4 U.S. EPA (1986).

5 Health and Welfare Canada (1993).

6 U.S. EPA (1986) -- Water and fish ingestion guideline.

7 pH 8, temperature 0°C.

8 Hardness 175 mg/L as $CaCO_3$ (median winter value for Athabasca River near Fort McMurray).

9 Insufficient data to develop criteria, value is the L.O.E.L.

TABLE VI-2

WATER QUALITY OF THE ATHABASCA RIVER

Parameter	Units	Athabasca River upstream Ft.McMurray (1985-1995)*												Athabasca R. upstream Lease 19 (1995)			Athabasca R. downstream Lease 25 (1995)	
		Spring			Summer			Fall			Winter			Spring	Summer	Fall	Spring	Summer
		Range	Median	n	Range	Median	n	Range	Median	n	Range	Median	n	AW004-C001	AW004-C002	AW004-C003	AW009-C001	AW009-C002
Conventional Parameters and Major Ions																		
Bicarbonate	mg/L	114 - 216	141	24	114-128	119	14	144 - 193	155	12	162-267	212	23	119	108	116	127	110
Calcium - Dissolved	mg/L	26 - 56	38	18	29-35	31	9	34-42	37	7	39-74	52	13	30.7	32.5	27	33.6	33.5
Chloride - Dissolved	mg/L	1.0 - 9.0	3.7	18	0.5-4.6	1.9	9	1.9-7.2	3.2	7	2.7-14	6.3	13	9.6	3.1	14.8	7.1	2.6
Carbon - Particulate Total	mg/L	0.1 - 2.9	0.34	10	1.27-3.6	2.67	4	0.25-1.68	0.97	2	0.03-0.27	0.15	2					
Carbon - Total Organic	mg/L	7.5 - 19	8.85	6	3.2-16	6.05	4	5.4-10.7	6.8	4	5.7-9	7.6	12					
Carbon - Dissolved Organic	mg/L	5.2 - 17.2	7.6	19	1-14.7	3.9	4	2.7-10.7	5.2	7	5.7-8.8	7.3	15	7.1	16.7	9.2	7.6	16.1
Carbon - Dissolved Inorgani	mg/L	43 - 44	44	3				24		1								
Carbonate - Dissolved	mg/L	<0.5 - 7	<0.5	8	<0.5-5	0.5	8	<0.5-<5	<0.5	6	0.5-10	0.5	11					
Colour True	Rel. Units	10.0 - 80.0	24	19	<5-70	20	9	<4-50	15	7	5.0-30	20	15					
Fluoride	mg/L				0.08-0.16	0.1	9	0.08-0.18	0.12	7	0.12-0.19	0.13	13	0.12			0.14	
Hydrocarbons, Recoverable	mg/L													< 1	1	< 1	< 1	< 1
Magnesium - Dissolved	mg/L	6.2 - 17	9.5	18	6-8.1	7.7	9	8.9-11.6	10.5	7	11.1-21	14.5	13	8.4	8	7.9	8.9	8.2
Oil & Grease	mg/L	0.08 - 1.32	0.29	4	<0.2-0.3	0.2	3	<0.2-0.22	0.21	2	<0.2-0.21	0.21	2					
Oxygen - BOD	mg/L	0.1 - 3.3	0.6	25							0.1-3	0.6	16					
Oxygen - DO	mg/L	9.07-15.7	11.98	32	8.3-9.48	8.8	12	9.5-14.4	12.4	9	11.2-13.8	12	26					
Oxygen - COD	mg/L	11.0 - 28	14.5	11							<5-34	18	11					
pH		7.2 - 8.53	8	31	7.44-8.5	8.1	16	7.76-8.4	8.07	13	6.9-8.5	7.9	25	7.81	7.63	7.82	7.94	7.63
Potassium - Dissolved	mg/L	0.9 - 2.65	1.45	18	0.61-1.13	0.8	9	0.85-1.4	1.04	7	1.1-2.1	7.76	13	1.2	0.9	1.2	1.2	0.7
Residue - Filterable	mg/L	129 - 496	183	9	121-398	150	6	140-214	185	5	220-355	273	12					
Residue - Non filterable	mg/L	1 - 415	14	17	11-326	55	10	1.0-84	6	8	<0.4-92.3	2	14					
Residue - Total	mg/L	266 - 336	290	7	248		1	227		1	284-288	284	3					
Silica - Reactive	mg/L	3.1 - 6.4	4.17	18	1.32-5.4	4.3	9	2.32-6.18	3.3	7	3.1-12	6.4	13					
Sodium - Dissolved	mg/L	4.0 - 23	11.7	18	4.5-8.2	5	9	6-13.8	12	7	13.7-24.6	18.2	13	13.6	8.6	16.6	11.5	8.3
Specific Conductance	µS/cm	216 - 482	301	31	209-260	234	14	253-345	317	13	267-530	436	25	253	200	268	249	205
Sulphide - Dissolved	mg/L	<0.001 - 0.002	<0.001	11	<0.001-0.002	<0.001	3	<0.001- 0.00	<0.001	4	<0.001-0.001	<0.001	9					
Sulphate - Dissolved	mg/L	14 - 57	26.8	18	14.4-24	19.6	9	16-38	32	7	33.3-58	51	13	18.3	13.1	20.3	19.2	14.2
Sulphur - Total	mg/L													6.6			7.3	
Total Alkalinity (as CaCO3)	mg/L	94 - 177	122	18	94-111	98	9	118-158	127	7	133-231	174	13	97.4	88.2	94.8	104	90.3
Total Cyanide	mg/L	<0.001 - 0.001	<0.001	3										< 0.001	< 0.001	0.005	0.1	< 0.001
Total Dissolved Solids	mg/L	117 - 314	223	29	117-159	127	14	139-196	181	9	187-319	251	15	141	120	146	145	123
Total Hardness (as CaCO3)	mg/L	90 - 210	134	17	102-120	105	9	122-153	130	7	143-271	192	13	111	114	100	121	118
Total Phenolics	mg/L	0.001 - 0.01	0.004	17	<0.001-0.004	0.002	8	<0.001-0.002	0.002	7	<0.001-0.001	0.001	13	0.001	0.001	< 0.001	0.002	0.001
Turbidity	NTU	1.5 - 195	40	17	3-166	38	8	3.8-54	5.8	7	0.4-161	2.3	15					
Nutrients																		
Ammonia - Total	mg/L	0.01 - 0.06	0.02	14	<0.01-0.02	<0.001	5	<0.01-0.02	0.01	5	<0.01-0.08	0.04	14					
Ammonia - Dissolved	mg/L	0.004 - 0.04	0.017	7	0.005-0.021	0.01	4	0.003-0.018	0.01	2	0.063		1					
Chlorophyll A	mg/m3	0.2 - 14.4	1.1	11	1.4-7.7	3.3	6	1.2-2.6	1.85	4	0.2-0.4	0.3	5					
Nitrogen - Dissolved Kjeldah	mg/L	0.26 - 0.46	0.4	3	0.3-0.44	0.37	2	0.36		1	0.34-0.46	0.4	3					
Nitrogen - Particulate Total	mg/L	0.02 - 0.17	0.04	8	0.12		1				<0.02		1					
Nitrogen - Total Kjeldahl	mg/L	0.24 - 1.79	0.48	21	0.18-1	0.29	10	0.18-1.9	0.26	7	0.24-0.95	0.36	15					
Nitrogen - Total	mg/L	0.316 - 1.79	0.525	21	0.18-1	0.303	9	0.257		1	0.378-1.116	0.5	15					
Nitrite plus Nitrate Nitrogen	mg/L	0.001 - 0.23	0.109	22	<0.001-0.047	0.003	9	<0.001-0.03	0.003	7	0.005-0.19	0.14	15	0.015	0.11	0.007	0.003	0.1
Nitrite - Dissolved	mg/L	0.001- 0.05	0.002	11	<0.001-0.003	<0.001	4	<0.001-1.9	<0.001	9	<0.001-0.002	<0.001	3					
Phosphorus - Particulate	mg/L	0.004 - 0.29	0.062	13	0.011-0.229	0.12	4	0.009-0.079	0.014	5	0.002-0.144	0.007	12					
Phosphorus - Total	mg/L	0.01 - 0.3	0.064	28	0.02-0.24	0.05	16	0.009-0.108	0.016	12	0.003-0.179	0.019	26	0.048	0.39	0.028	0.04	0.44
Metals (Total)																		
Aluminum	mg/L	0.005 - 1.44	0.019	15	0.111-2.5	0.6	7	<0.01-0.76	0.08	5	0.01-0.07	0.03	11	0.17	8.64	0.11	0.15	10.1
Antimony	mg/L													< 2E-04	2E-04	< 2E-04	< 0.0002	0.0003
Arsenic	mg/L	0.0004 - 0.0019	0.0004	13	0.0004-0.0012	8E-04	5	0.0003-0.001	8E-04	4	0.0004-0.000	0.0005	5	6E-04	0.007	5E-04	0.0008	0.007
Barium	mg/L	0.06 - 0.12	0.083	14	0.059-0.15	0.08	6	0.065-0.08	0.073	4	0.08-0.122	0.087	6	0.05	0.2	0.04	0.06	0.21
Beryllium	mg/L	<0.001 - 0.001	<0.001	3	<0.001-0.003	0.002	2	<0.001		1	<0.001 - 0.00	<0.001	2	< 0.001	0.004	< 0.001	< 0.001	0.004
Boron	mg/L	0.04		1	0.04		1	0.04		1	0.01-0.05	0.03	2	0.05	0.05	0.09	0.03	0.05
Cadmium	mg/L	0.0002 - 0.002	0.001	14	<0.0002-0.001	0.001	6	<0.001-0.001	0.001	4	<0.001-0.003	0.001	6	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003
Chromium	mg/L	0.001 - 0.01	0.0025	14	0.004-0.032	0.004	6	0.001 - 0.007	0.003	5	0.002-0.006	0.003	10	< 0.002	0.003	< 0.002	< 0.002	< 0.002
Cobalt	mg/L	<0.001 - 0.01	<0.001	14	<0.001-0.004	0.001	6	<0.001-0.001	<0.001	4	0.001-0.004	0.001	6	< 0.003	< 0.003	< 0.003	0.006	0.005
Copper	mg/L	<0.001 - 0.01	0.002	18	0.002-0.014	0.003	9	<0.001-0.004	<0.001	7	0.001-0.007	0.002	14	< 0.001			0.004	
Iron	mg/L	0.101 - 7.51	0.22	15	0.25-10.7	1.89	6	0.19-2.42	0.78	4	0.13-0.25	0.2	5	0.43	17.9	0.91	0.43	19.4
Lead	mg/L	<0.001-0.01	0.002	14	<0.002-0.003	0.003	6	0.002-0.003	0.003	4	<0.002-0.009	0.002	10	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Lithium	mg/L	<0.005		1	0.014		1	0.017		1	<0.005-0.02	0.013	5	0.006	0.014	0.006	0.006	0.019
Manganese	mg/L	0.004-0.023	0.016	18	0.029-0.26	0.044	7	0.013-0.073	0.017	6	<0.004-0.016	0.007	9	0.04	0.509	0.033	0.044	0.534
Mercury	µg/L	0.04 - 0.2	0.1	18	<0.05-0.1	0.05	9	<0.05-0.1	<0.05	7	<0.05-0.1	0.05	13	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Molybdenum	mg/L	0.001-0.01	0.002	14	<0.001-<0.003	0.001	6	<0.001-0.01	0.002	4	<0.001-0.007	0.001	5	< 0.003	< 0.003	< 0.003	0.004	< 0.003
Nickel	mg/L	0.001-0.01	0.004	14	0.004-0.014	0.009	6	0.002-0.005	0.004	4	0.001-0.009	0.004	6	0.005	< 0.005	< 0.005	< 0.005	0.009
Selenium	mg/L	0.0001-0.001	0.0001	13	<0.0001-0.0004	2E-04	6	0.0001-0.000	2E-04	4	0.0001-0.000	0.0002	6	< 2E-04	< 2E-04	< 2E-04	< 0.0002	< 0.0002
Silicon	mg/L													2.12			1.85	
Silver	mg/L	0.0003		1	<0.001		1	<0.001		1	<0.001-0.001	<0.001	3	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Strontium	mg/L	0.18		1	0.22		1	0.22		1	0.32-0.36	0.34	2	0.19	0.229	0.171	0.21	0.248
Titanium	mg/L													0.004	0.085	0.007	0.005	0.056
Uranium	mg/L													< 0.5			< 0.5	
Vanadium	mg/L	0.002-0.02	0.003	14	<0.002-0.016	0.004	6	<0.002-0.005	0.003	4	<0.001-0.009	0.002	6	< 0.002	0.009	0.003	0.004	0.015
Zinc	mg/L	0.001-0.03	0.005	19	0.005-0.038	0.008	8	<0.001-0.03	0.009	6	0.001	0.034	14	0.019	0.085	0.017	0.019	0.095
Bacteria																		
Total Coliforms	No/100 mL	4.0 - 250	68	11	12-240	24	3	<4-84	44	2	1.0-56	28	5					
Fecal Coliforms	No/100 mL	2.0 - 8.0	<4	11	<4-76	10	4	<4-24	14	2	1.0-4	4	5					
Detectable Trace Organic Compounds																		
Naphthalene	µg/L																0.02	
Methyl Naphthalene	µg/L																0.03	
Naphthenic Acids	mg/L													< 1	< 1	< 1	< 1	< 1

NOTES

* Median values; Data from NAQUADAT (1985) for Site 00AL07CC0600.

Historical trace organics data are not available.

TABLE VI-3

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
			ORGANICS						
Total Petroleum Hydrocarbons (mg/L)									
Total Petroleum Hydrocarbons	-	-	-	-	-	-	99-113	-	-
Hydrocarbons, Recoverable	<1-1	<1-9	<1-22	<1-19	-	<1	<1	<1	-
Total Extractable Hydrocarbons (mg/L)									
Total Extractable Hydrocarbons	-	-	38.9-59.8	-	-	-	<1	<1	-
Naphthenic Acids (mg/L)									
Naphthenic acids	<1	<1	62-94	47-55	-	<2-5	<1-4	<1-5	-
Polycyclic Aromatic Hydrocarbons (µg/L)									
1-Methyl-7-isopropylphenanthrene (Retene)	<0.04	<0.04	<0.04	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
Acenaphthene	<0.02	<0.02	<0.02-<0.08	<0.02	<0.02-0.12	<0.02	<0.02	<0.02	-
Acenaphthylene	<0.02	<0.02	<0.02-0.16	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Anthracene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Benzo(a)anthracene/chrysene	<0.02	<0.02	<0.02-0.27	<0.02	<0.02-0.1	<0.02	<0.02-1	<0.02	-
Benzo(a)pyrene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.02	<0.02	<0.02	<0.02	-
Benzo(b&k)fluoranthene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Benzo(ghi)perylene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.03	<0.02	0.02-0.03	<0.02	-
Biphenyl	<0.04	<0.04	<0.04-0.08	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
C2 sub'd benzo(a)anthracene/chrysene	<0.04	<0.04	<0.04-0.83	<0.04	<0.04-0.05	<0.04	<0.04-0.12	<0.04	-
C2 sub'd benzo(b&k)fluoranthene/ benzo(a)pyrene	<0.04	<0.04	<0.04-0.18	<0.04	<0.04-0.04	<0.04	<0.04-0.07	<0.04	-
C2 sub'd biphenyl	<0.04	<0.04	<0.04-0.25	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
C2 sub'd dibenzothiophene	<0.04	<0.04	<0.04-2.2	<0.04	<0.1-0.52	<0.04	<0.04-0.19	<0.04	-
C2 sub'd fluorene	<0.04	<0.04	<0.04-1.1	<0.04-0.28	<0.04-0.35	<0.04	<0.04-0.16	<0.04	-
C2 sub'd naphthalene	<0.04	<0.04	<0.04-0.25	<0.04-0.07	0.25-0.3	<0.04	<0.04-0.04	<0.04	-
C2 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-4.5	<0.04-0.06	<0.1-0.39	<0.04	<0.04-0.22	<0.04	-
C3 sub'd dibenzothiophene	<0.04	<0.04	<0.04-4.1	<0.04	<0.1-0.08	<0.04	<0.04-0.12	<0.04	-
C3 sub'd naphthalene	<0.04	<0.04	<0.04-0.3	<0.04-0.27	<0.1-0.78	<0.04	<0.04-0.34	<0.04	-
C3 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-3.6	<0.06-0.12	<0.1-0.21	<0.04	<0.04-0.25	<0.04	-
C4 sub'd dibenzothiophene	<0.04	<0.04	<0.04-4.4	<0.04	<0.1-0.06	<0.04	<0.04	<0.04	-
C4 sub'd naphthalene	<0.04	<0.04	<0.04-2	0.04-0.56	<0.1-0.6	<0.04	<0.04-0.09	<0.04	-
C4 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04-1.7	<0.04-0.06	<0.04-<0.1	<0.04	<0.04-0.33	<0.04	-
Dibenzo(a,h)anthracene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Dibenzothiophene	<0.02	<0.02	<0.02-0.07	<0.02	<0.02-0.03	<0.02	<0.02-0.09	<0.02	-
Fluoranthene	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02-0.03	<0.02	<0.02	<0.02	-
Fluorene	<0.02	<0.02	<0.02-0.03	<0.02	<0.02-0.14	<0.02	<0.02	<0.02	-
Indeno(c,d-123)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02-<0.05	<0.02	<0.02	<0.02	-
Methyl acenaphthene	<0.04	<0.04	<0.04-0.19	<0.04-0.28	<0.04-<0.1	<0.04	<0.04	<0.04	-
Methyl benzo(a)anthracene/chrysene	<0.04	<0.04	<0.04-0.5	<0.04	<0.04-0.11	<0.04	<0.04-0.12	<0.04	-
Methyl benzo(b&k) fluoranthene/ methyl benzo(a)pyrene	<0.04	<0.04	<0.04-0.3	<0.04	<0.04-0.05	<0.04	<0.04-0.07	<0.04	-
Methyl biphenyl	<0.04	<0.04	<0.04-<0.08	<0.04	<0.04-<0.1	<0.04	<0.04	<0.04	-
Methyl dibenzothiophene	<0.04	<0.04	<0.04-0.65	<0.04-0.05	<0.1-0.21	<0.04	<0.04-0.21	<0.04	-

TABLE VI-3'

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

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	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Methyl fluoranthene/pyrene	<0.04	<0.04	<0.04-0.65	<0.04-0.08	<0.1-0.12	<0.04	<0.04-0.31	<0.04	-
Methyl fluorene	<0.04	<0.04	<0.04-0.3	<0.04-0.26	<0.04-0.25	<0.04	<0.04	<0.04	-
Methyl naphthalene	<0.02-<0.1	<0.02	<0.02-<0.08	<0.02-0.05	<0.02-0.34	<0.02	<0.02-0.1	<0.02	-
Methyl phenanthrene/anthracene	<0.04	<0.04	<0.04-0.79	<0.04-0.07	<0.1-0.46	<0.04	<0.04-0.19	<0.04	-
Naphthalene	<0.02	<0.02-0.02	<0.02-0.05	<0.02-0.09	0.23-0.56	<0.02	<0.02	<0.02	-
Phenanthrene	<0.02	<0.02	<0.02-0.09	<0.02	<0.02-0.12	<0.02	<0.02	<0.02	-
Pyrene	<0.02	<0.02	<0.02-0.04	<0.02	<0.02-0.09	<0.02	<0.02-0.16	<0.02	-
Polycyclic Aromatic Nitrogen Heterocycles (µg/L)									
7-Methyl quinoline	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.12-0.46	<0.02	-
Acridine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02-0.13	<0.02	-
C2 Alkyl subst'd carbazoles	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
C2 Alkyl subst'd quinolines	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.09-0.4	<0.02	-
C3 Alkyl subst'd quinolines	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Carbazole	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Methyl acridine	<0.02	<0.02	<0.02-<0.04	<0.02	<0.02	<0.02	<0.02-0.6	<0.02	-
Methyl carbazoles	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-
Phenanthridine	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02-0.21	<0.02	-
Quinoline	<0.02	<0.02	<0.02	<0.02-0.09	<0.02	<0.02	<0.02-0.71	<0.02	-
Phenols (µg/L)									
2,4-Dimethylphenol	<0.1	<0.1	<0.2-1	<0.02	<0.1	<0.1	<0.1-1	<0.1	-
2,4-Dinitrophenol	<2	<2	<4-<20	<1-<20	<20	<2	<2	<2	-
2-Nitrophenol	<0.2	<0.2	<0.4-<2	<0.4-<2	<2	<0.2	<0.2	<0.2	-
4,6-Dinitro-2-methylphenol	<2	<2	<20	<4-<20	<20	<2	<2	<2	-
4-Nitrophenol	<2	<2	<4-<20	<4-<20	<20	<2	<2	<2	-
m-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
o-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
p-Cresol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
Phenol	<0.1	<0.1	<0.1-<1	<0.1-<1	<0.1	<0.1	<0.1	<0.1	-
Phenols	-	-	<0.002	<0.002	-	<0.002	<0.002	<0.002	-
Volatiles (µg/L)									
1,1,1-Trichloroethane	<1	<1	<1-<15	<1	<1	<1	<1-4	<1	-
1,1,2,2-Tetrachloroethane	<5	<5	<5-<75	<5	<5	<5	<5	<5	-
1,1,2-Trichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,1-Dichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,1-Dichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,2,3-Trichloropropane	<2	<2	<2-<30	<2	<2	<2	<2	<2	-
1,2-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,2-Dichloroethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,2-Dichloropropane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,3-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
1,4-Dichlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
2-Butanone (MEK)	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-

TABLE VI-3

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

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	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
2-Chloroethylvinylether	<5	<5	<5-<75	<5	<5	<5	<5	<5	-
2-Hexanone	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
4-Methyl-2-pentanone (MIBK)	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
Acetone	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Acrolein	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Acrylonitrile	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Benzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromodichloromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromoform	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Bromomethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
Carbon disulfide	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Carbon tetrachloride	<1	<1	<1-<15	<1	<1	<1	<1-3	<1	-
Chlorobenzene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Chloroethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
Chloroform	<1	<1	<1-<15	<1	<1	<1	<1-3	<1	-
Chloromethane	<10	<10	<10-<150	<10	<10	<10	<10	<10	-
cis-1,3-Dichloropropene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
cis-1,4-Dichloro-2-butene	<2	<2	<2-<30	<2	<2	<2	<2	<2	-
Dibromochloromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Dibromomethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Dichlorodifluoromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Ethanol	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Ethyl methacrylate	<200	<200	<200-<3000	<200	<200	<200	<200	<200	-
Ethylbenzene	<1	<1	<1-<15	<1-1.5	<1	<1-1.2	<1-1.2	<1-1.5	-
Ethylene dibromide	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Iodomethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
m+p-Xylenes	<1	<1	<1-15	<1-5	<1	<1 - 4.1	<1-4.5	<1-5.7	-
Methylene chloride	<1	<1	<1-<30	<1	<1	<1	<1-5.7	<1	-
o-Xylene	<1	<1	<1-15	<1-2.7	<1	<1-1.7	<1-2.2	<1-2.8	-
Styrene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Tetrachloroethylene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Toluene	<1	<1	<1-<15	<1	<1	<1	<1-1	<1	-
trans-1,2-Dichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
trans-1,3-Dichloropropene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
trans-1,4-Dichloro-2-butene	<5	<5-5	<5-<75	<5	<5	<5	<5	<5	-
Trichloroethene	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Trichlorofluoromethane	<1	<1	<1-<15	<1	<1	<1	<1	<1	-
Vinyl acetate	<100	<100	<100-<1500	<100	<100	<100	<100	<100	-
Vinyl chloride	<20	<20	<20-<300	<20	<20	<20	<20	<20	-
INORGANICS									
General (mg/L)									
pH (pH units)	7.63-7.82	7.4-8.18	7.91-8.54	7.99-8.2	8.01-8.07	7.66-8.31	6.8-8.9	7.3-8.4	6.6

TABLE VI-3

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Specific Conductance (µS/cm)	200-268	159-572	1891-4900	1325-1514	1740-1790	588-747	381-1650	209-465	-
Calcium	27-33	19-60	33.3-118	23.5-57.1	29.9-43.2	54-99	32-69	26-55	-
Chloride	3.1-14.8	<0.5-57	45.4-510	15.3-17.3	<0.5-33.4	29-41	30-354	1.0-18	-
Magnesium	7.9-21	6.4-18.4	7.2-28	8.7-11.3	2.73-18.1	19-30	8-18.7	6.0-16	-
Potassium	0.9-2.65	0.41-2.2	<11.5-29	8.4-10.8	0.5-18.9	1.9-3.1	1.2-9.3	0.7-8	-
Sodium	8.6-25	7.5-61	347-1170	273-335	7.7-16600	26-53	28-246	5.0-23	-
Bicarbonate	108-267	97-29	330.84-800	847-884	34-1210	222-309	116-220	116-207	-
Carbonate	<0.5-10	<0.5	<0.05-20	<0.5	<0.5	<0.5-4	<0.5-10	<0.5-5	-
Biological Oxygen Demand	0.1-3.3	-	1.6-6.9	5-9.6	-	<0.1-0.9	<0.1-11.2	<0.1-2.5	-
Chemical Oxygen Demand	<5-28	-	200-430	120-360	-	19-47	11-305	<5-49	-
Dissolved Organic Carbon	1-17.2	12-27.5	52-65.3	36.1-42.5	-	9.8-15	5.0-42	4.0-17	-
Nitrate & Nitrite	<0.001-0.19	<0.003-0.1	<0.003-0.05	0.11-0.26	0.011	<0.003-0.01	<0.003-0.01	<0.003-0.12	0.2
Phenols	<0.001-0.01	<0.001-0.005	<0.002-0.02	<0.001-0.004	0.01	<0.001-0.08	<0.001	<0.001-0.001	-
Sulphate	13.1-58	1.6-53	555-1290	29.1-143	6.7-118	60-142	30-116	15-49	-
Sulphide	<0.001-0.002	-	-	-	-	-	-	-	-
Total Ammonia	<0.01-0.08	<0.01-0.11	0.098-3.98	4.37-6.01	17.2-19.9	<0.001-0.04	<0.006-25	<0.01-0.22	-
Total Dissolved Solids	117-319	87-339	1400-1805	878-1007	1090-1100	365-518	440-510	145-175	-
Total Kjeldahl Nitrogen	0.26-0.46	-	0.95-6.8	7.4-8.75	-	0.3-0.44	0.5-36.3	0.19-0.7	-
Total Organic Carbon	3.2-19	-	56.1-68	38.4-45	-	10.1-12.2	8.2-16	6.5-15.3	-
Total Phosphorus	0.003-0.39	0.014-0.20	0.006-0.1	0.14-0.43	<0.1-0.2	0.01-0.04	<0.003-0.29	0.02-0.17	-
Total Sulphur	6.6	2.1-17.3	186-266	12.7-48.4	5.6-12.2	20.5-44	15-19	5.9-7.9	-
Total Suspended Solids	4-624	0.4-211	<0.4-17	17-64		<0.4-20	6.0-27	2-126	-
Metals and Trace Elements (mg/L)									
Aluminum	<0.01-8.64	<0.01-1.89	<0.01-1.92	0.08-1.15	<0.01-0.88	<0.01-0.07	0.23-5.93	0.05-1.15	-
Antimony	<0.0002 - 0.0002	<0.0002-0.0003	-	-	0.0006	-	0.002	-	<0.2
Arsenic	0.0004-0.007	<0.0002-0.002	0.0007-0.0058	0.0026-0.003	0.0036	<0.0002-0.002	<0.0001-0.17	0.0002-0.004	<0.2
Barium	0.04-0.2	0.02-0.07	0.05-0.18	0.08-0.1	0.15-0.77	0.07-0.12	0.05-0.1	0.05-0.1	0.13
Beryllium	<0.001-0.004	<0.001-0.004	<0.001-0.004	<0.001-0.002	<0.001	<0.001-0.003	<0.001-0.005	<0.001-0.002	<0.01
Boron	0.01-0.09	0.05-0.14	2.26-4.26	1.65-1.88	0.21-2.31	0.12-0.22	0.05-0.15	0.01-0.07	1.21
Cadmium	<0.0002-0.003	<0.003-0.005	<0.003-0.007	<0.003-0.004	<0.0002-<0.001	<0.003-0.003	<0.001-0.01	<0.001-0.003	<0.01
Chromium	<0.002-0.032	<0.002-0.014	<0.002-0.003	<0.002-0.002	<0.002-0.03	<0.002-0.002	<0.0002-0.03	<0.002-0.01	<0.005
Cobalt	<0.001-0.01	<0.003-0.005	<0.003-0.007	<0.003-0.005	0.003-0.02	<0.003-0.01	<0.001-0.01	<0.001-0.004	<0.02
Copper	<0.001-0.01	<0.001-0.002	<0.001-0.004	0.002-0.01	<0.001	<0.001-0.01	<0.001-0.064	0.006-0.03	0.01
Cyanide	<0.001-0.005	<0.001-0.03	<0.001-0.06	0.001-0.002	-	<0.001-0.002	<0.002-0.003	<0.001-0.001	0.07
Fluoride	0.08-0.18	0.14-0.24	-	-	2.1-2.8	-	0.07-0.38	-	0.9
Iron	0.101-17.9	0.38-4.81	<0.01-1.01	1.24-2.21	0.01-22.5	0.007-0.3	0.005-2.56	0.22-2.28	0.35
Lead	<0.001-0.01	<0.02	<0.0003-0.02	<0.02	<0.0003-<0.01	<0.02	<0.002-0.05	<0.02-<0.05	<0.05
Lithium	<0.005-0.02	0.006-0.02	0.16-0.27	0.12-0.14	0.19-0.23	<0.013-0.02	0.009-0.022	0.004-0.01	-
Manganese	<0.004-0.51	0.014-0.21	<0.001-0.06	0.12-0.21	0.06 - 1.76	0.02-0.11	<0.001-0.12	0.012-0.15	1.41
Mercury(µg/L)	<0.05-0.2	<0.05	<0.05-0.05	<0.05-0.26	0.4	<0.05-0.52	<0.05-0.62	<0.05-0.52	<0.1
Molybdenum	<0.001-0.01	<0.003-0.004	0.15-1.42	<0.003-0.02	<0.003-0.07	<0.003-0.003	<0.004-0.6	<0.002-0.002	2.23
Nickel	<0.005-0.01	<0.005-0.012	<0.005-0.03	<0.005-0.01	0.005-0.06	<0.005-0.01	<0.002-0.15	<0.001-0.02	0.5

TABLE VI-3

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

Page 5 of 5

	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
Chemical	Athabasca River[1]	Reference Tributaries[2]	Consolidated Tailings Release Water[3]	Tar Island Dyke Seepage Water[4]	Plant 4 Seepage[5]	Mine Drainage[6]	Refinery Wastewater[7]	Cooling Pond E[8]	Gypsum Leachate[9]
Selenium	<0.0001-0.0004	<0.0002-0.0003	<0.0002-0.04	<0.0002-0.0002	<0.00004	<0.0002	<0.0001-0.006	<0.0001-0.0005	<0.2
Silicon	2.12	1.13-3.6	2.32-5.58	5.63-10.1	1.1-6.12	2.82-3.89	2.45-3.53	2.17-5.05	-
Silver	<0.001-0.001	<0.002-0.003	<0.0002-0.002	<0.002	<0.0002-<0.001	<0.002-0.002	<0.002-0.05	<0.002-0.05	<0.01
Strontium	0.18-0.36	0.073-0.21	0.75-2.12	0.27-0.34	0.42-0.77	0.15-0.28	0.24-0.29	0.18-0.22	-
Thallium	-	-	-	-	<0.0003-<0.01	-	<0.01-<1	<0.1	<0.05
Tin	-	-	-	-	<0.0003-0.44	-	-	-	-
Titanium	0.004-0.09	<0.003-0.05	<0.003-0.02	<0.003-0.02	0.004-0.01	<0.003-0.003	<0.003-0.047	<0.003-0.01	-
Uranium	<0.5	<0.5	0.007-0.5	<0.5	<0.0002-<0.1	<0.5	<0.5-0.5	<0.5-0.5	<0.2
Vanadium	<0.002-0.02	<0.002-0.008	<0.002-0.17	0.003-0.01	<0.002-0.05	<0.002-0.005	0.005-1.61	<0.002-0.013	0.13
Zinc	<0.001-0.09	0.012-0.16	0.003-0.06	0.01-0.06	0.01-0.07	0.003-0.04	0.001-0.273	<0.005-0.05	0.12
Zirconium	-	-	-	-	0.0012-0.0013	-	-	-	-

[1] Golder, 1995 unpublished data (site: upstream of L19, n= 1 to 4); NAQUADAT (code: 00AL07CC0600, 1985-1995, n= 1 to 26).

[2] Data from the tributaries were grouped and included data from Legget Creek, McLean Creek, Steepbank River and Wood Creek sampled by Golder during 1995 (Golder 1996; n= 1 to 20).

[3] Suncor and Syncrude, 1995 unpublished data from CT field studies, (n= 6 to 18).

[4] Suncor, 1995 unpublished data from Lease 86 Study, ID: RW 127, (n= 1 to 4).

[5] Suncor, 1995 unpublished data, samples from Plant 4 Beach #2 aqueous extract and RG088/089, (n=1 to 4).

[6] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW250 & 252, n= 2 to 8).

[7] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW254, n= 2 to 4); NAQUADAT (codes: 20AL07DA1000/1001, 1980-1995, (n=1 to 80); Suncor's Monthly Water Monitoring Reports.

[8] Suncor, 1995 unpublished data from Lease 86 Study (Suncor ID: RW256, n= 1 to 4); NAQUADAT (code: 20AL07DA1013, 1980-1995, n= 1 to 18); Suncor's Monthly Water Monitoring Reports.

[9] Suncor, 1995 unpublished FGD Pilot Study (Sample is 50% gypsum : 50% flyash, n=1).

TABLE VI-4

CHEMICAL SPECIFIC AND WHOLE EFFLUENT TOXICITY BASED LIMITS - AQUATIC LIFE BASED

PARAMETER	Maximum Allowable Load	Maximum Current Wastewater Load	Pond E Contribution Load	Wastewater System Contribution Load	Maximum Allowable Concentration	Maximum Current Wastewater Concentration	Pond E Contribution Concentration	Wastewater System Contribution Concentration
GENERAL	(kg/d)	(kg/d)	(kg/d)	(kg/d)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Ammonia	1481.0	11.9	9.5	2.4	8	0.1431	0.23	0.07
Cyanide (Total)	4.47	1.3	0.1	1.14	0.022	0.0193	0.003	0.033
Phenolics	2.98	<0.14	<0.07	<0.07	5.8	<0.002	<0.002	<0.002
METALS								
Aluminum	69.70	335.7	130.8	204.9		4.6743	3.18	5.93
Arsenic	49.20	6.04	0.16	5.88	0.36	0.0942	0.004	0.17
Barium	903.20	7.7	4.2	3.49		0.1015	0.102	0.101
Beryllium	0.53	0.15	0.08	0.069	0.13	0.0020	0.002	0.002
Cadmium	0.46	0.33	0.12	0.21	0.0074	0.0046	0.003	0.006
Chromium	8.25	1.33	0.33	1.00	0.016	0.0194	0.008	0.029
Cobalt	7.75	0.34	0.16	0.17		0.0045	0.004	0.005
Copper	16.50	3.4	1.19	2.21	0.03	0.0480	0.029	0.064
Iron	806.20	203.2	114.74	88.47		2.6650	2.79	2.56
Lead	2.14	1.9	0.86	1.00	0.166	0.0253	0.021	0.029
Mercury	0.01	0.046	0.02	0.02	0.0024	0.0006	0.00052	0.0007
Molybdenum	723.10	20.859	0.12	20.74		0.3274	0.003	0.6
Nickel	20.00	6.390	1.27	5.11	2.28	0.0946	0.031	0.148
Selenium	0.89	0.220	0.02	0.20	0.26	0.0034	0.0004	0.0059
Strontium	178.90	19.0	9.13	9.92		0.2573	0.222	0.287
Vanadium	155.80	62.7	7.07	55.64		0.9534	0.172	1.61
Zinc	17.10	11.5	2.02	9.43	0.188	0.1707	0.049	0.273
TRACE ORGANICS								
Volatiles								
ethylbenzene	7.95	0.101	0.049	0.052	32	0.0014	0.0012	0.0015
chloroform	1232.00	0.086	0.041	0.045	28.9	0.0012	0.001	0.0013
m,p-Xylene	29.81	0.382	0.185	0.197		0.0052	0.0045	0.0057
o-Xylene	1.99	0.187	0.090	0.097		0.0025	0.0022	0.0028
Polycyclic Aromatic Hydrocarbons								
napthalene	616.00	0.020	0.002	0.018	2.3	0.0003	0.00004	0.00053
fluoranthene	516.70	0.012	0.001	0.011	3.98	0.0002	0.00002	0.00031
Others								
toxicity - chronic	993.60	406	119	287		5.83	2.90	8.30
toxicity - acute					0	0	0	0

TABLE VI-5

ESTIMATED FREQUENCY OF EXCEEDING THEORETICAL FINAL EFFLUENT LIMIT

	Limit[1]	Wastewater System			Pond E Cooling		
		Frequency[2] of Exceeding Theoretical Limit			Frequency[2] of Exceeding Theoretcial Limit		
		79.5K	87.0K	107.0K	79.5K	87.0K	107.0K
Chromium (mg/L)	0.016	0.013	0.013	0.013	0	0	0
Copper (mg/L)	0.03	3.8%	3.8%	3.8%	0	0	0
Mercury (kg/d)	0.01	23.8%	8.8%	8.8%	0.125	0.063	0.063

[1] Calculated water quality based effluent limit based upon AEP (1995).
[2] Based upon 1986-1995 effluent monitoring.

TABLE VI-6

CHEMICAL SPECIFIC LIMITS - HUMAN HEALTH

PARAMETER	Water Quality Criteria USEPA		Maximum Allowable Load	Existing (1995) Wastewater Load	Pond E Contribution Load	Wastewater System Contribution Load	Existing (1995) Wastewater Concentration	Pond E Contribution Concentration	Wastewater System Contribution Concentration
GENERAL	Carcinogens (mg/L)	Non-carcinogens (mg/L)	(kg/d)	(kg/d)	(kg/d)	(kg/d)	(mg/L)	(mg/L)	(mg/L)
Cyanide (Total)		0.7	7258	1.26	0.12	1.14	0.0193	0.003	0.033
METALS									
Arsenic		0.000018	0.19	6.04	0.16	5.88	0.0942	0.004	0.17
Barium		1	9425	7.69	4.2	3.49	0.1015	0.102	0.101
Iron		0.3	1140	203.22	114.7	88.47	2.6650	2.79	2.56
Manganese		0.05	319	5.84	2.8	3.01	0.0788	0.069	0.087
Mercury		0.00014	1.5	0.046	0.021	0.02	0.0006	0.00052	0.0007
Nickel		0.61	6275	6.39	1.3	5.11	0.0946	0.031	0.148
TRACE ORGANICS									
Volatiles									
Benzene	0.0012		32	0.08	<0.041	0.03	0.0010	<0.001	0.001
Bis(2-Ethyl-hexyl)Phthalate	15		396576	0.56	<0.041	0.52	0.0086	<0.001	0.015
Butylbenzyl-Phthalate		5.2	53914	0.08	<0.041	0.03	0.0010	<0.001	0.001
Carbon Tetrachloride	0.00025		7	0.14	<0.041	0.10	0.0021	<0.001	0.003
Chloroform	0.0057		151	0.09	0.041	0.04	0.0012	0.001	0.0013
Dibutyl-Phthalate		2.7	27994	0.14	<0.041	0.10	0.0021	<0.001	0.003
Diethyl-Phthalate		23	238464	0.08	<0.041	0.03	0.0010	<0.001	0.001
Ethylbenzene		3.1	32141	0.10	0.049	0.05	0.0014	0.0012	0.0015
Isophorone		0.0084	87	0.08	<0.041	0.03	0.0010	<0.001	0.001
Methylene chloride	0.0047		124	<0.041	<.041	0.20	0.00285	0.001	0.0057
Toluene		6.8	70502	0.08	<0.041	0.03	0.0010	<0.001	0.001
Polycyclic Aromatic Hydrocarbons									
Benzo(a)anthracene	0.0000028		0.074	<0.006	<.002	0.01	0.00014	<0.00004	0.00028
Pyrene	0.96		25381	<0.004	<.001	0.01	0.00008	<0.00002	0.00016
Phenolics									
2,4-Dichlorophenol		0.093	964	0.08	<0.041	0.03	0.0010	<0.001	0.001

TABLE VI-7

FLOW RATES - EXISTING AND FUTURE (L/s)

Outfall ID	Outfall Description	1995	2001	2010	2020	Equilibrium
S1	Shipyard Lake Groundwater	0.00	0.00	2.50	6.20	6.80
S2	South Mine Discharge Point	15.29	28.26	30.81	103.16	65.91
S3	TID Seepage	19.00	19.00	19.00	15.00	5.70
S4	Wastewater/Cooling Pond E	950.88	613.88	443.88	458.45	35.01[1]
S5	Steepbank Mine Groundwater	0.00	0.00	1.10	1.40	1.40
S6	Mid-Plant Discharge Point	12.54	12.54	12.54	12.54	0.00
S7	Pond 4 Seepage	1.00	1.00	1.00	1.00	1.00
S8	Pond 5 Seepage	0.00	0.00	3.50	3.50	4.70
S9	North Mine	14.65	3.51	3.51	59.09	32.83
S10	Pond 6 Drainage Outlet	0.00	0.00	0.00	137.90	31.18
S11	Pond 6 Seepage	0.00	0.00	6.80	6.80	3.60
S12	Syncrude Lakes	n/a	n/a	n/a	n/a	154.00
Total		1013.36	678.19	524.64	805.04	307.12

[1] Natural runoff from reclaimed plant site.

Note:
- Flows from AGRA (1996), except for S12 (W.E.R. 1992); based on an average year.
- For outfall locations, please refer to Figure D1.0-2.

TABLE VI-8
TOTAL LOADS FROM ALL SUNCOR DISCHARGE SOURCES (kg/d)

Parameter	Scenario				
	1995	2001	2010	2020	Equilibirium
ORGANICS -					
2,4,6-Trichlorophenol	0.20	0.15	0.15	0.15	0
2,4-Dichlorophenol	0.029	0.022	0.022	0.022	0
2,4-Dimethylphenol	0.029	0.035	0.023	0.035	0.0063
Benzene	0.029	0.022	0.022	0.022	0
Benzo(a) anthracene	0.029	0.026	0.022	0.025	0.0017
Bis(2-Ethyl-Hexyl)Phthal	0.43	0.33	0.33	0.33	0
Butylbenzyl-Phthalate	0.029	0.022	0.022	0.022	0
Carbon tetrachloride	0.087	0.066	0.066	0.066	0
Chloroform	0.087	0.066	0.066	0.066	0
Dibutyl-Phthalate	0.087	0.066	0.066	0.066	0
Diethyl-Phthalate	0.029	0.022	0.022	0.022	0
Ethylbenzene	0.0051	0.0068	0.007	0.022	0.012
Fluorene	0	0.00060	0.000036	0.00039	0.00019
Isophorone	0.029	0.02	0.022	0.022	0
Methylene chloride	0.16	0.12	0.12	0.12	0
m+p Xylene	0.012	0.21	0.028	0.24	0.13
m-cresol	0.0000059	0.0000059	0.0000059	0.0000059	0
naphthalene	0.00012	0.0016	0.00024	0.0010	0.00031
o-xylene	0.22	0.30	0.12	0.32	0.11
Phenols - Total	0.27	0.51	0.24	1.12	0.85
Pyrene	0	0.00066	0.000048	0.00052	0.00025
Toluene	0.029	0.022	0.022	0.022	0
Total PAH's	0.0055	0.40	0.044	0.40	0.18
INORGANICS					
Aluminum - Total	235	178	155	182	12.7
Ammonia - Total	757	657	586	650	25.3
Antimony - Total	0.058	0.045	0.044	0.04	0
Arsenic - Total	5.13	3.87	3.80	3.88	0.041
Barium - Total	8.85	7.97	4.67	8.25	2.33
Beryllium-Total	0.18	0.14	0.095	0.17	0.054
Boron - Total	13.5	70.0	17.2	75.8	29.2
Cadmium - Total	0.46	0.37	0.29	0.41	0.070
Calcium	5315	4484	2980	5394	1695
Chloride	11421	15080	8886	15327	3592
Chromium - Total	1.27	0.85	0.78	0.83	0.038
Cobalt - Total	0.53	0.44	0.33	0.49	0.10
Copper - Total	3.41	1.96	1.91	2.06	0.12
Cyanide -Total	0.15	0.82	0.16	0.90	0.39
Iron - Total	201	146	103	124	9.34
Lead - Total	4.08	2.15	1.91	2.15	0.13
Lithium-Total	1.55	4.99	1.52	5.30	1.88
Manganese - Total	12.7	9.70	6.55	10.1	1.91
Mercury - Total	0.05	0.03	0.024	0.030	0.0053
Molybdenum - Total	17.5	32.1	15.0	34.0	9.67
Nickel - Total	5.35	4.07	3.63	4.57	0.47
Phosphorus-Total	23.8	17.1	16.1	18.7	0.95
Selenium - Total	0.20	0.19	0.14	0.19	0.025
Silver - Total	0.15	0.14	0.12	0.16	0.032
Strontium - Total	21.7	40.9	14.4	42.9	16.0
Sulphate	6600	21329	5684	22582	9456
Thallium	34.1	23.4	23.4	23.4	0
Uranium - Total	0	0.093	0.01	0.091	0.044
Vanadium - Total	47.2	37.8	35.7	37.9	1.16
Zinc - Total	10.6	7.76	7.10	8.42	0.82
GENERAL					
Toxicity	421	373	276	451	126
TSS	194	458	304	856	300

TABLE VI-9 LOADS OF CONSTITUENTS AT 11 DISCHARGE OUTFALLS FROM SUNCOR MINE FOR THE YEAR OF 2020 (kg/d)

ID of Discharge Outfall:	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Outfall Description:	Shipyard Lake	South Mine Drainage	TID Seepage	Wastewater/Cooling	Steepbank Mine GW	Mid-plant Drainage	Pond 4 Seeapge	Pond 5 - Seepage	North Mine Drainage	Pond 6 - Drainage	Pond 6 -Seepage
Parameter											
Aluminum - Total	1.03E+00	6.91E+00	1.49E+00	1.50E+02	2.32E-01	5.41E-01	9.94E-02	5.81E-01	5.47E+00	1.43E+01	1.13E+00
Ammonia - Total	2.13E+00	1.85E+01	7.79E+00	5.60E+02	4.81E-01	9.76E+00	5.19E-01	1.20E+00	1.88E+01	2.91E+01	2.34E+00
Antimony - Total	0.00E+00	0.00E+00	0.00E+00	4.37E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Arsenic - Total	3.11E-03	2.14E-02	3.89E-03	3.78E+00	7.02E-04	3.92E-03	2.59E-04	1.75E-03	1.59E-02	4.44E-02	3.41E-03
Barium - Total	9.64E-02	1.22E+00	1.30E-01	4.02E+00	2.18E-02	6.59E-02	8.64E-03	5.44E-02	6.63E-01	1.86E+00	1.06E-01
Benzene	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a) anthracene	1.45E-04	7.29E-04	0.00E+00	2.19E-02	3.27E-05	0.00E+00	0.00E+00	8.16E-05	4.15E-04	1.96E-03	1.59E-04
Beryllium-Total	2.14E-03	2.53E-02	2.59E-03	7.95E-02	4.84E-04	2.20E-03	1.73E-04	1.21E-03	1.48E-02	4.30E-02	2.35E-03
Bis(2-Ethyl-Hexyl)Phthalate	0.00E+00	0.00E+00	0.00E+00	3.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Boron - Total	2.28E+00	1.59E+01	2.44E+00	7.47E+00	5.15E-01	5.38E-01	1.62E-01	1.29E+00	1.08E+01	3.19E+01	2.50E+00
Butylbenzyl-Phthalate	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium - Total	3.54E-03	3.49E-02	5.18E-03	2.73E-01	7.98E-04	0.00E+00	3.46E-04	2.00E-03	2.30E-02	6.19E-02	3.88E-03
Calcium	6.32E+01	7.87E+02	7.40E+01	2.50E+03	1.43E+01	8.22E+01	4.93E+00	3.57E+01	4.47E+02	1.32E+03	6.93E+01
Carbon tetrachloride	0.00E+00	0.00E+00	0.00E+00	6.56E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chloride	2.73E+02	1.56E+03	2.24E+01	8.06E+03	6.17E+01	1.17E+02	1.49E+00	1.54E+02	8.81E+02	3.89E+03	3.00E+02
Chloroform	0.00E+00	0.00E+00	0.00E+00	6.56E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium - Total	1.61E-03	1.86E-02	2.59E-03	7.65E-01	3.63E-04	1.18E-04	1.73E-04	9.07E-04	1.17E-02	3.11E-02	1.76E-03
Cobalt - Total	3.75E-03	6.42E-02	6.48E-03	2.91E-01	8.47E-04	1.16E-02	4.32E-04	2.12E-03	2.86E-02	7.41E-02	4.11E-03
m-cresol	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.88E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Copper - Total	2.14E-03	6.39E-02	7.78E-03	1.87E+00	4.84E-04	5.42E-03	5.18E-04	1.21E-03	3.20E-02	7.10E-02	2.35E-03
Cyanide -Total	2.95E-02	2.25E-01	2.59E-03	8.52E-02	6.65E-03	4.25E-03	1.73E-04	1.66E-02	9.18E-02	4.08E-01	3.23E-02
Dibutyl-Phthalate	0.00E+00	0.00E+00	0.00E+00	6.56E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2,4-Dichlorophenol	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Diethyl-Phthalate	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2,4-Dimethylphenol	5.36E-04	2.70E-03	0.00E+00	2.19E-02	1.21E-04	0.00E+00	0.00E+00	3.02E-04	1.54E-03	7.25E-03	5.88E-04
Ethylbenzene	0.00E+00	6.69E-03	1.94E-03	2.71E-03	0.00E+00	0.00E+00	1.30E-04	0.00E+00	4.91E-03	5.59E-03	0.00E+00
Fluorene	1.61E-05	8.10E-05	0.00E+00	0.00E+00	3.63E-06	0.00E+00	0.00E+00	9.07E-06	4.62E-05	2.18E-04	1.76E-05
Iron - Total	5.41E-01	7.04E+00	2.86E+00	9.58E+01	1.22E-01	1.12E+00	1.91E-01	3.05E-01	6.63E+00	8.72E+00	5.93E-01
Isophorone	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Lead - Total	1.07E-02	5.40E-02	0.00E+00	1.89E+00	2.42E-03	0.00E+00	0.00E+00	6.05E-03	3.08E-02	1.45E-01	1.18E-02
Lithium-Total	1.46E-01	9.88E-01	1.87E-01	8.76E-01	3.29E-02	1.16E-02	1.24E-02	8.23E-02	7.47E-01	2.06E+00	1.60E-01
Manganese - Total	3.11E-02	2.21E+00	2.76E-01	5.45E+00	7.02E-03	4.49E-01	1.84E-02	1.75E-02	6.99E-01	9.38E-01	3.41E-02
Mercury - Total	2.68E-05	2.55E-03	3.37E-04	2.24E-02	6.05E-06	1.53E-05	2.25E-05	1.51E-05	1.39E-03	2.79E-03	2.94E-05
Methylene chloride	0.00E+00	0.00E+00	0.00E+00	1.25E-01	0.00E+00	1.18E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Molybdenum - Total	7.61E-01	5.98E+00	2.33E-02	1.32E+01	1.72E-01	4.80E-02	1.56E-03	4.29E-01	2.23E+00	1.03E+01	8.34E-01
naphthalene	2.68E-05	1.98E-04	6.48E-05	8.05E-05	6.05E-06	0.00E+00	4.32E-06	1.51E-05	1.82E-04	3.63E-04	2.94E-05
Nickel - Total	1.58E-02	6.09E-01	6.48E-03	3.56E+00	3.57E-03	2.06E-04	4.32E-04	8.92E-03	7.35E-02	2.70E-01	1.73E-02
Phenols - Total	8.57E-03	3.61E-01	5.18E-03	1.01E-01	1.94E-03	0.00E+00	3.46E-04	4.84E-03	1.48E-01	4.80E-01	9.40E-03
Phosphorus-Total	5.14E-02	9.44E-01	5.57E-01	9.76E+00	1.16E-02	5.32E+00	3.72E-02	2.90E-02	1.10E+00	8.64E-01	5.64E-02
Pyrene	2.14E-05	1.08E-04	0.00E+00	0.00E+00	4.84E-06	0.00E+00	0.00E+00	1.21E-05	6.16E-05	2.90E-04	2.35E-05
Selenium - Total	2.14E-03	1.11E-02	2.59E-04	1.37E-01	4.84E-04	5.88E-06	1.73E-05	1.21E-03	6.57E-03	2.90E-02	2.35E-03
Silver - Total	1.07E-03	1.34E-02	0.00E+00	1.10E-01	2.42E-04	5.88E-05	0.00E+00	6.05E-04	6.02E-03	2.38E-02	1.18E-03
Strontium - Total	1.14E+00	7.27E+00	4.37E-01	1.04E+01	2.56E-01	3.72E-01	2.91E-02	6.41E-01	4.38E+00	1.67E+01	1.25E+00
Sulphate	6.91E+02	4.23E+03	1.85E+02	3.58E+03	1.56E+02	6.58E+01	1.24E+01	3.90E+02	2.49E+03	1.00E+04	7.58E+02
Thallium	0.00E+00	0.00E+00	0.00E+00	2.34E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Toluene	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total PAH's	1.57E-02	8.19E-02	2.98E-03	3.70E-03	3.54E-03	1.79E-04	1.99E-04	8.85E-03	4.98E-02	2.12E-01	1.72E-02
2,4,6-Trichlorophenol	0.00E+00	0.00E+00	0.00E+00	1.53E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TSS	9.11E+00	2.06E+02	8.29E+01	1.08E+02	2.06E+00	2.04E+01	5.53E+00	5.14E+00	1.90E+02	2.17E+02	9.99E+00
Uranium - Total	3.75E-03	1.89E-02	0.00E+00	0.00E+00	8.47E-04	0.00E+00	0.00E+00	2.12E-03	1.08E-02	5.08E-02	4.11E-03
Vanadium - Total	9.11E-02	6.15E-01	1.30E-02	3.54E+01	2.06E-02	3.25E-03	8.64E-04	5.14E-02	2.90E-01	1.26E+00	9.99E-02
m+p Xylene	8.04E-03	5.69E-02	0.00E+00	9.95E-04	1.81E-03	3.23E-03	0.00E+00	4.54E-03	2.91E-02	1.28E-01	8.81E-03
o-xylene	8.04E-03	5.07E-02	3.50E-03	9.74E-02	1.81E-03	1.40E-03	2.33E-04	4.54E-03	3.12E-02	1.17E-01	8.81E-03
Zinc - Total	3.00E-02	5.14E-01	7.52E-02	6.82E+00	6.77E-03	3.55E-02	5.01E-03	1.69E-02	2.72E-01	6.11E-01	3.29E-02

TABLE VI-10
MAXIMUM PREDICTED RIVER CONCENTRATION AFTER MIXING WITH 10% OF 7Q10 FLOW COMPARED TO CHRONIC AQUATIC LIFE GUIDELINE

	Max. River Concentration (mg/L)	Chronic Guideline (mg/L)	Guideline Source
ORGANIC			
Benzene	0.000010	0.3	CCREM
Chloroform	0.000030	1.24	U.S. EPA
2,4-Dichlorophenol	0.000010	0.0002	CCREM
Ethylbenzene	0.000010	0.7	CCREM
m+p Xylene	0.000106	0.03	OME
Naphthalene	0.00000042	0.62	U.S. EPA
o-xylene	0.000144	0.002	OME
Phenols - Total	0.0015	0.001	CCREM
2,4,6-Trichlorophenol	0.000071	0.97	U.S. EPA
INORGANIC			
Aluminum - Total	0.11	0.1	CCREM
Ammonia - Total	0.34	1.53	CCREM
Antimony - Total	0.000020	0.007	OME
Arsenic - Total	0.0023	0.19	U.S. EPA
Barium - Total	0.084	1	ASWQO
Beryllium-Total	0.000078	0.0001	CCREM
Boron - Total	0.063	0.5	ASWQO
Cadmium - Total	0.0012	0.0018	CCREM
Calcium	54.4	1000	CCREM
Chloride	13.2	230	U.S. EPA
Chromium - Total	0.0034	0.02	CCREM
Cobalt - Total	0.0012	0.009	OME
Copper - Total	0.0030	0.019	U.S. EPA
Cyanide -Total	0.00039	0.0052	U.S. EPA
Iron - Total	0.26	0.3	ASWQO
Lead - Total	0.0030	0.007	CCREM
Lithium-Total	0.0073	2.5	CCREM
Manganese - Total	0.012	0.05	ASWQO
Mercury - Total	0.000014	0.000012	U.S. EPA
Molybdenum - Total	0.016	0.01	CCREM
Nickel - Total	0.0071	0.15	CCREM
Phosphorus-Total	0.029	0.05	ASWQO
Selenium - Total	0.00029	0.001	CCREM
Silver - Total	0.000071	0.0001	CCREM
Strontium - Total	0.36	0.16	OME
Uranium - Total	0.000039	0.01	CCREM
Vanadium - Total	0.021	0.1	CCREM
Zinc - Total	0.014	0.03	CCREM
GENERAL			
Toxicity	0.20	1	U.S. EPA
TSS	0.38	10	ASWQO

CCREM (1987).
OME - Ontario (1992).
U.S. EPA (1986).
AEP (1977).

TABLE VI-11
MAXIMUM RELEASE WATER RIVER CONCENTRATION BEFORE DILUTION WITH RIVER WATER COMPARED TO ACUTE AQUATIC LIFE GUIDELINES

	Max. Release Water Concentration (mg/L)	Acute Guidelines (mg/L)	Guideline Source
ORGANIC			
Chloroform	0.0017	28.9	U.S. EPA
2,4-Dichlorophenol	0.00058	2.02	U.S. EPA
2,4-Dimethylphenol	0.0010	2.12	U.S. EPA
Isophorone	0.00058	117	U.S. EPA
Naphthalene	0.000050	2.3	U.S. EPA
Toluene	0.00058	17.5	U.S. EPA
INORGANIC			
Ammonia - Total	14.6	8	U.S. EPA
Arsenic - Total	0.10	0.36	U.S. EPA
Beryllium-Total	0.0040	0.13	U.S. EPA
Cadmium - Total	0.0071	0.0074	U.S. EPA
Chloride	510	860	U.S. EPA
Chromium	0.020	0.016	U.S. EPA
Copper - Total	0.049	0.03	U.S. EPA
Cyanide -Total	0.055	0.022	U.S. EPA
Lead - Total	0.050	0.17	U.S. EPA
Mercury - Total	0.00058	0.0024	U.S. EPA
Nickel - Total	0.094	2.27	U.S. EPA
Selenium - Total	0.0040	0.02	U.S. EPA
Silver - Total	0.0029	0.01	U.S. EPA
Zinc - Total	0.18	0.19	U.S. EPA

U.S. EPA (1986).

TABLE VI-12
MAXIMUM PREDICTED RIVER CONCENTRATION AFTER COMPLETING MIXING AT 366 CMS M^3/S COMPARED TO HUMAN HEALTH (NON-CARCINOGEN) GUIDELINES

	Max. River Concentration (mg/L)	Human Health (Carcinogen) Guideline (mg/L)	Guideline Source
ORGANIC			
Benzene	0.0000025	0.0012	U.S. EPA
Benzo(a) anthracene	0.0000029	0.0000028	U.S. EPA
Butylbenzyl-Phthalate	0.00000081	5.2	U.S. EPA
Carbon tetrachloride	0.0000075	0.00025	U.S. EPA
Chloroform	0.0000075	0.0057	U.S. EPA
Dibutyl-Phthalate	0.0000024	2.7	U.S. EPA
2,4-Dichlorophenol	0.00000081	0.093	U.S. EPA
Diethyl-Phthalate	0.00000081	23	U.S. EPA
Dis(2-Ethyl-Hexyl)Phthalate	0.000038	15	U.S. EPA
Ethylbenzene	0.00000081	3.1	U.S. EPA
Fluorene	0.000000044	1.3	U.S. EPA
Isophorone	0.00000081	0.0084	U.S. EPA
Methylene chloride	0.000014	0.0047	U.S. EPA
Pyrene	0.000000059	0.96	U.S. EPA
Toluene	0.00000081	6.8	U.S. EPA
Total PAH's	0.000045	0.0000028	U.S. EPA
INORGANIC			
Antimony - Total	0.0000016	0.014	U.S. EPA
Arsenic - Total	0.00064	0.000018	U.S. EPA
Barium - Total	0.080	1	U.S. EPA
Cyanide -Total	0.000033	0.7	U.S. EPA
Iron - Total	0.20	0.3	U.S. EPA
Manganese - Total	0.0074	0.05	U.S. EPA
Mercury - Total	0.0000011	0.00014	U.S. EPA
Nickel - Total	0.0052	0.61	U.S. EPA
Thallium	0.00087	0.0017	U.S. EPA

U.S. EPA (1986).

FIGURE VI-1

PROTOCOL FOR SCREENING RELEASE WATER QUALITY FOR ATHABASCA RIVER IMPACT ASSESSMENT

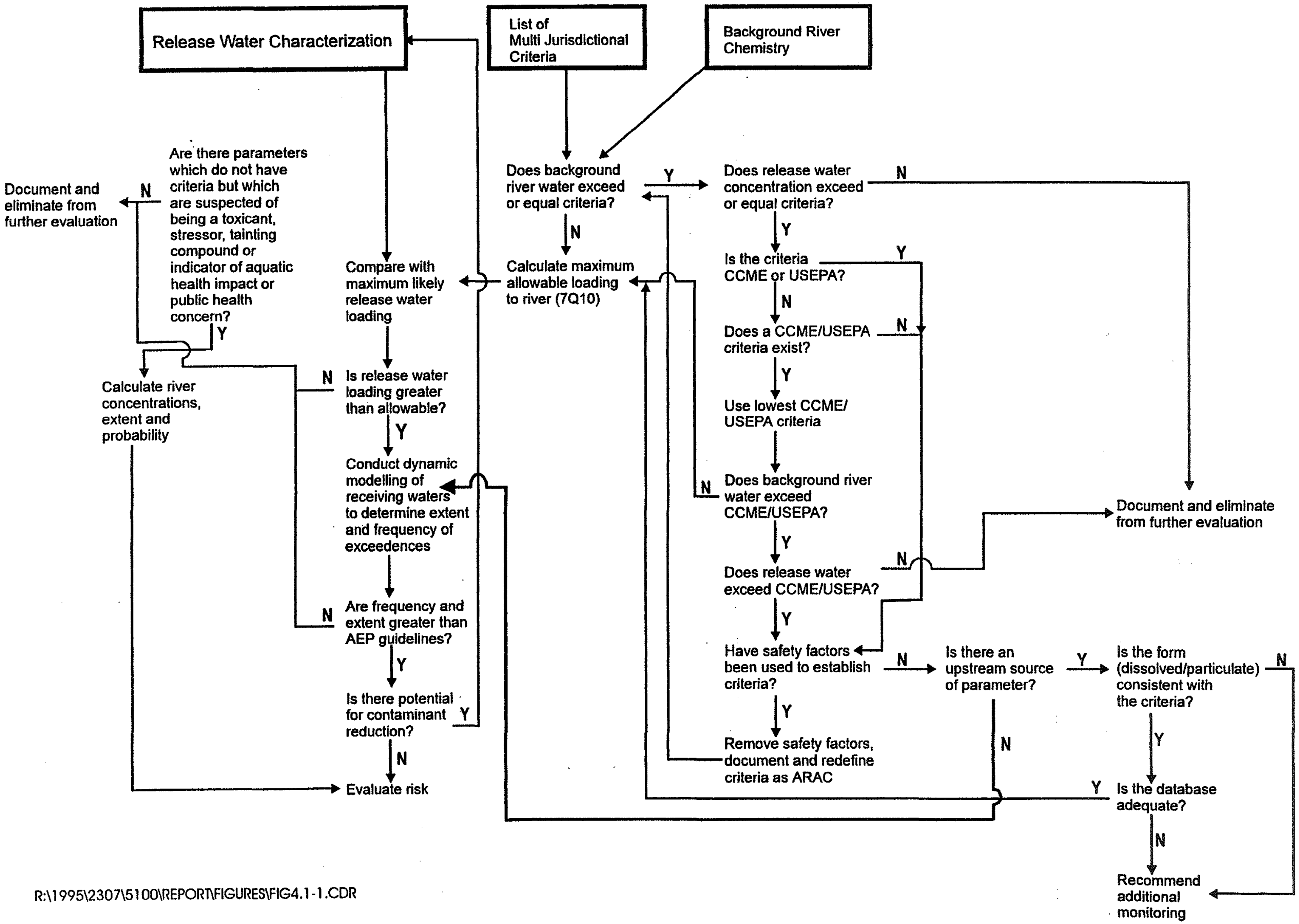

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Figure VI-2 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Aluminum - Total, River Flow of 115 cms

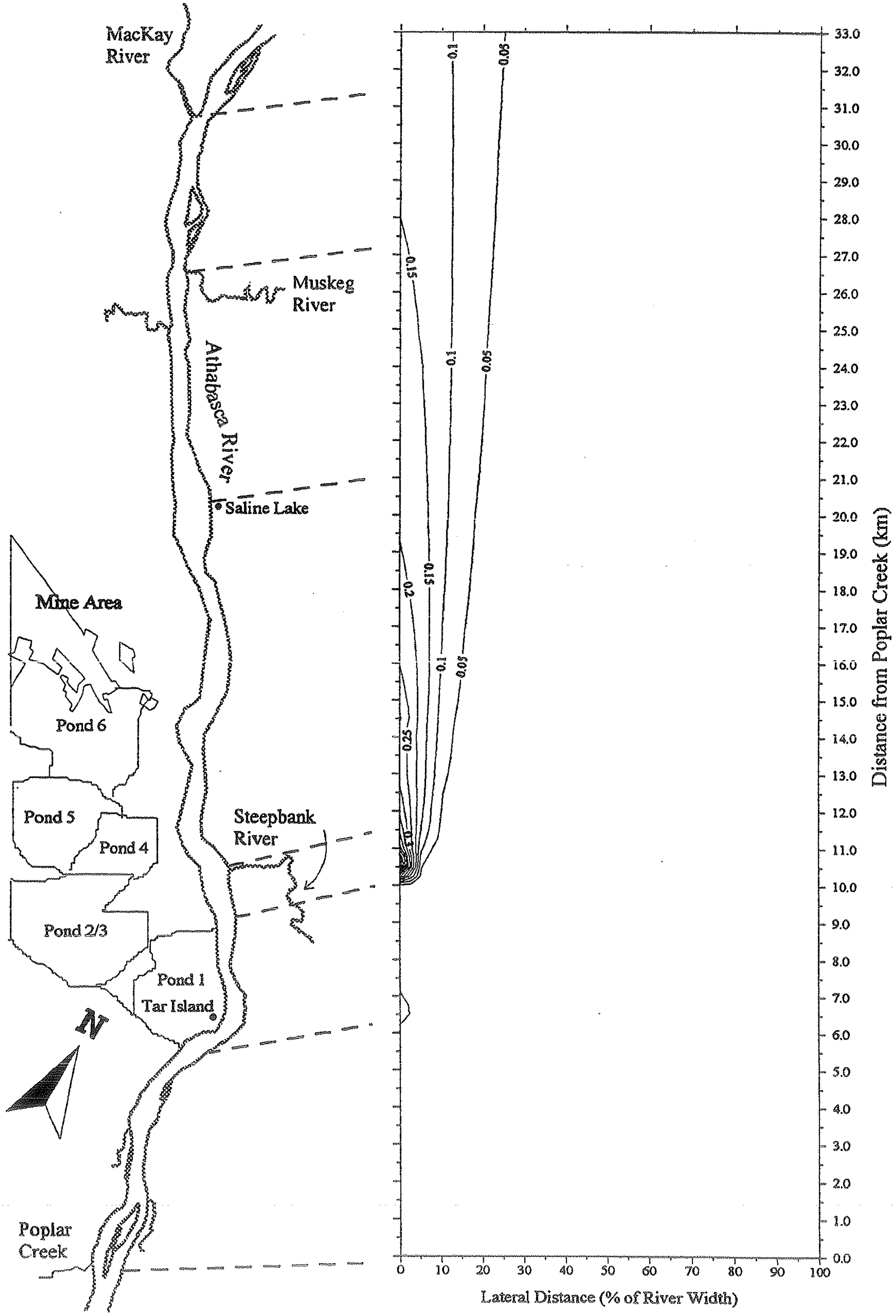

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Figure VI-3 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Ammonia - Total, River Flow of 115 cms

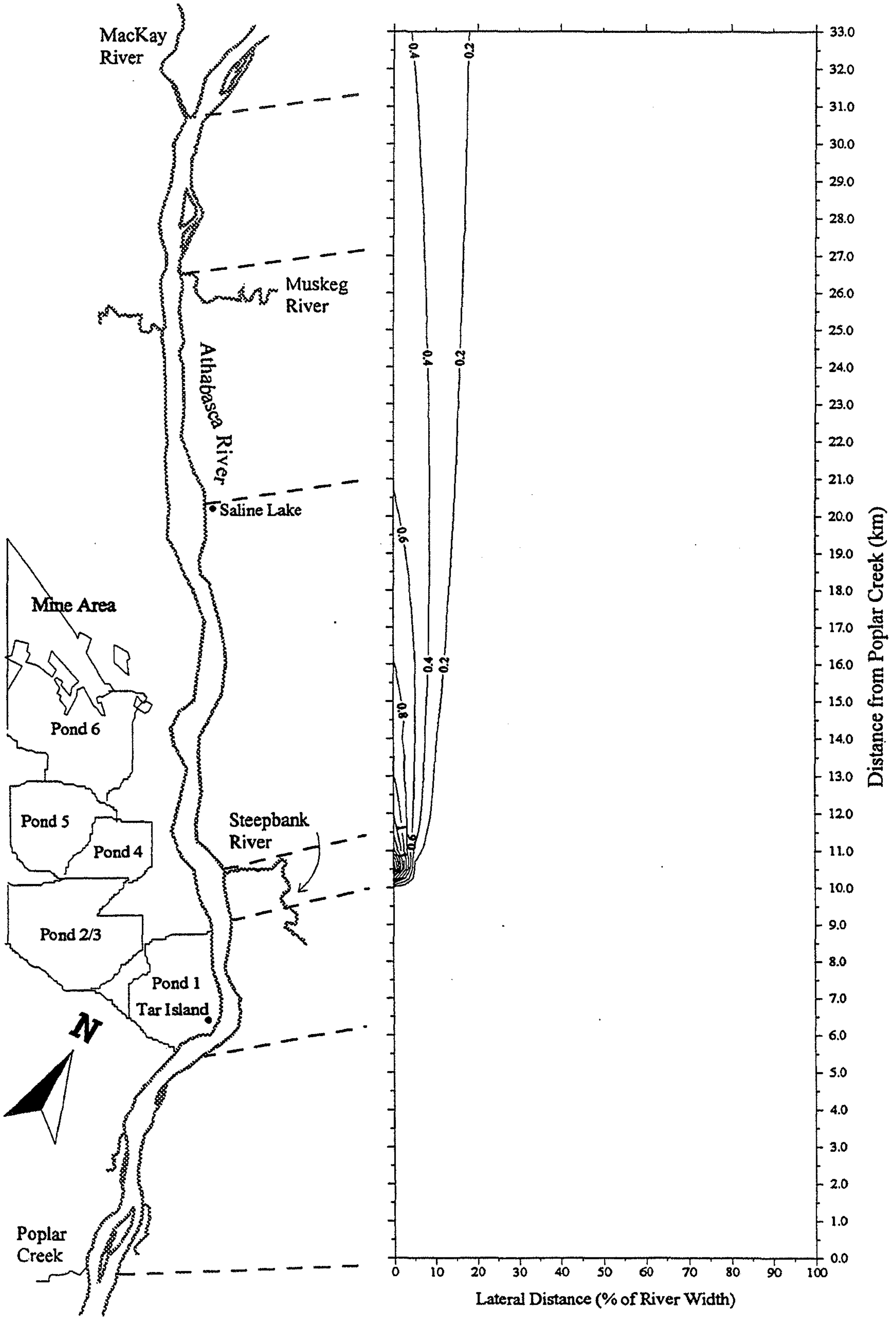

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Figure VI-4 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Antimony - Total, River Flow of 115 cms

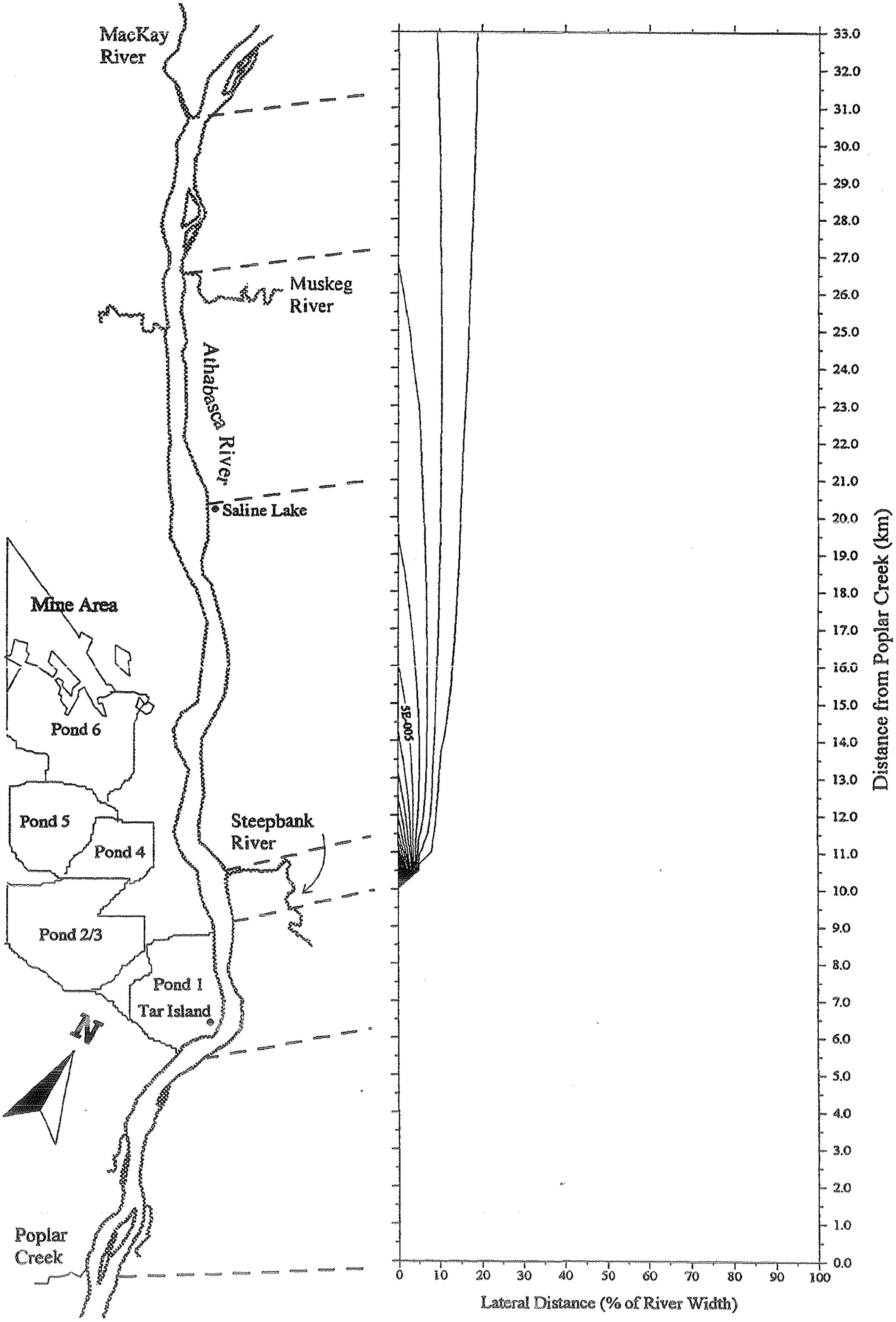

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Figure VI-5 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Arsenic - Total, River Flow of 115 cms

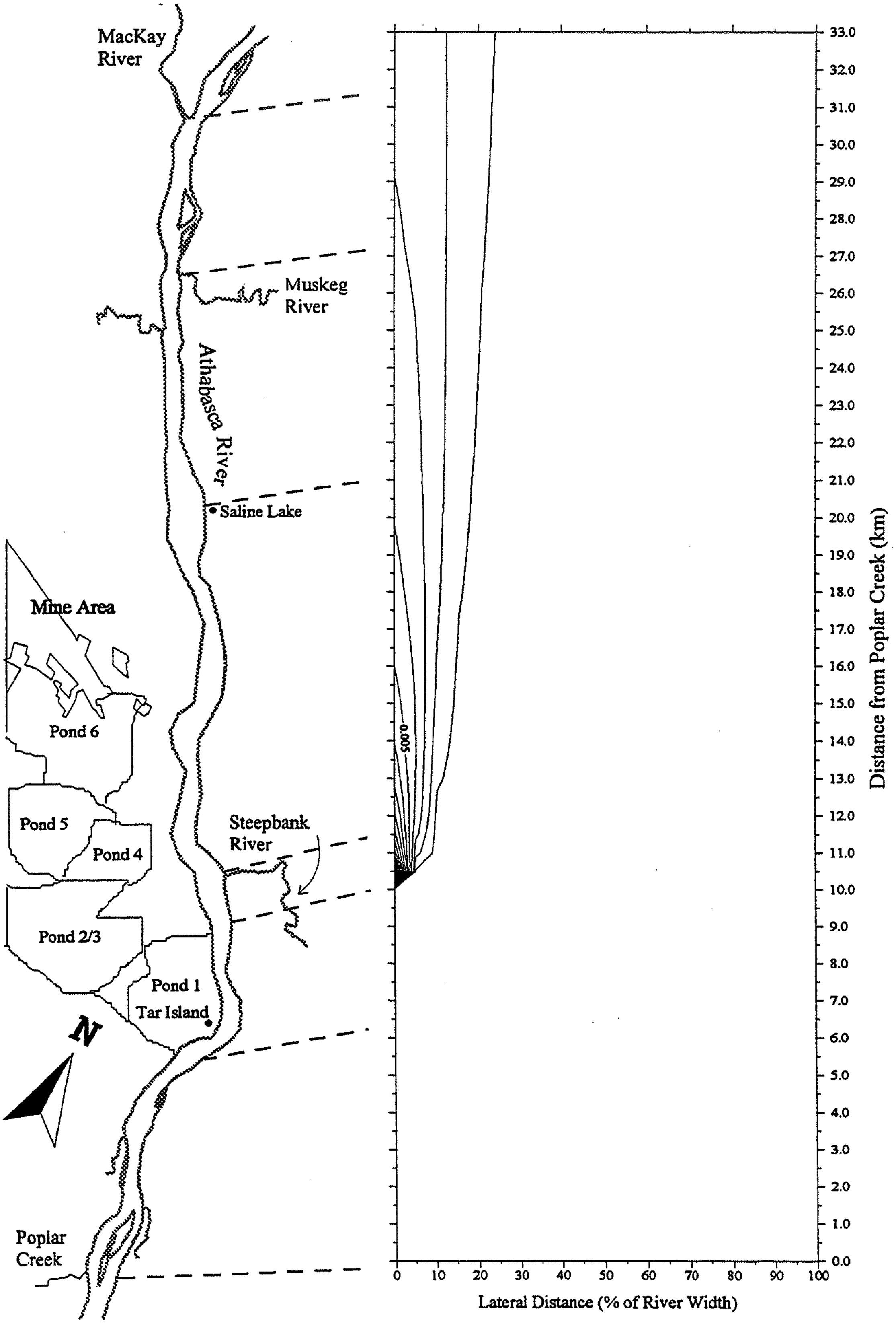

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Figure VI-6 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Barium - Total, River Flow of 115 cms

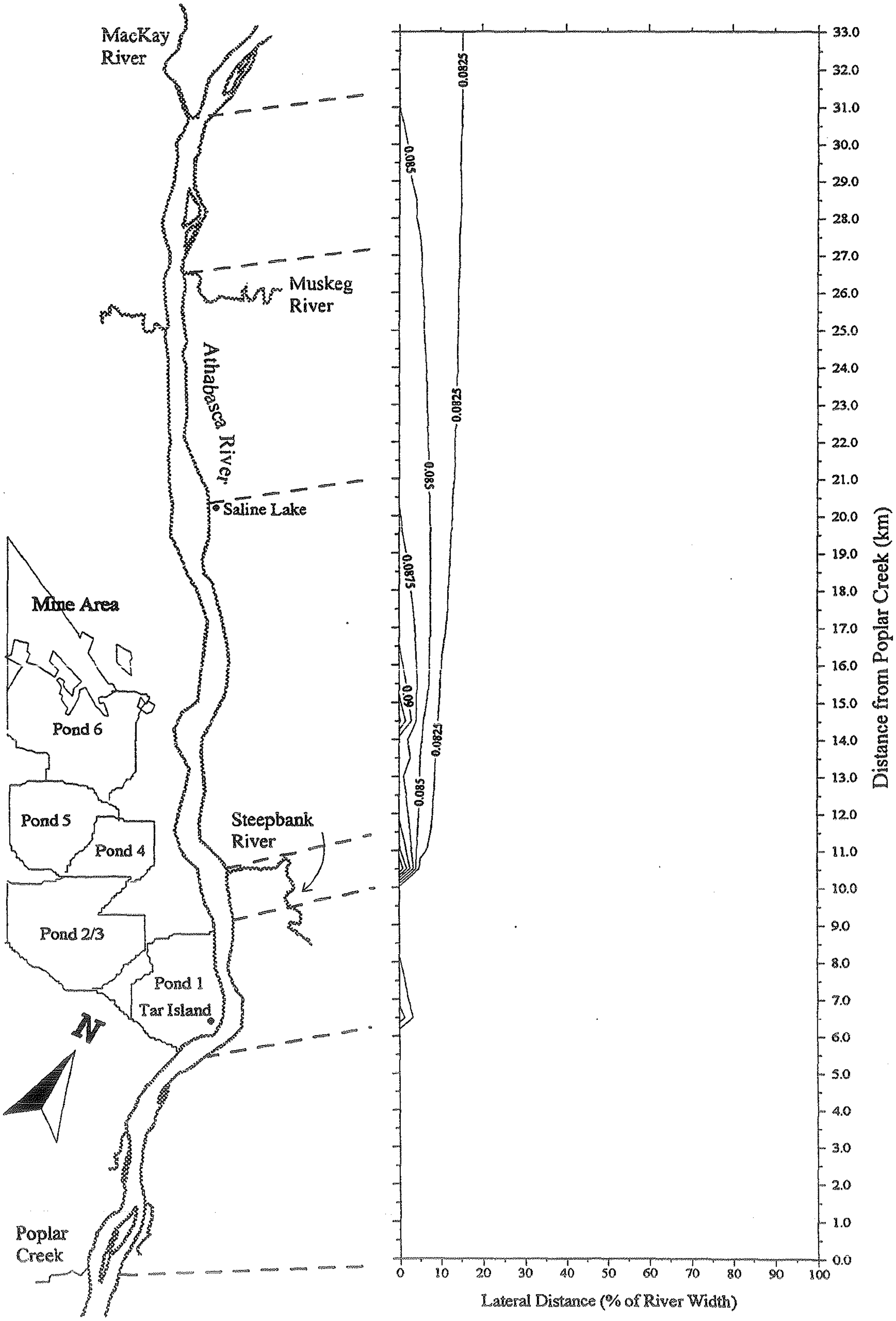

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Figure VI-7 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Benzene, River Flow of 115 cms

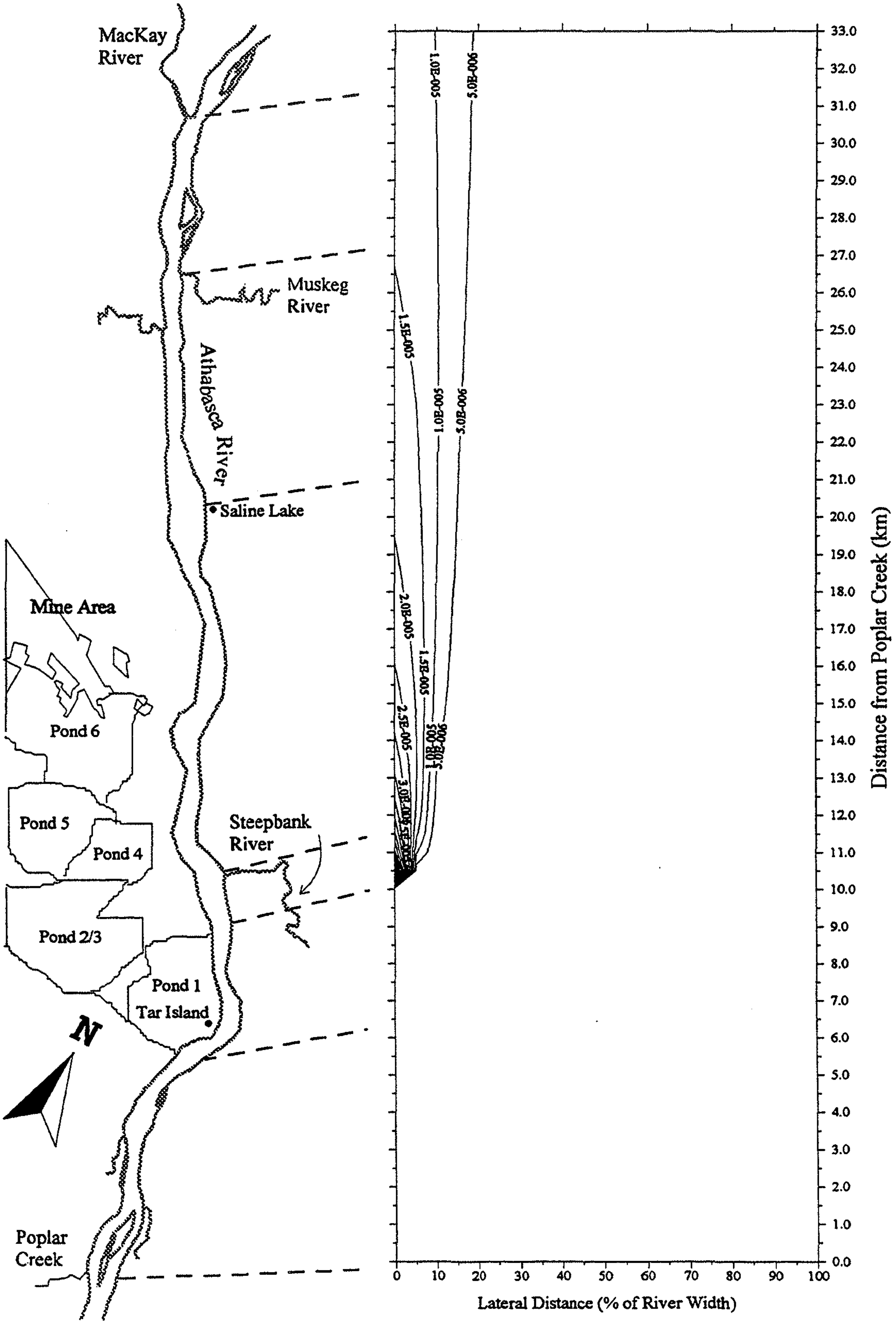

Figure VI-8 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Benzo(a) anthracene, River Flow of 115 cms

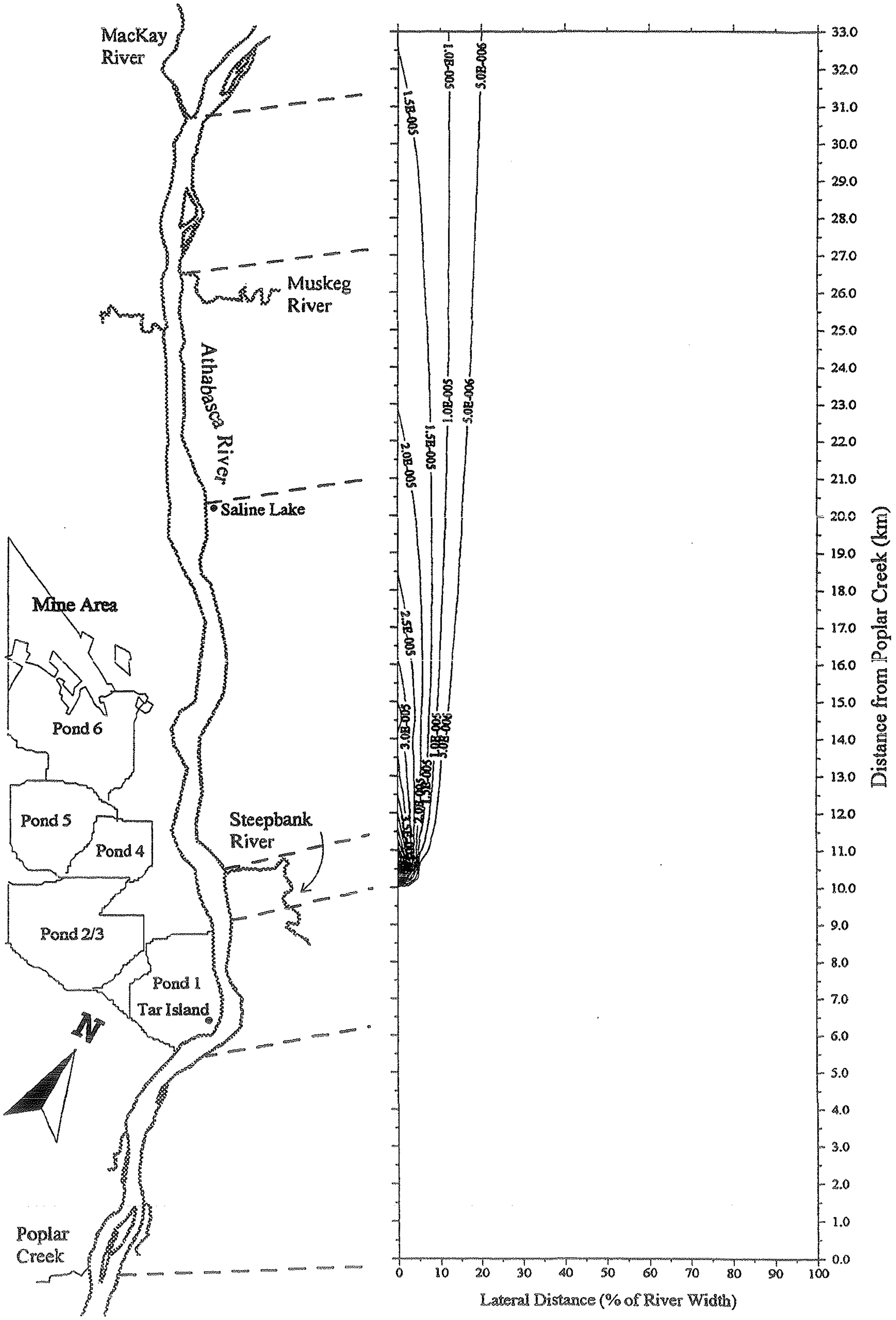

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Figure VI-9 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Beryllium-Total, River Flow of 115 cms

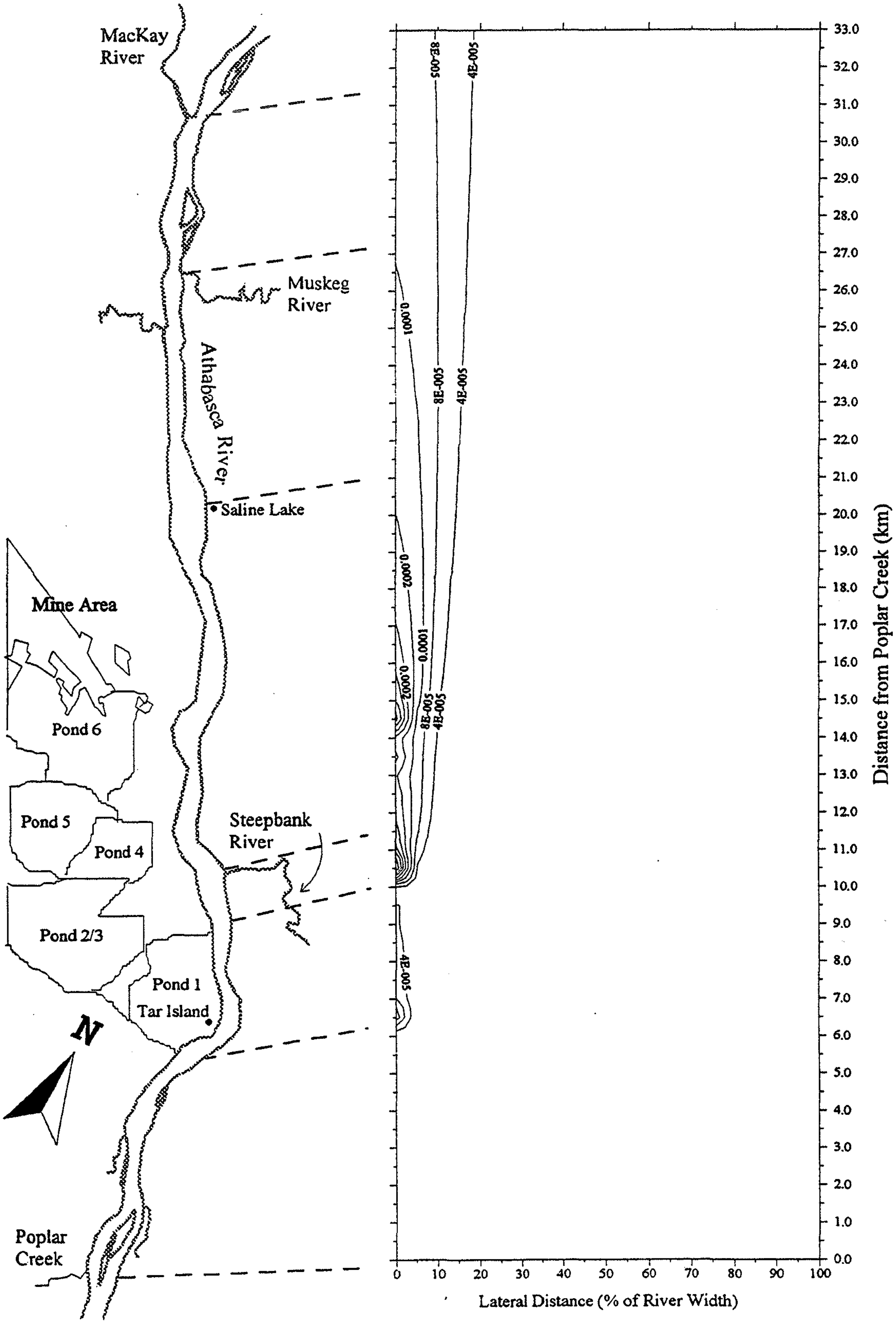

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Figure VI-10 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Bis(2-Ethyl-Hexyl)Phthalate, River Flow of 115 cms

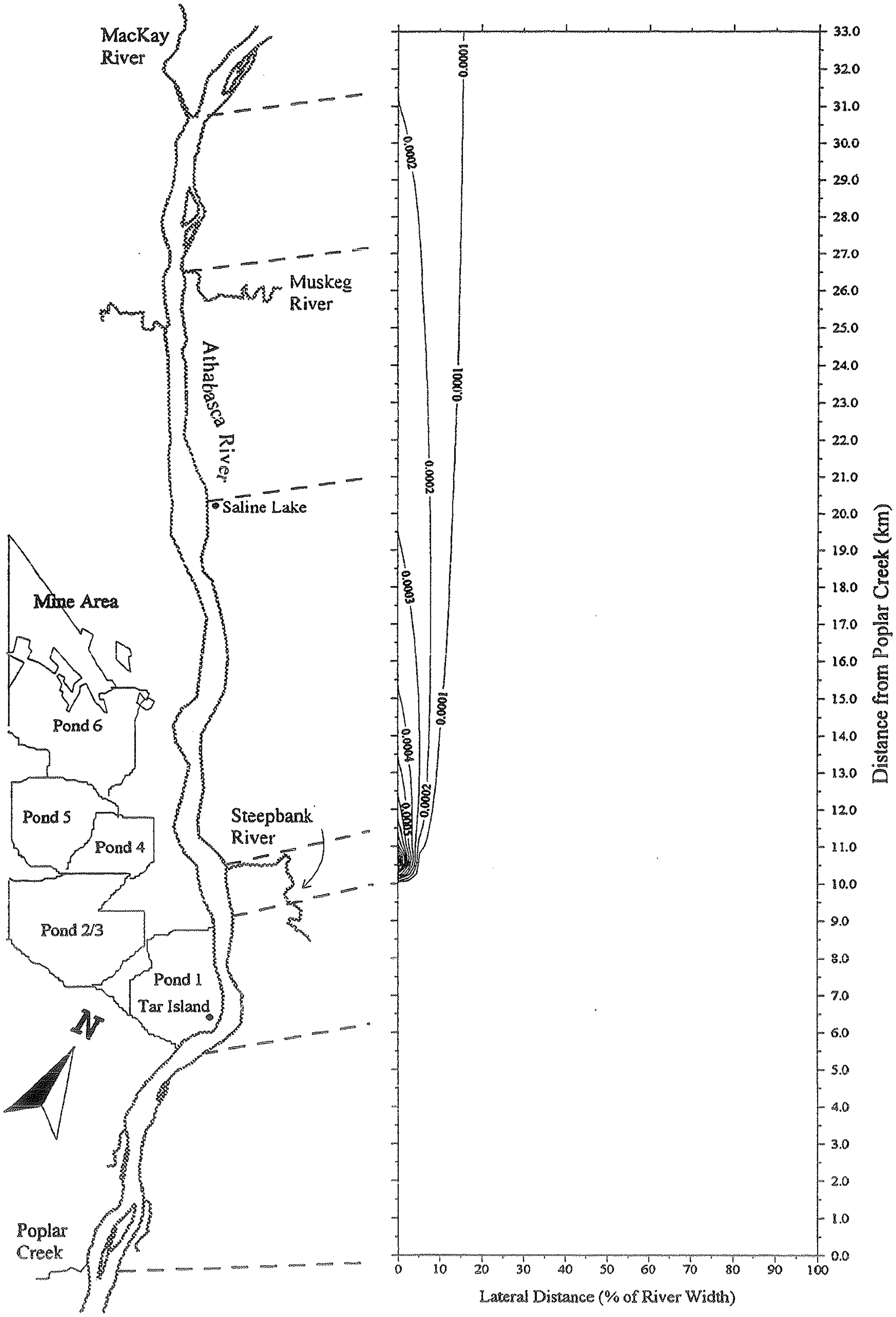

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Figure VI-11 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Boron - Total, River Flow of 115 cms

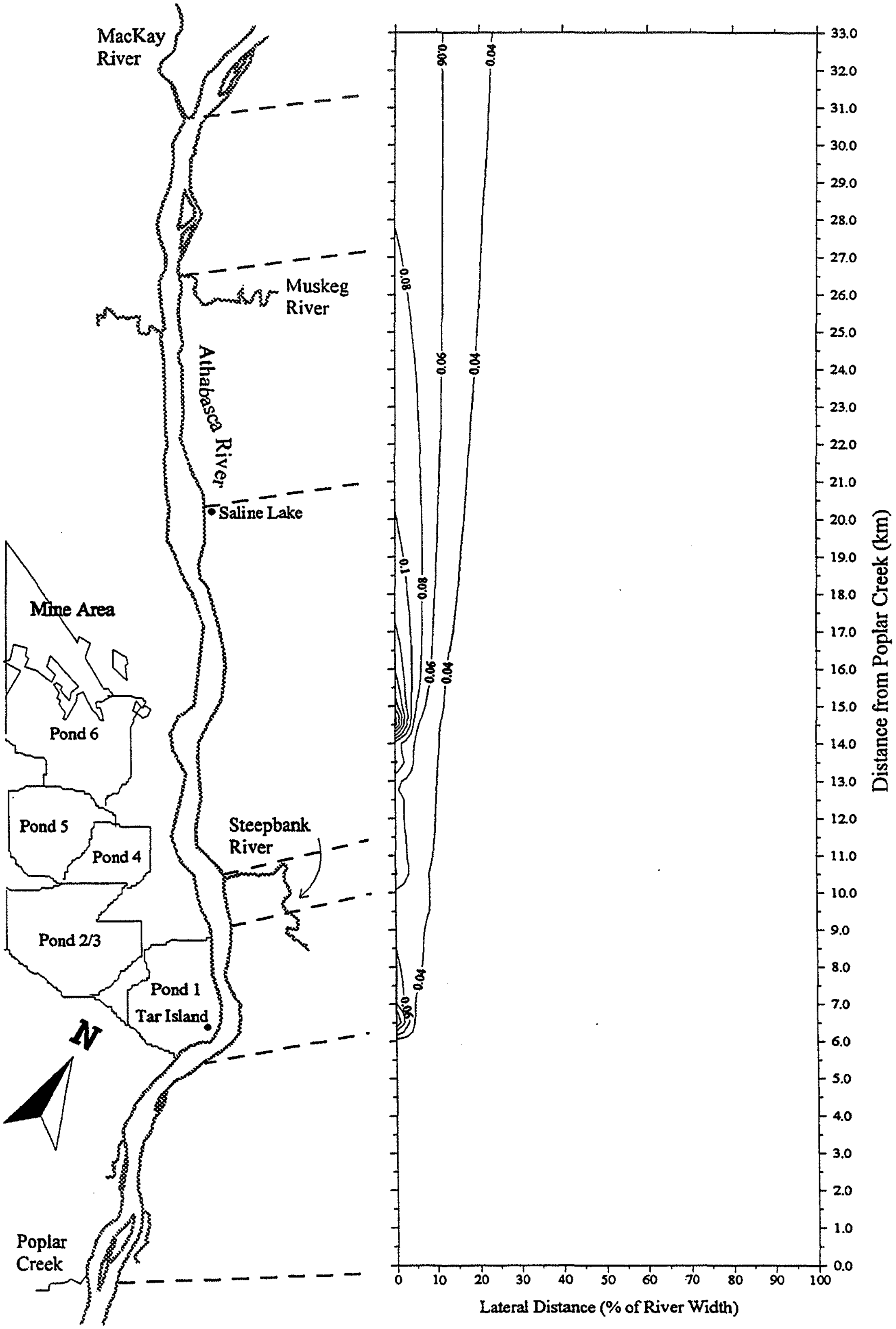

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Figure VI-12 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Butylbenzyl-Phthalate, River Flow of 115 cms

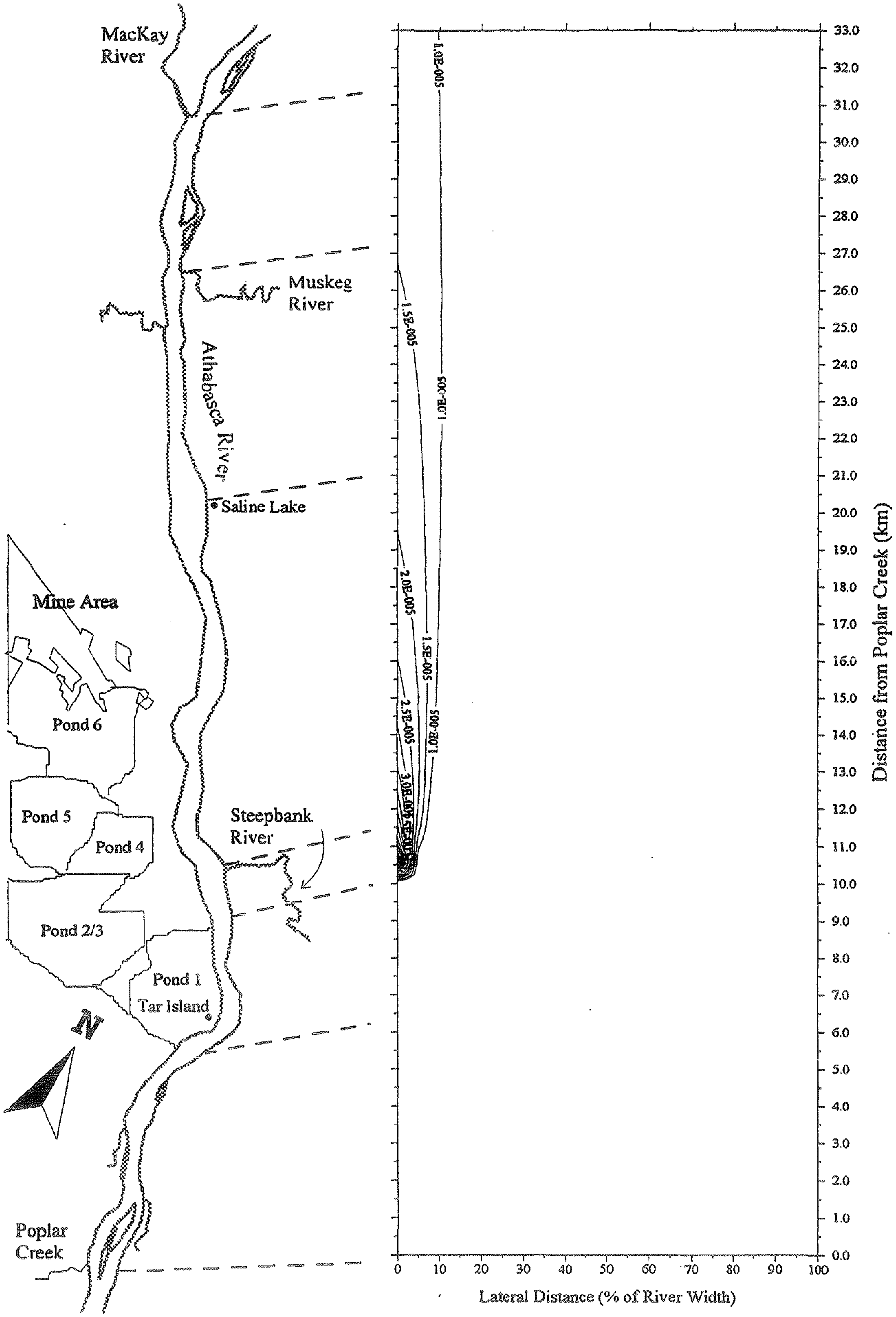

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Figure VI-13 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Cadmium - Total, River Flow of 115 cms

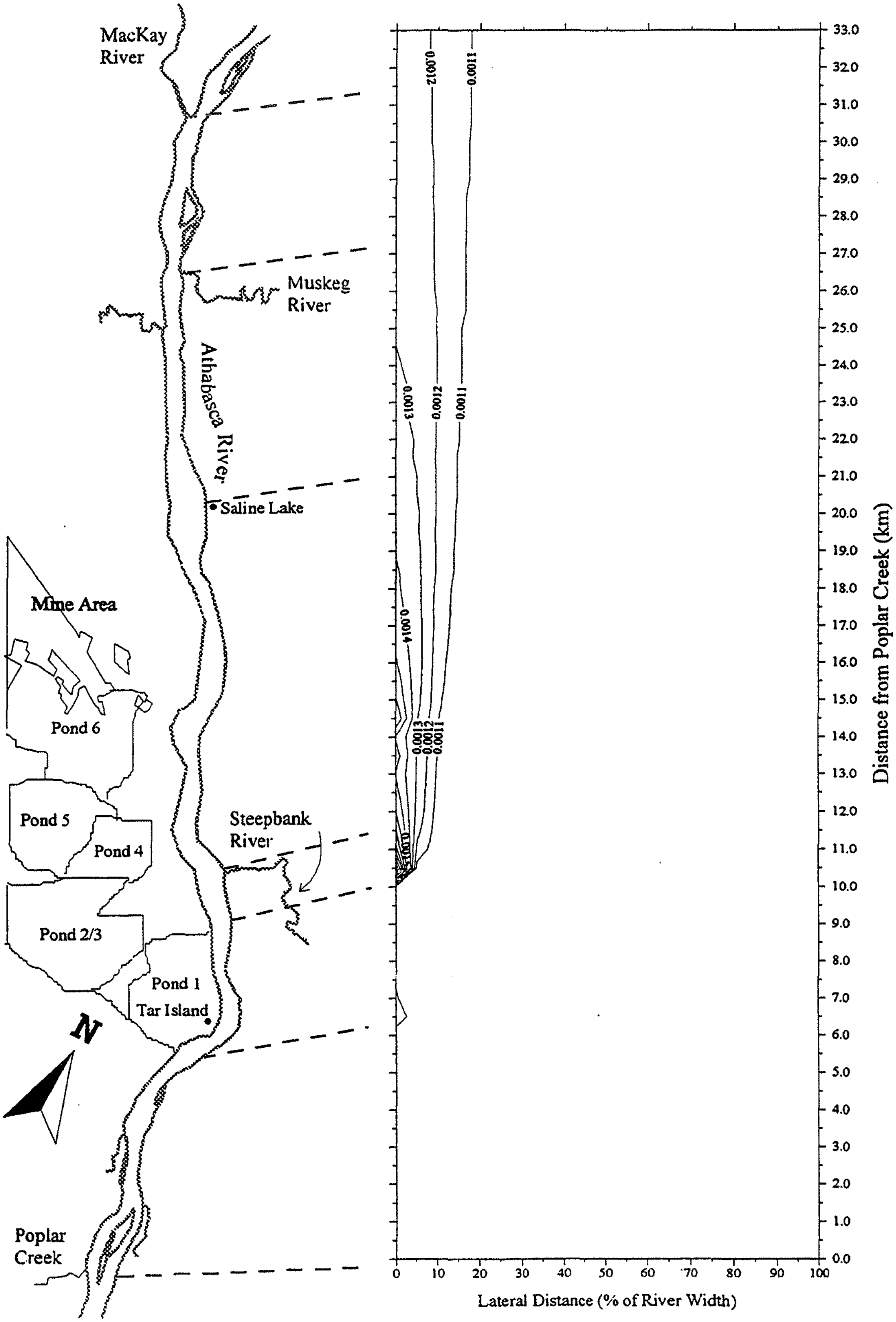

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Figure VI-14 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Calcium, River Flow of 115 cms

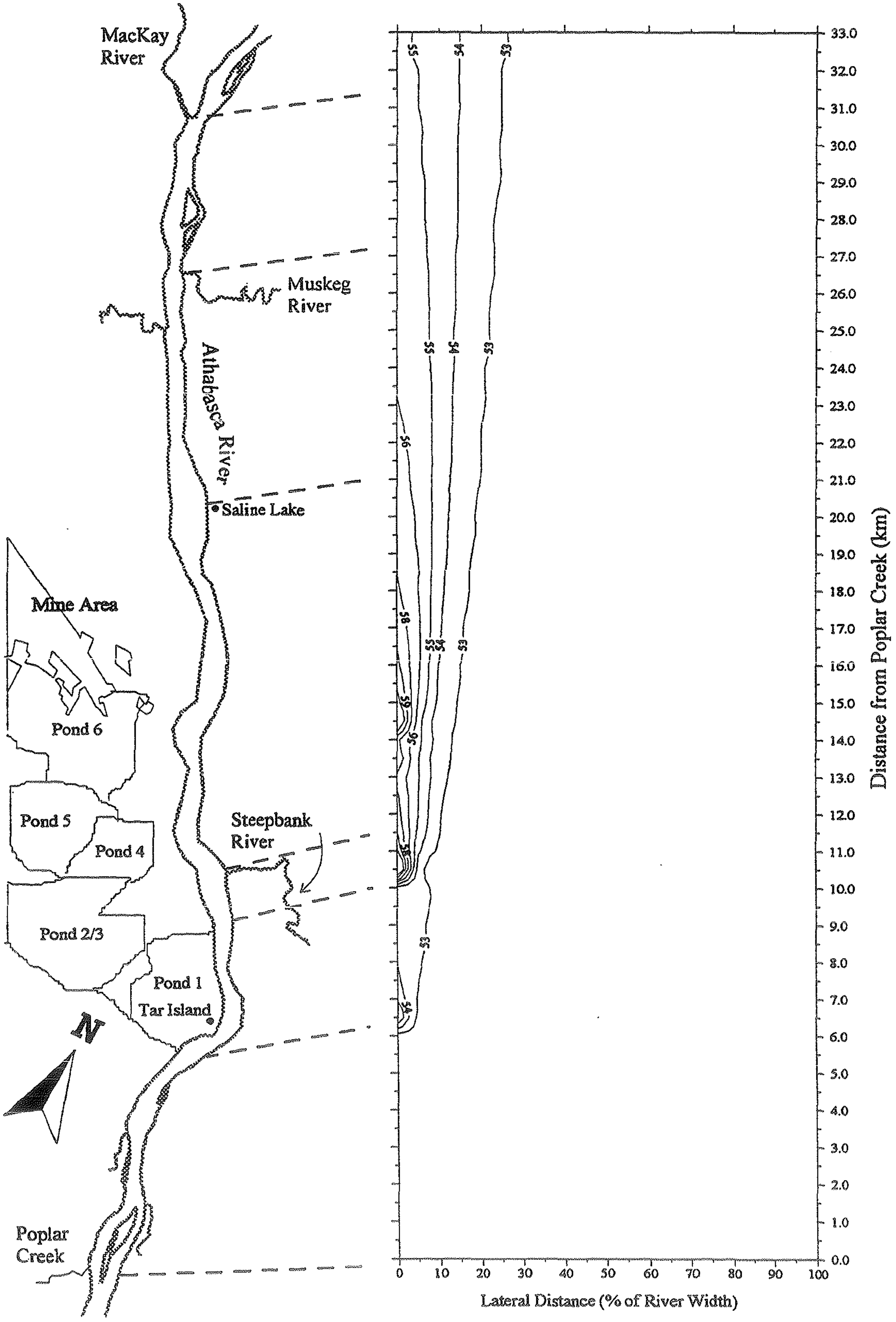

Figure VI-15 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Carbon tetrachloride, River Flow of 115 cms

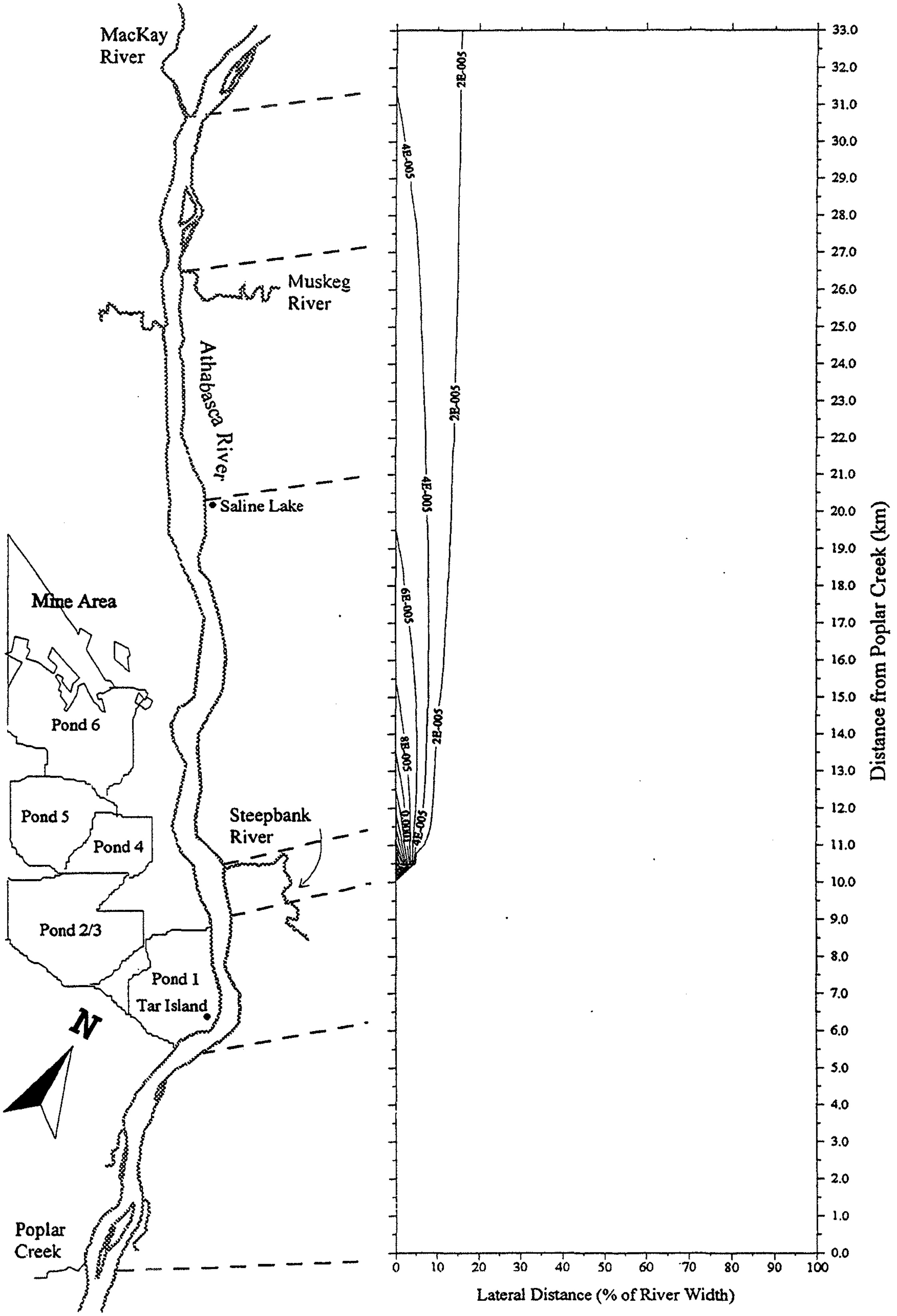

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Figure VI-16 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Chloride, River Flow of 115 cms

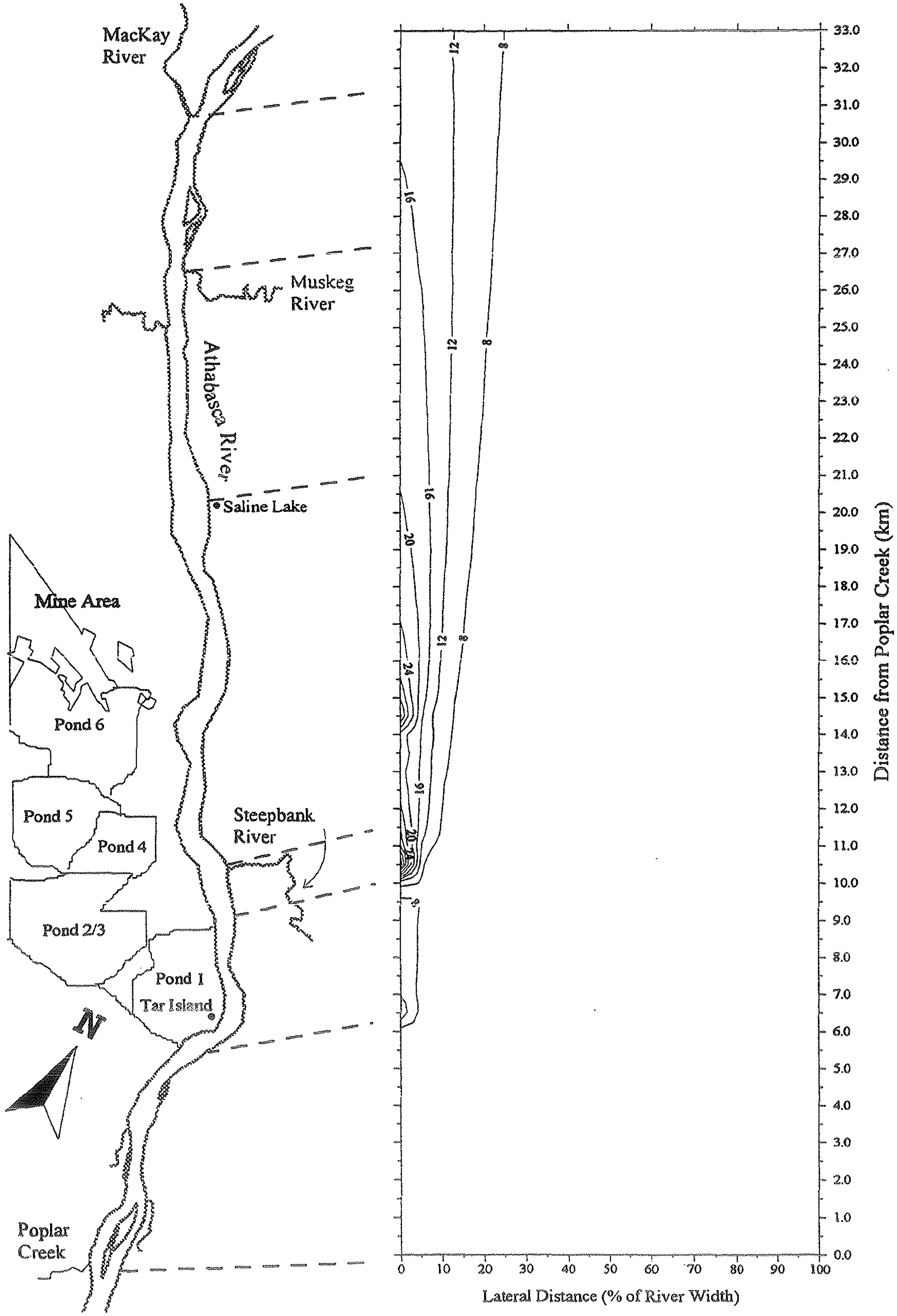

Figure VI-17 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Chloroform, River Flow of 115 cms

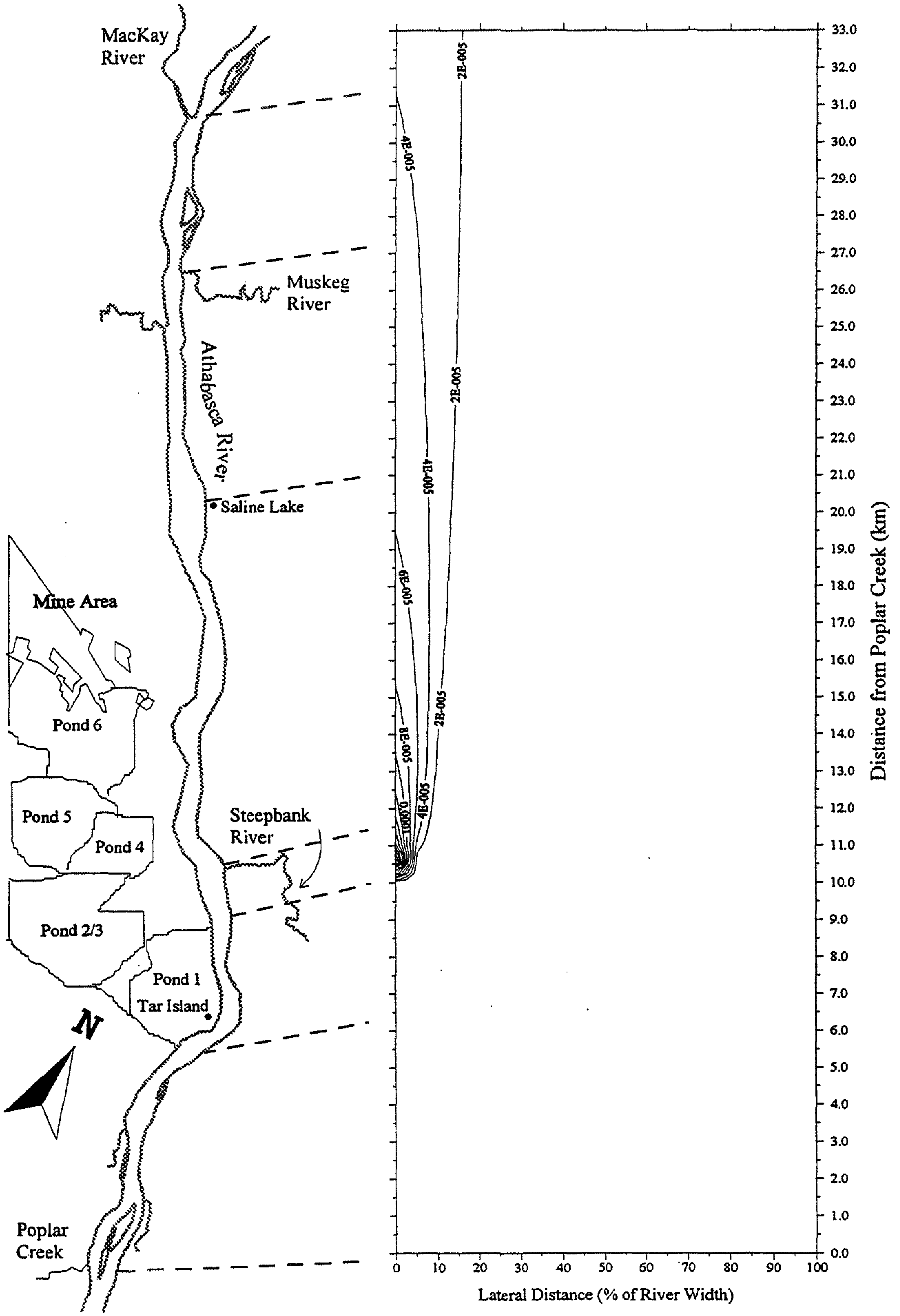

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Figure VI-18 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Chromium - Total, River Flow of 115 cms

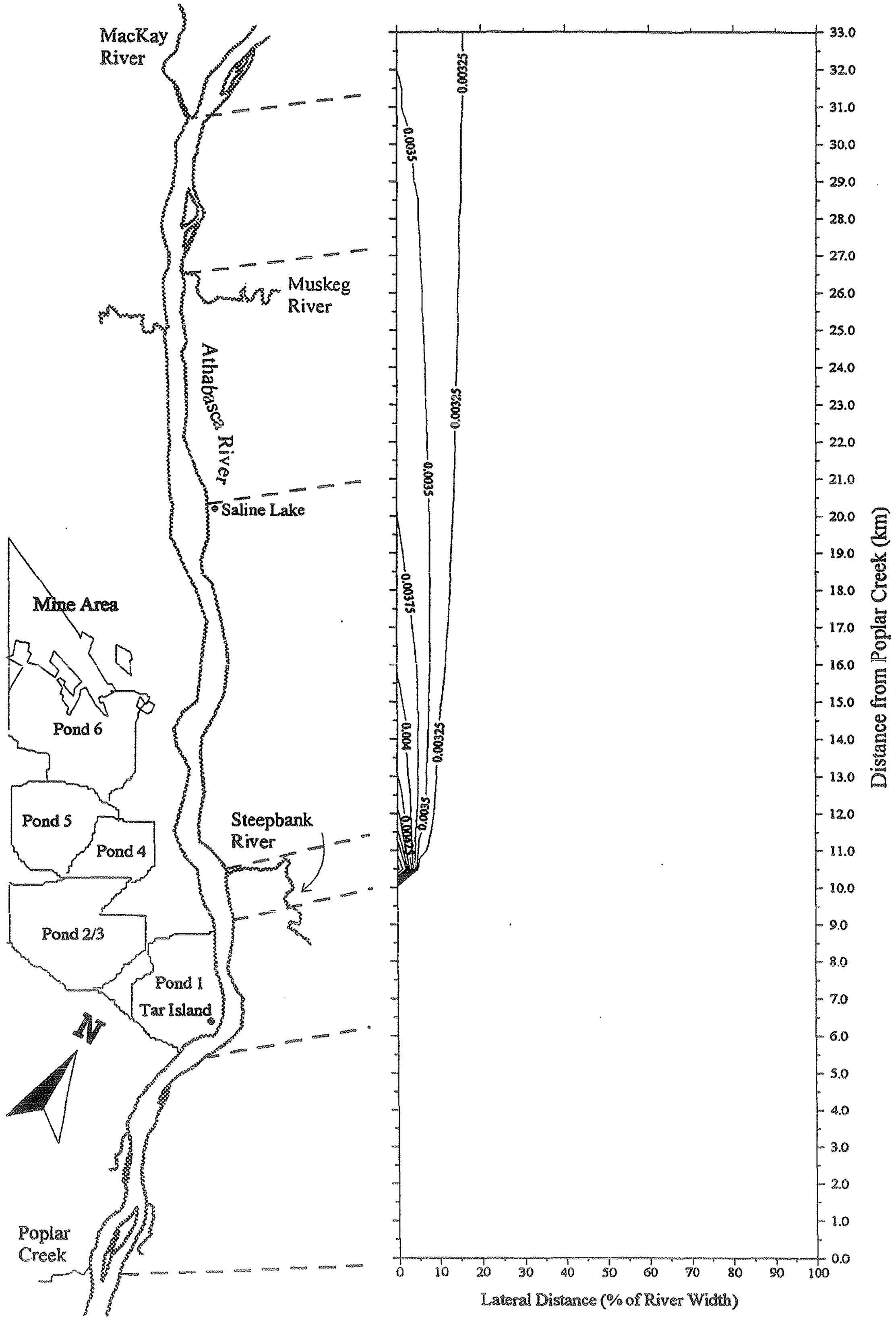

Figure VI-19 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Cobalt - Total, River Flow of 115 cms

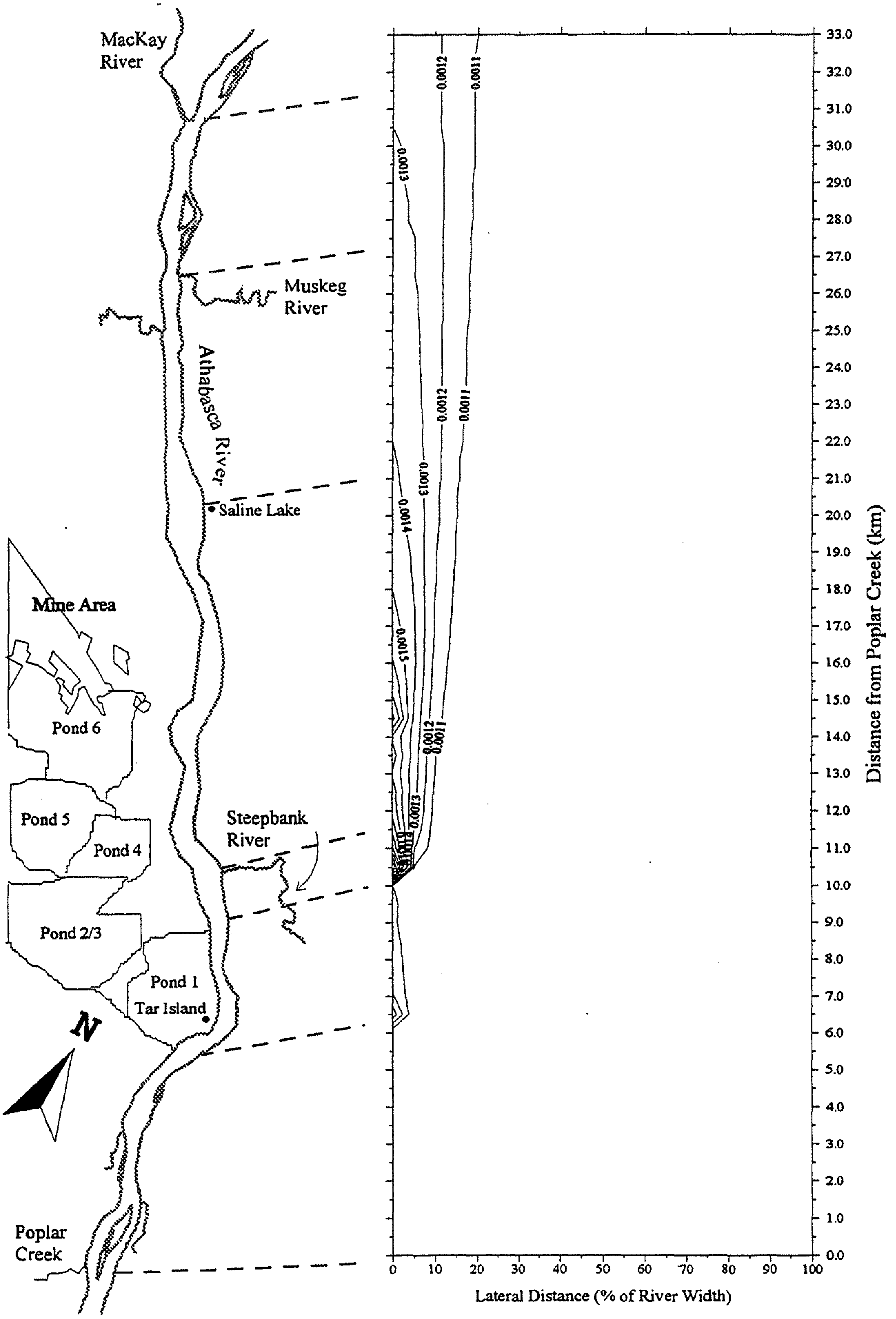

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**Figure VI-20 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Copper - Total, River Flow of 115 cms**

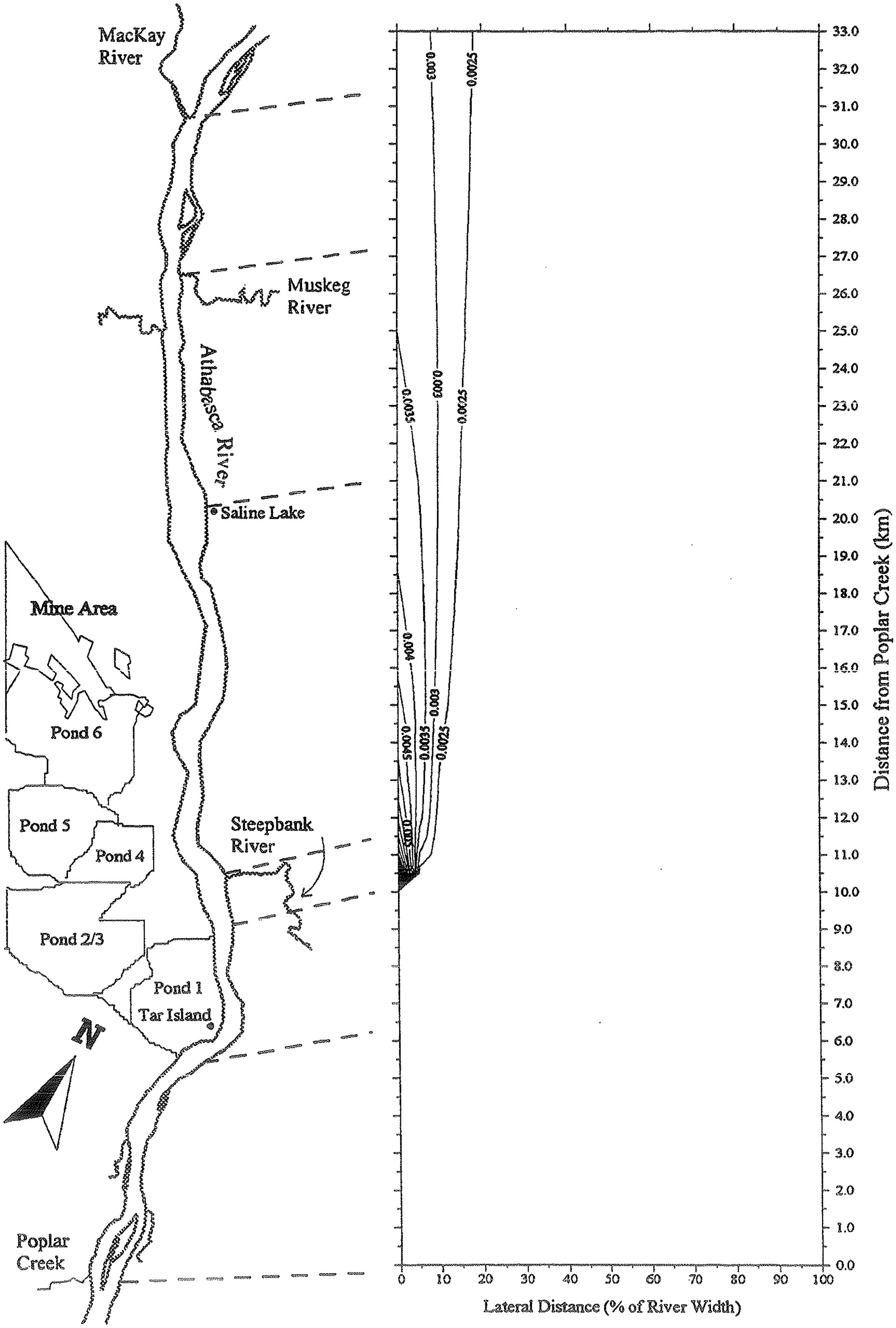

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Figure VI-21 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Cyanide -Total, River Flow of 115 cms

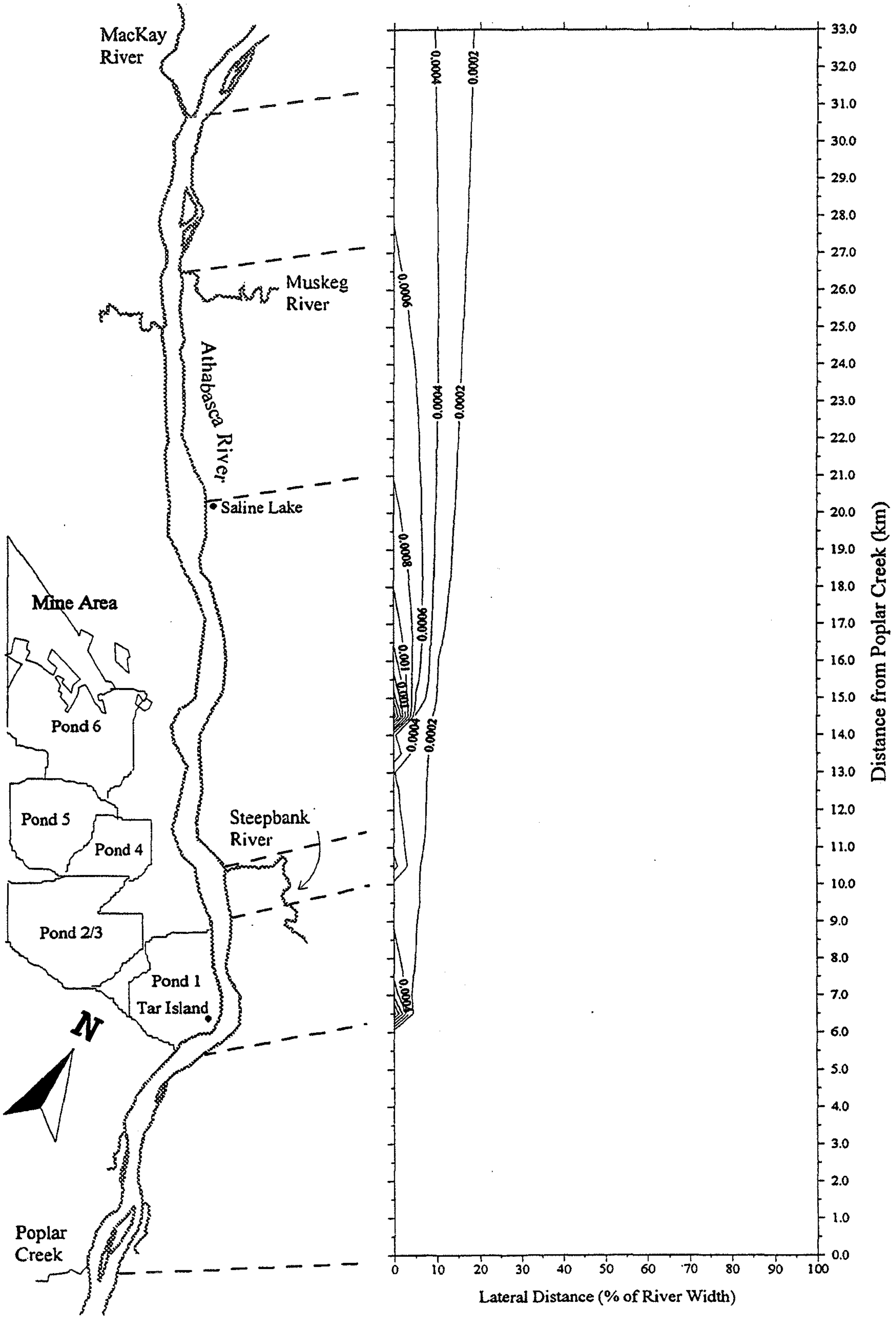

Figure VI-22 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Dibutyl-Phthalate, River Flow of 115 cms

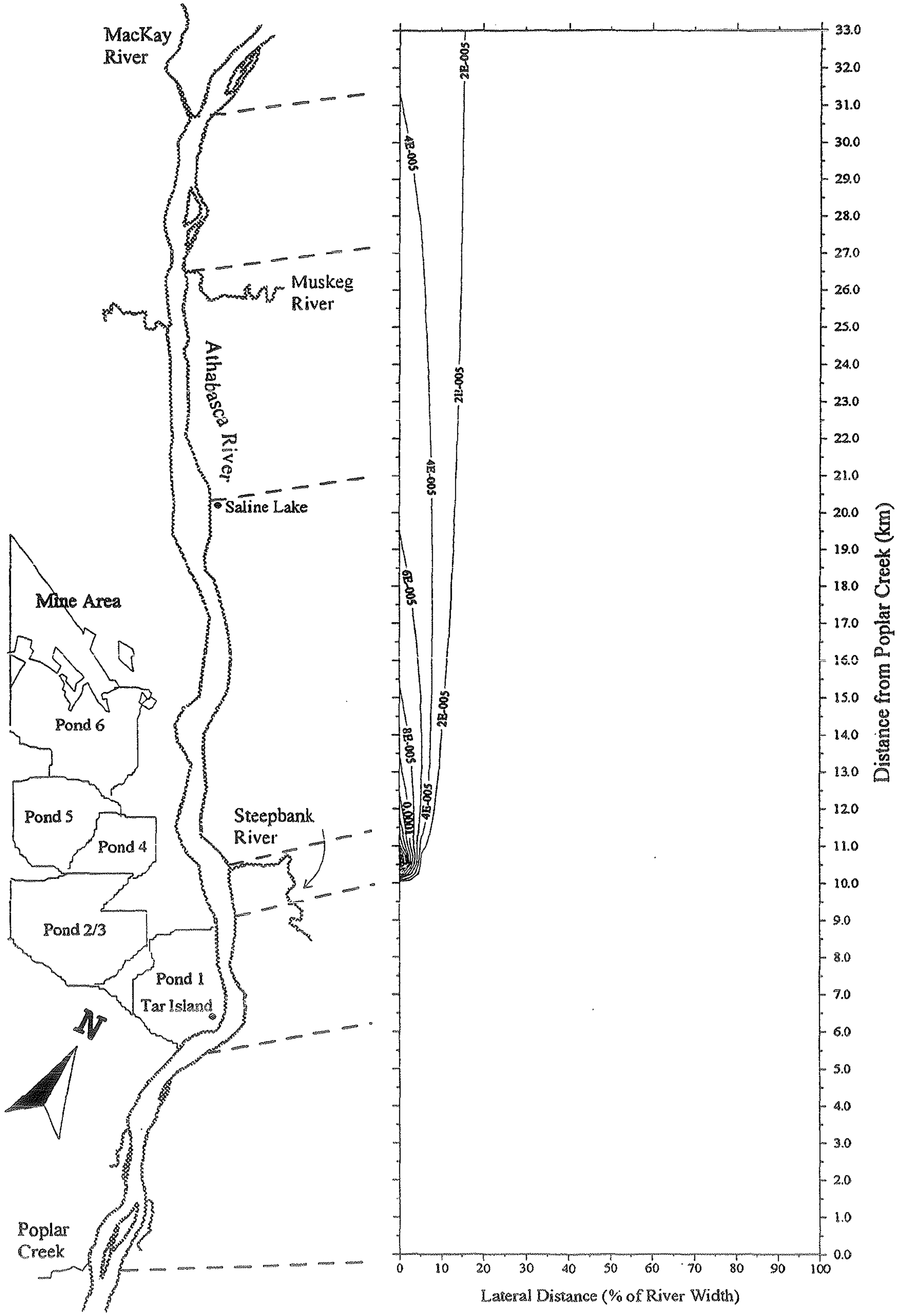

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Figure VI-23 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario 2,4-Dichlorophenol, River Flow of 115 cms

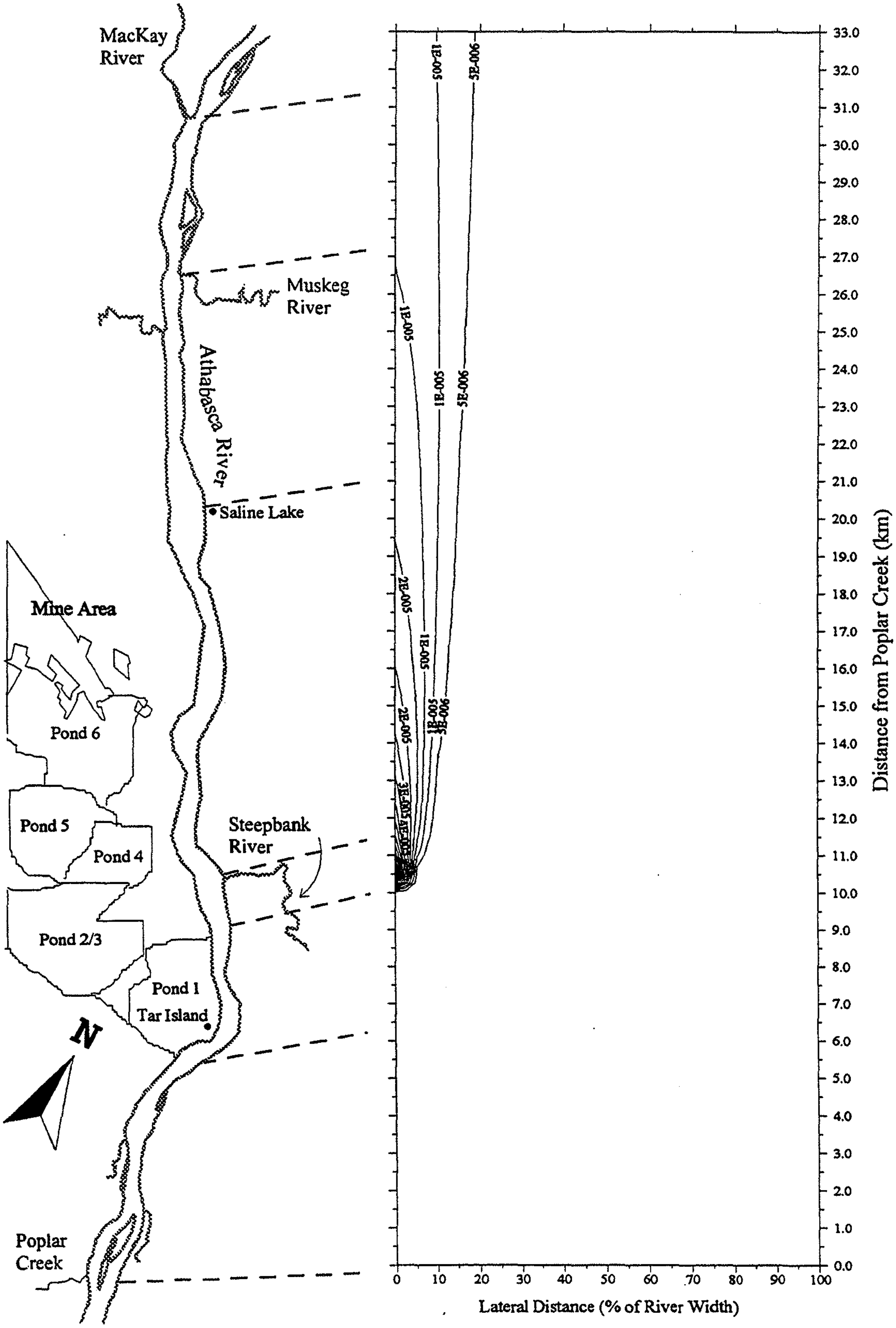

Figure VI-24 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Diethyl-Phthalate, River Flow of 115 cms

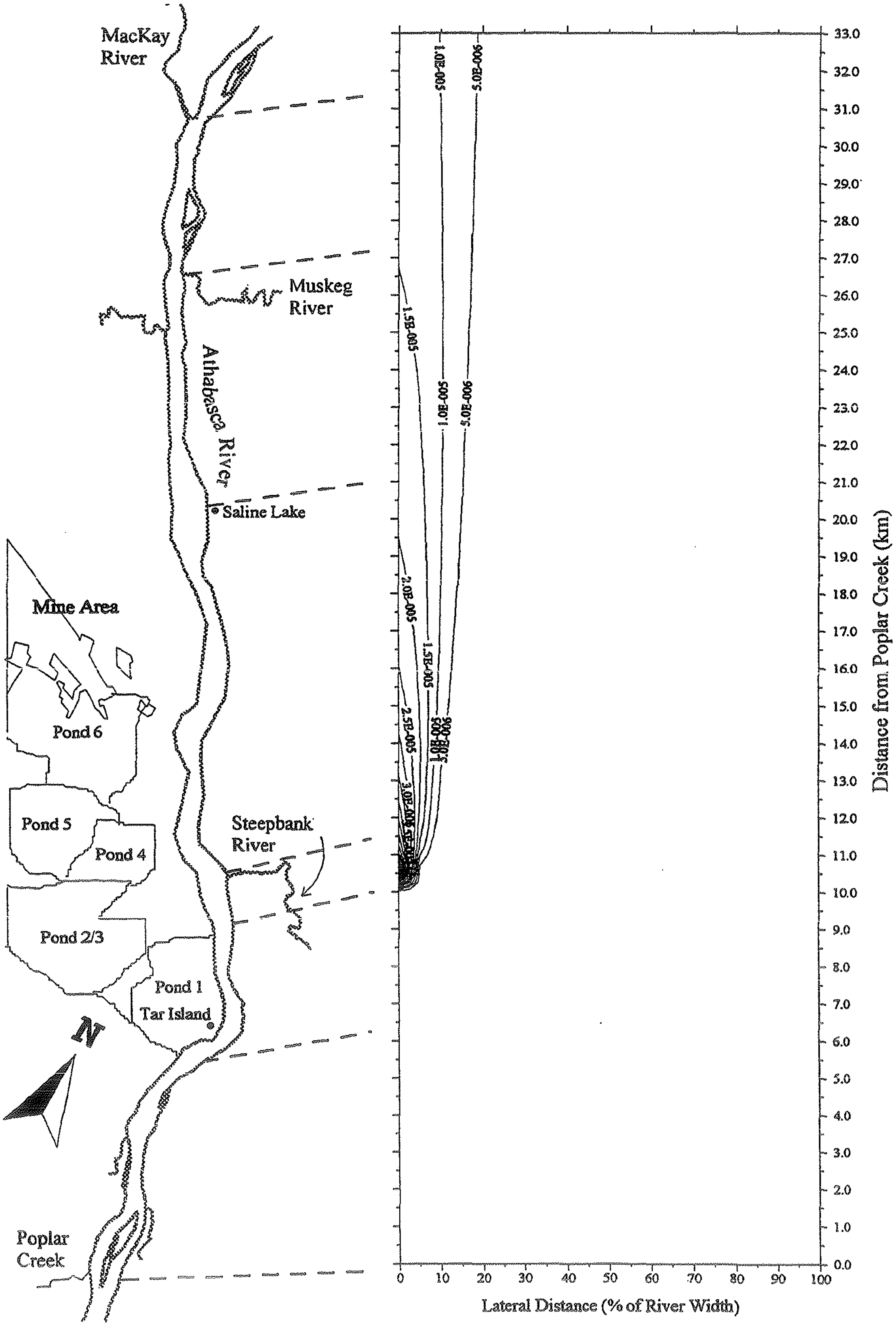

Figure VI-25 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
2,4-Dimethylphenol, River Flow of 115 cms

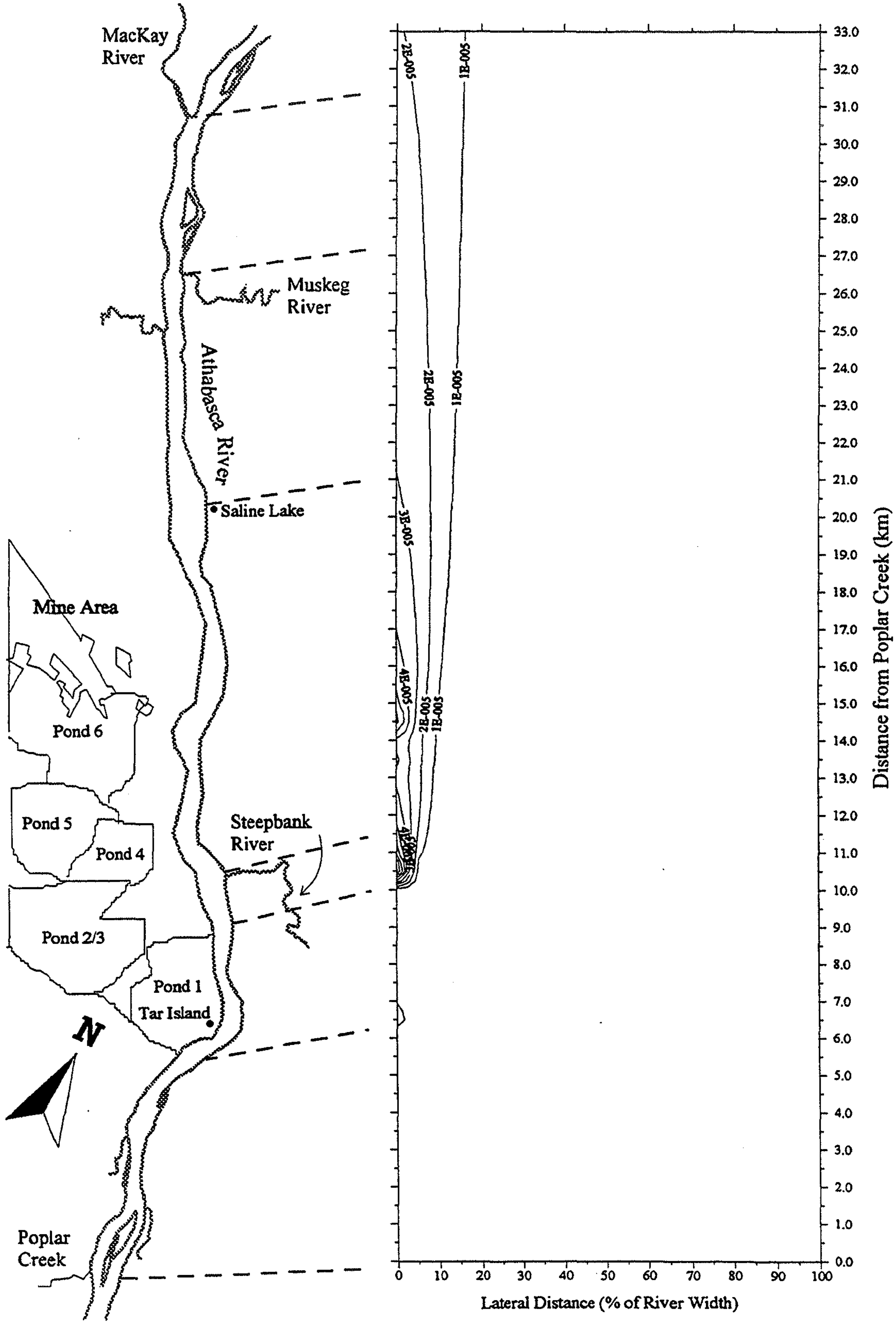

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Figure VI-26 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Ethylbenzene, River Flow of 115 cms

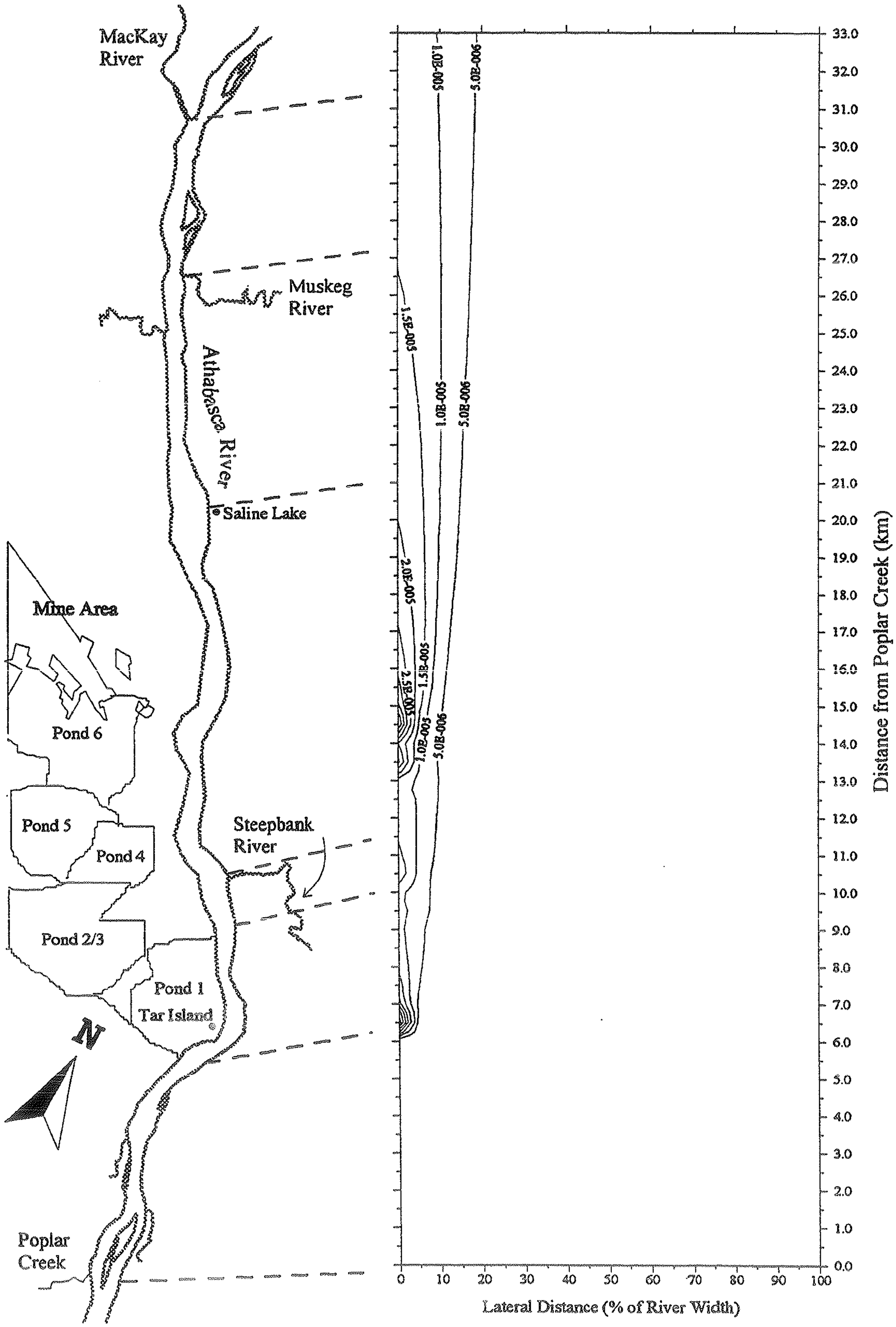

Figure VI-27 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Fluorene, River Flow of 115 cms

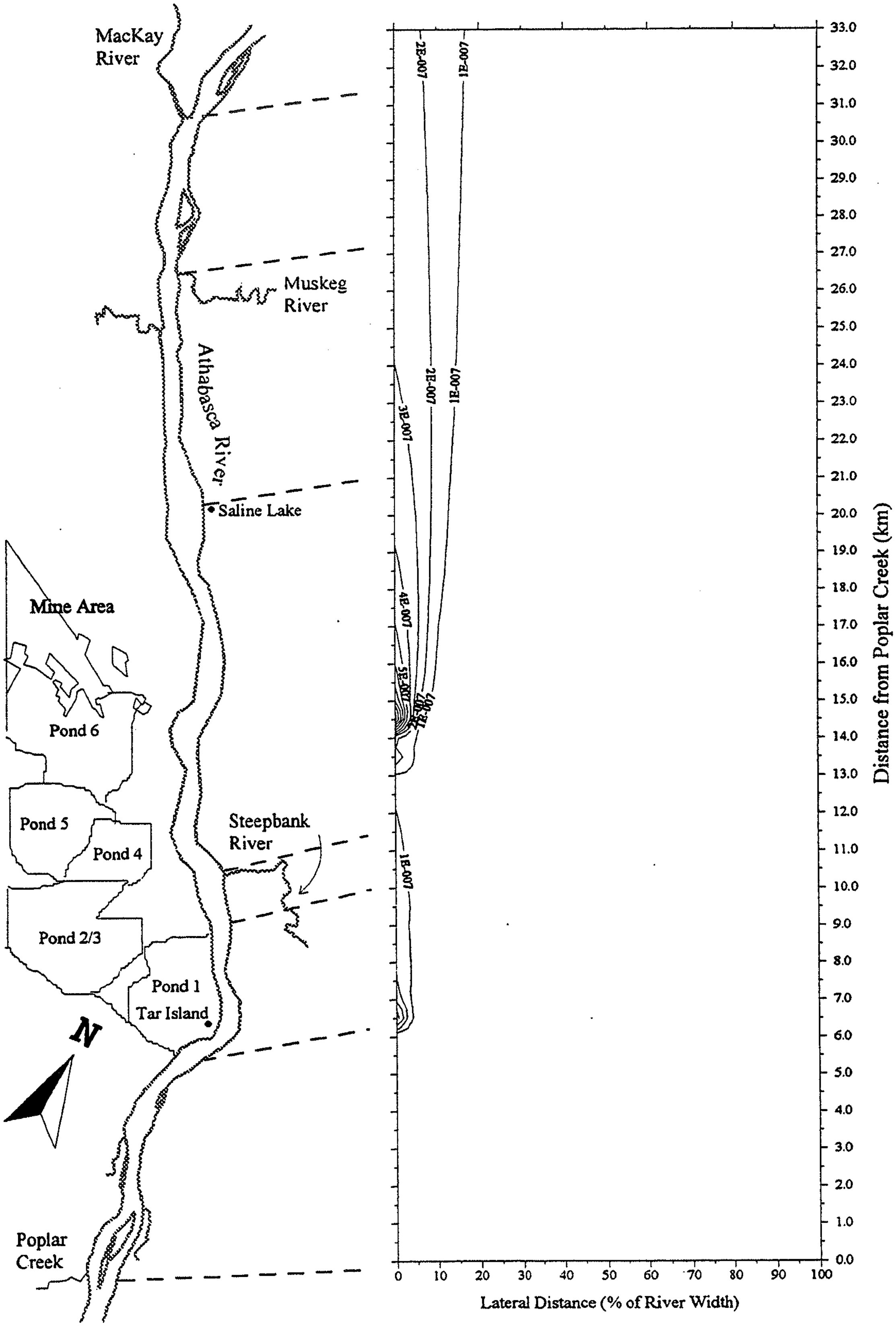

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Figure VI-28 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Iron - Total, River Flow of 115 cms

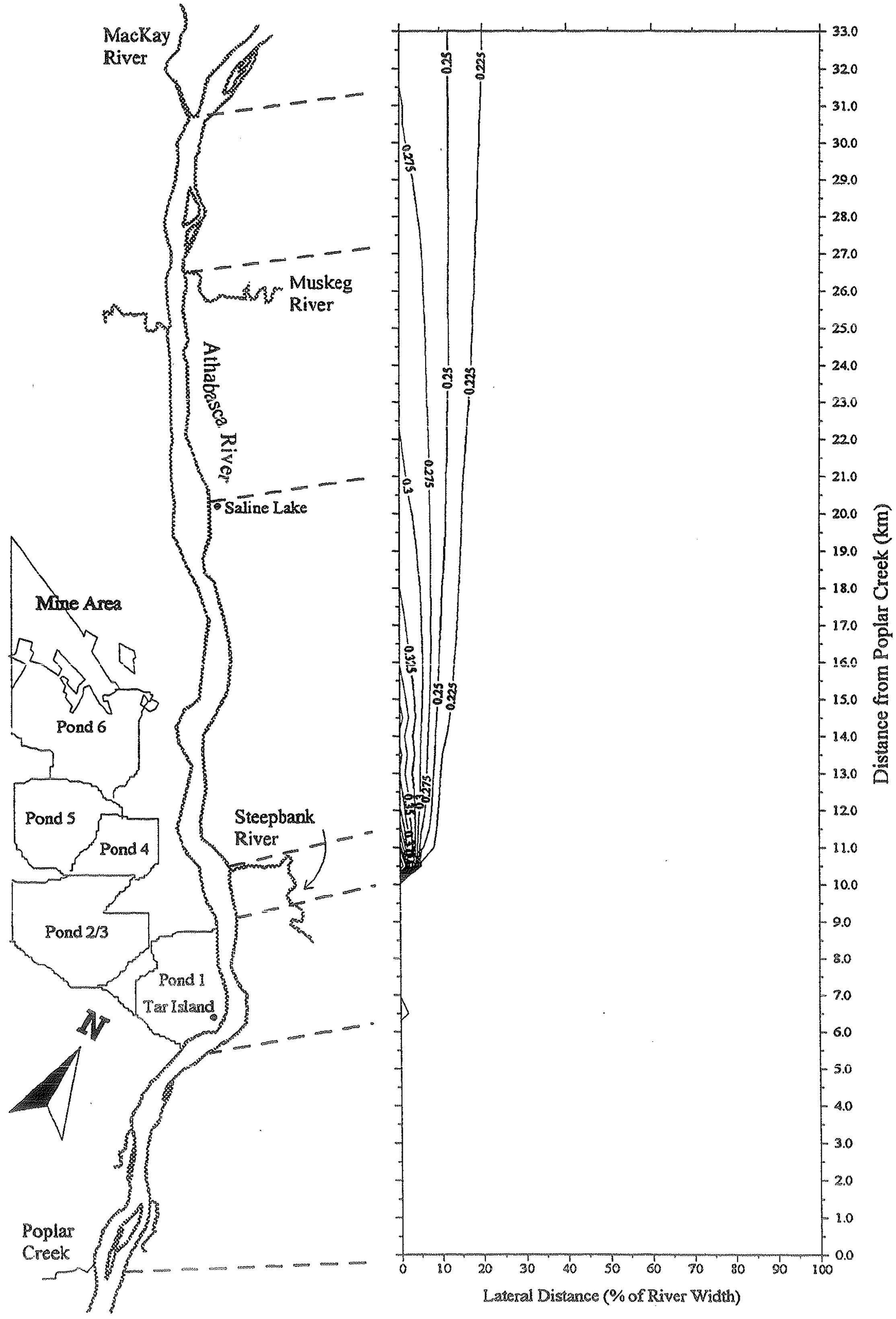

Figure VI-29 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Isophorone, River Flow of 115 cms

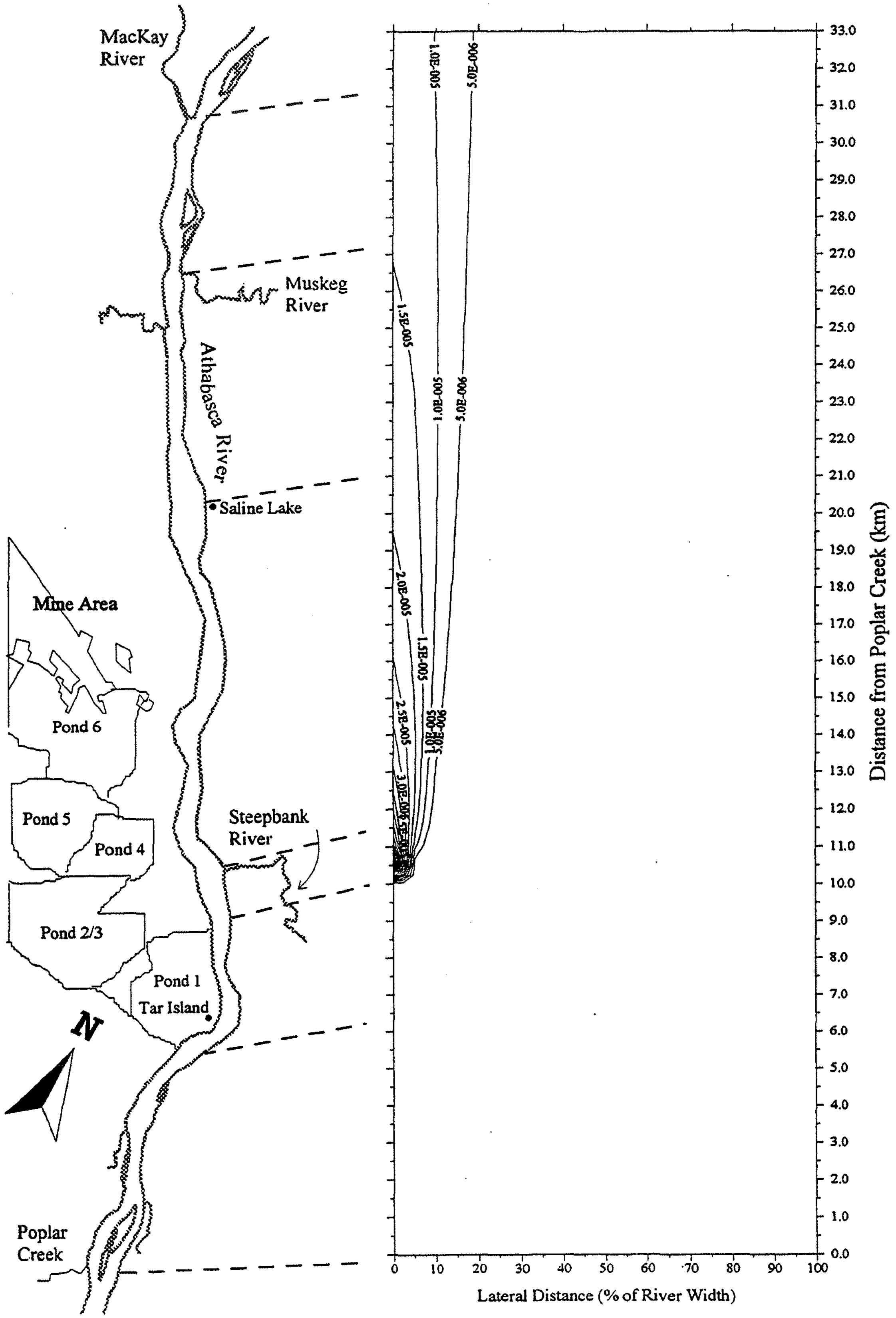

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Figure VI-30 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Lead - Total, River Flow of 115 cms

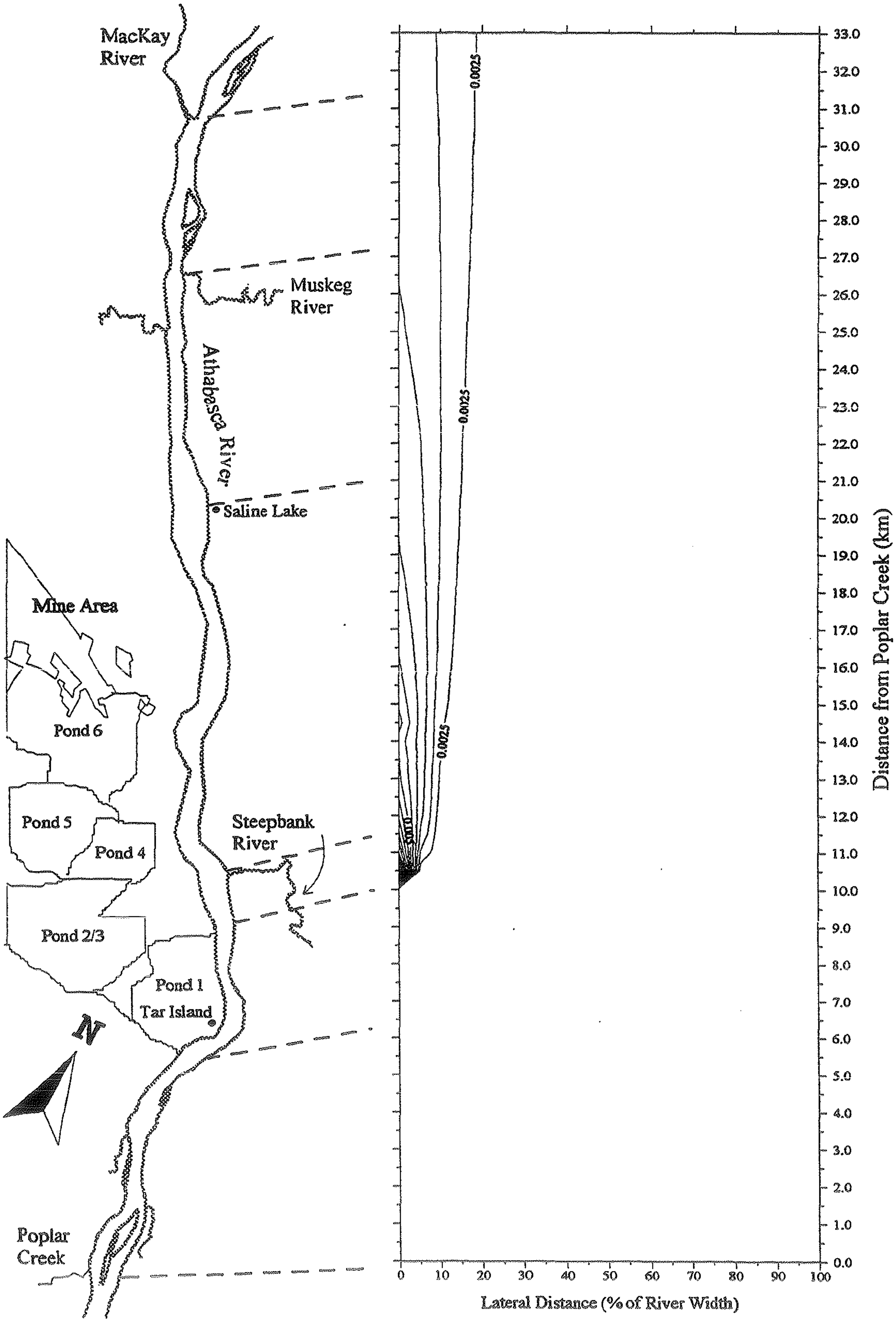

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Figure VI-31 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Lithium-Total, River Flow of 115 cms

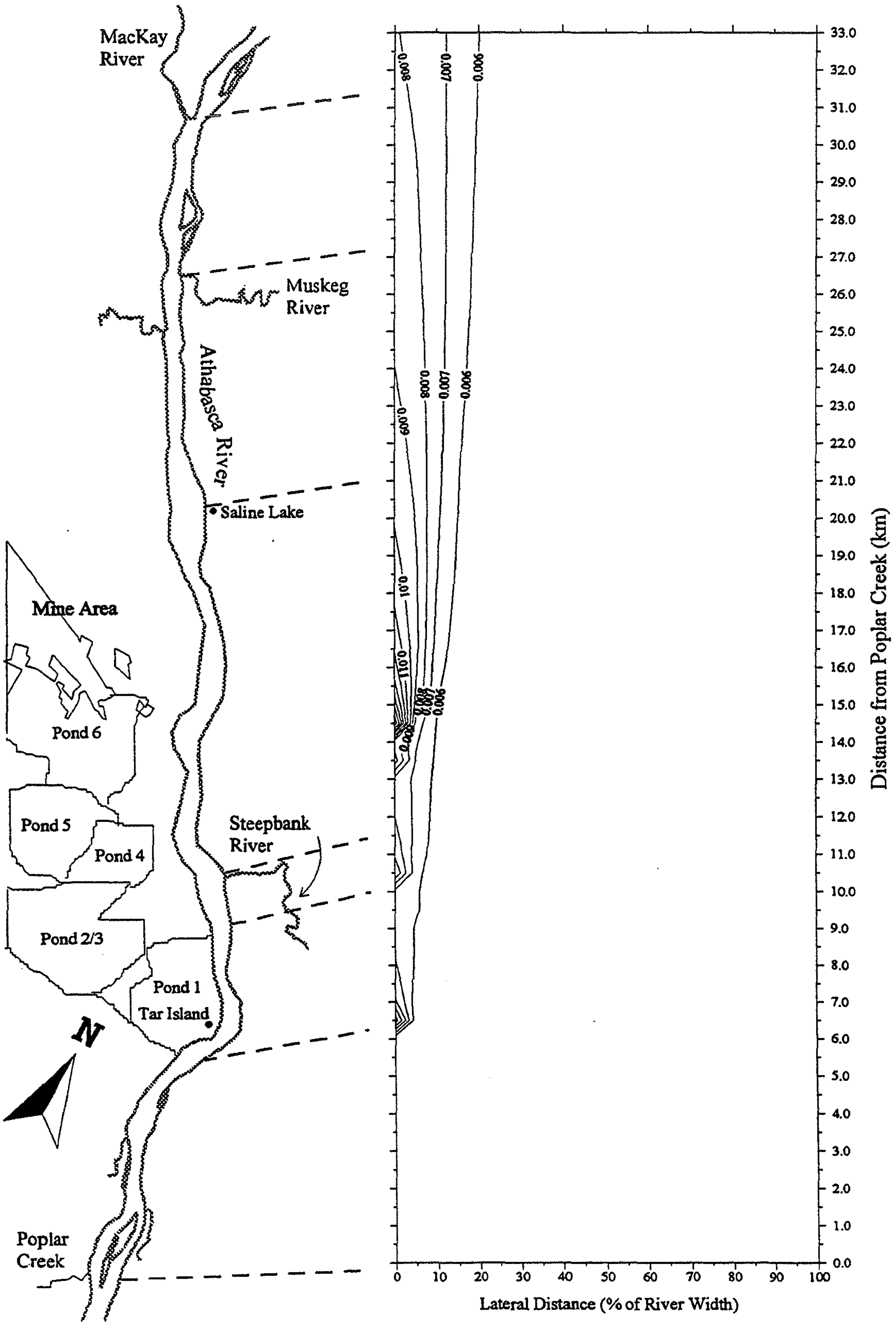

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**Figure VI-32 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Manganese - Total, River Flow of 115 cms**

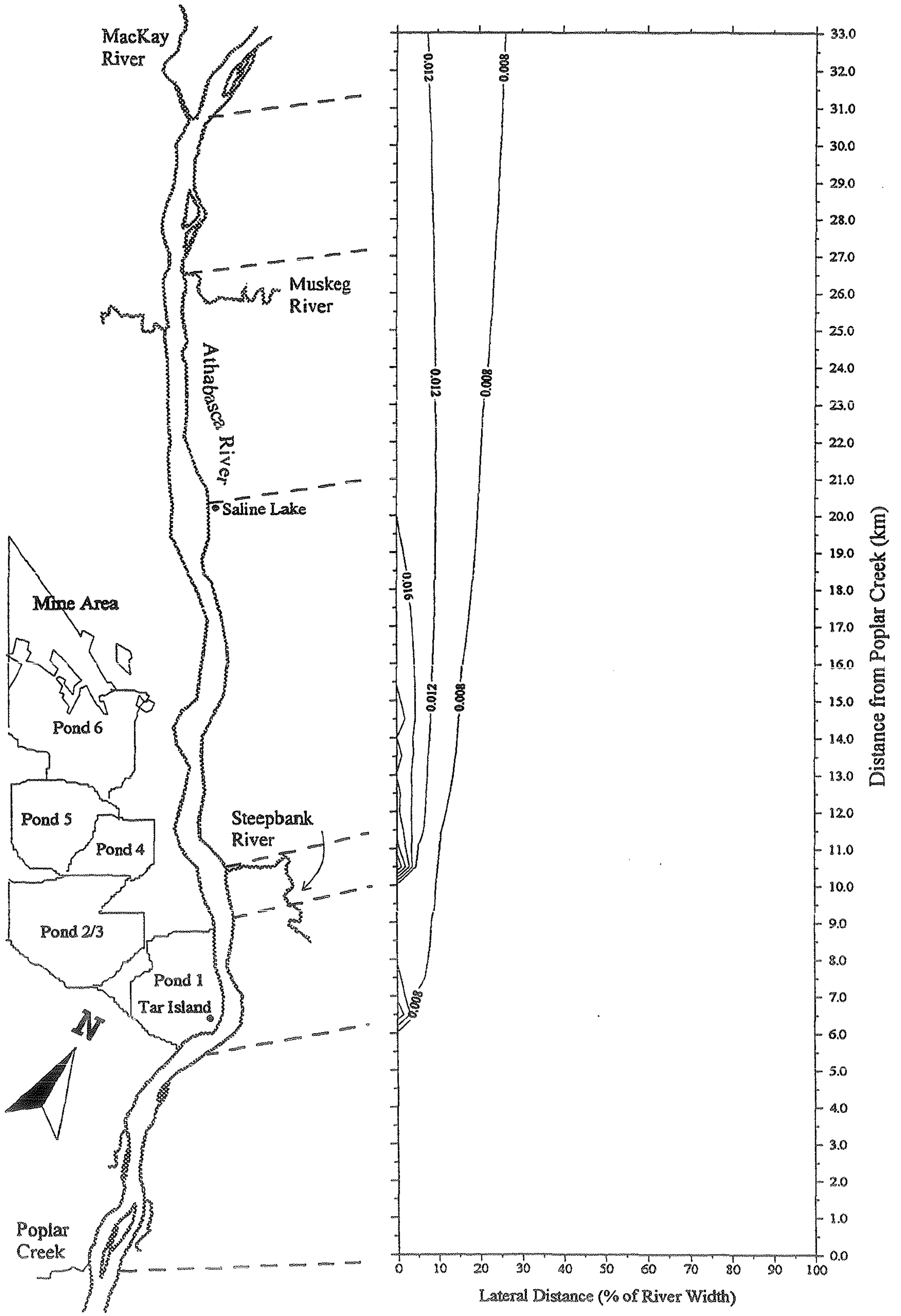

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Figure VI-33 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Mercury - Total, River Flow of 115 cms

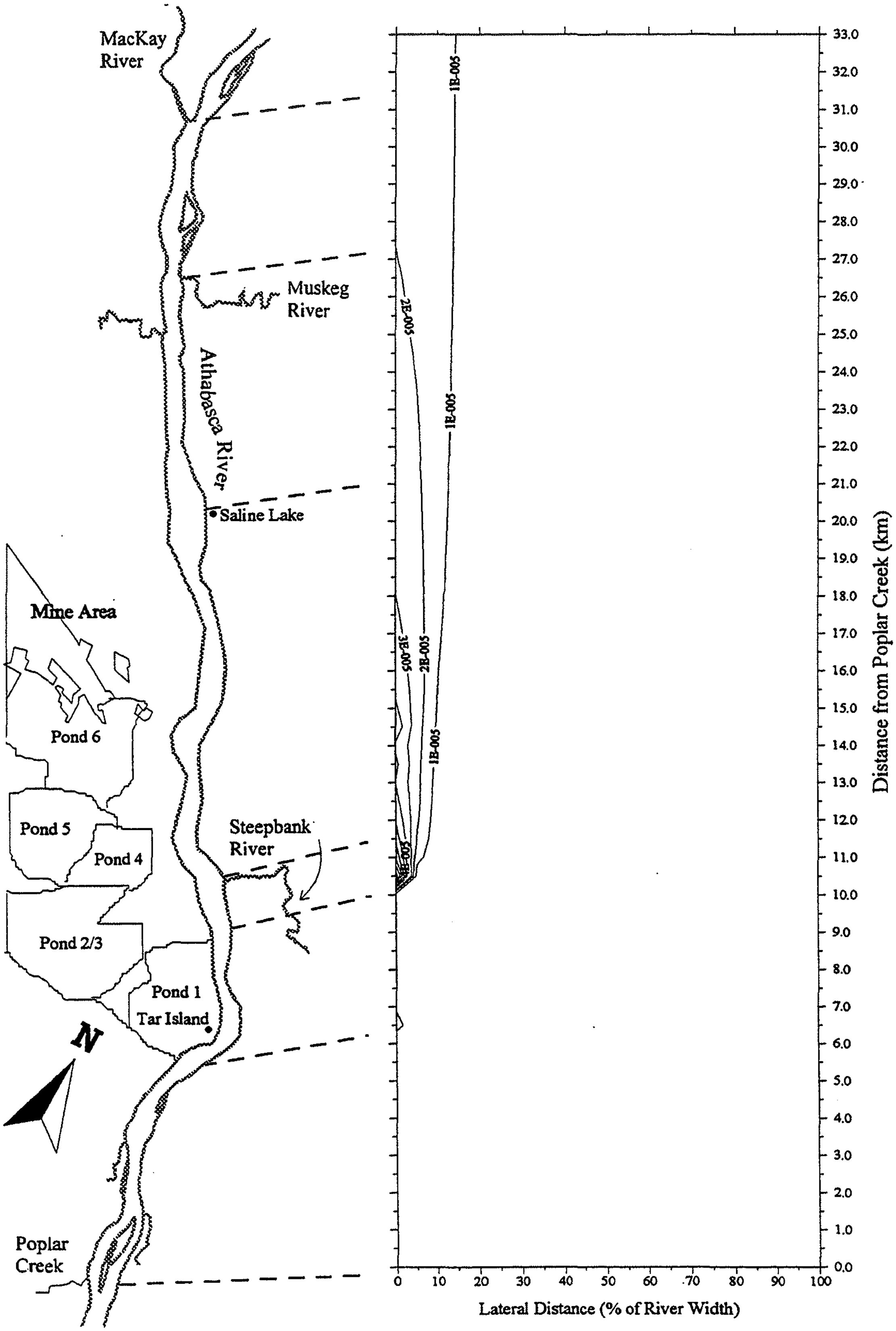

Figure VI-34 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Methylene chloride, River Flow of 115 cms

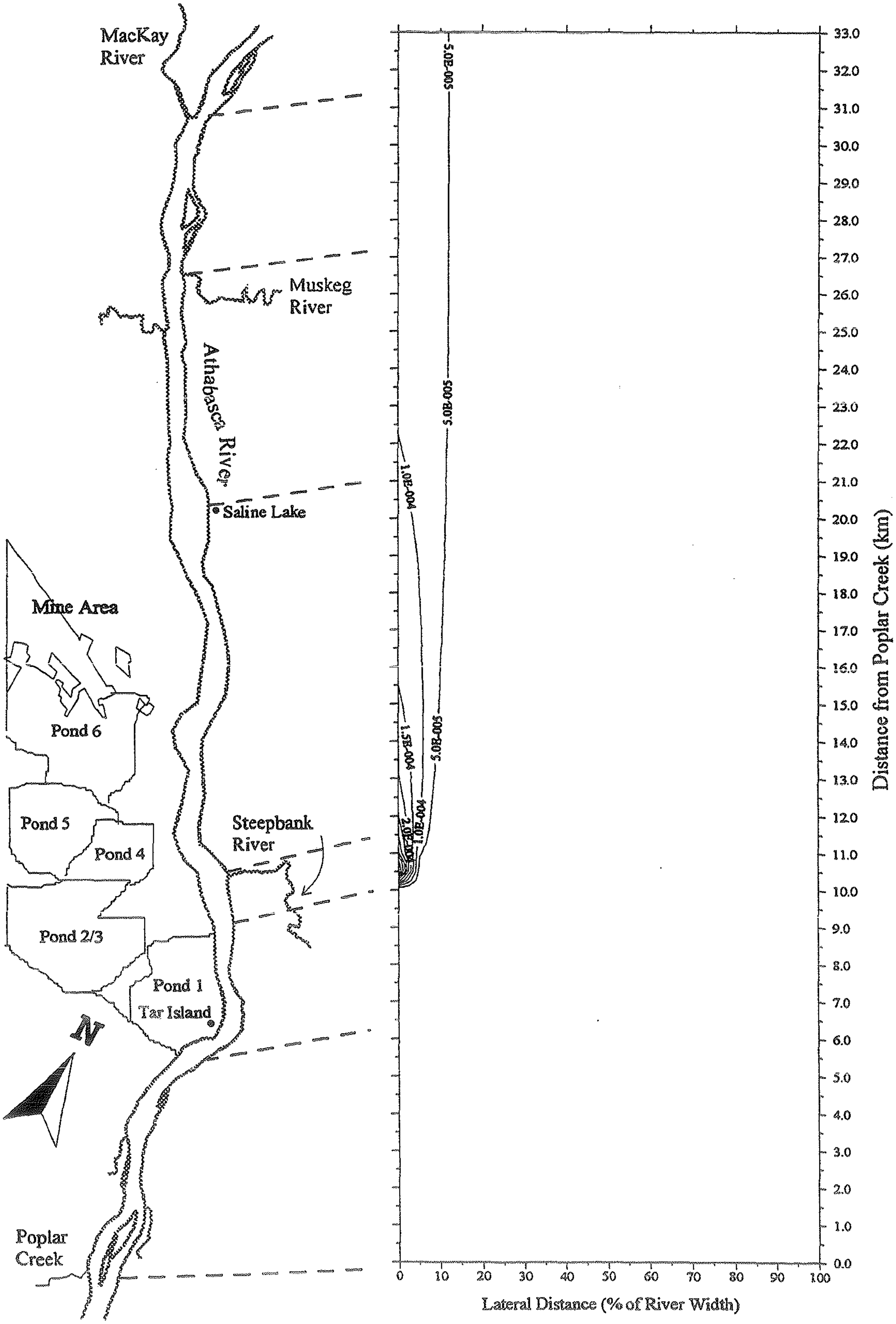

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Figure VI-35 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario m+p Xylene, River Flow of 115 cms

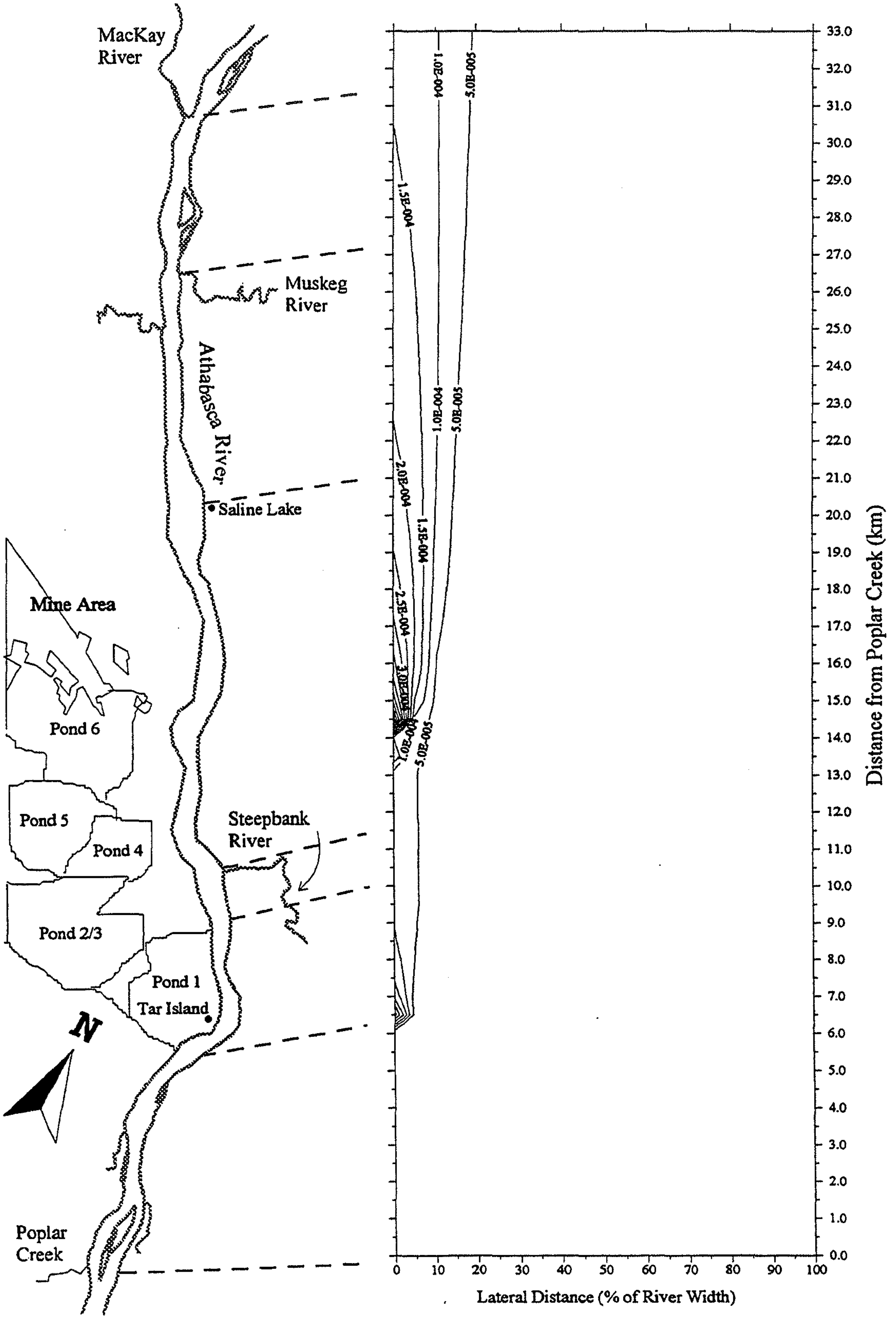

Figure VI-36 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
m-cresol, River Flow of 115 cms

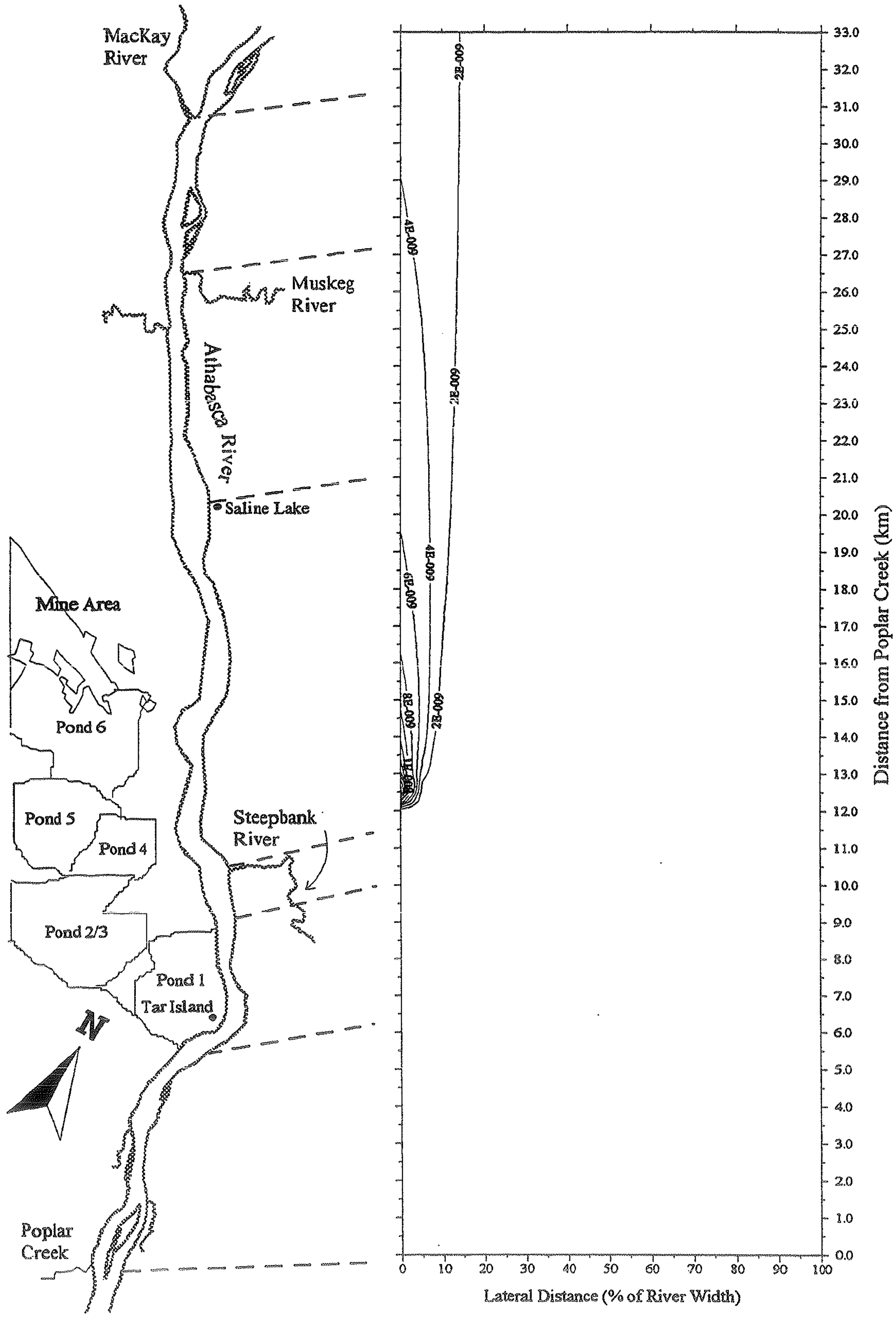

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Figure VI-37 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Molybdenum - Total, River Flow of 115 cms

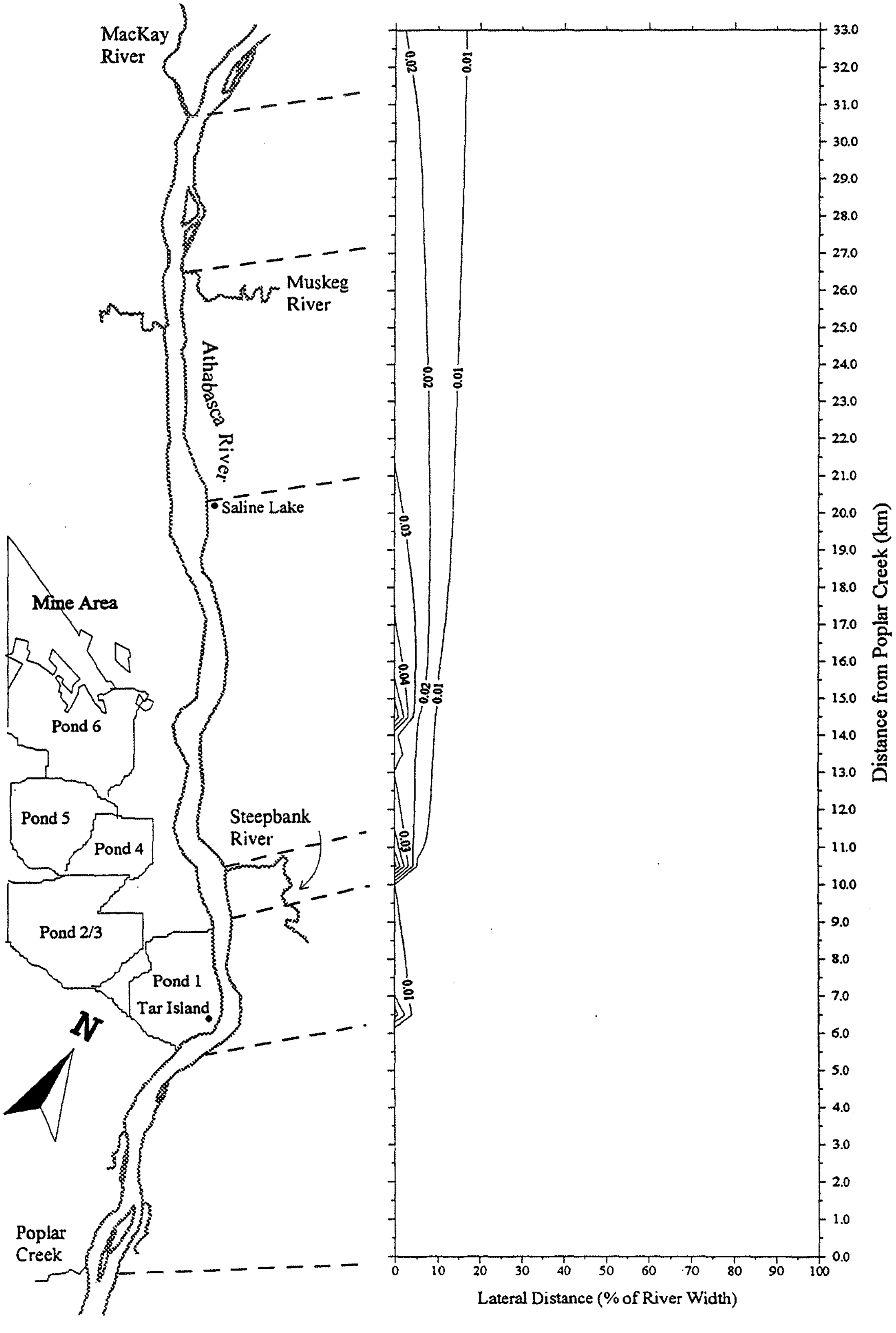

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Figure VI-38 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario naphthalene, River Flow of 115 cms

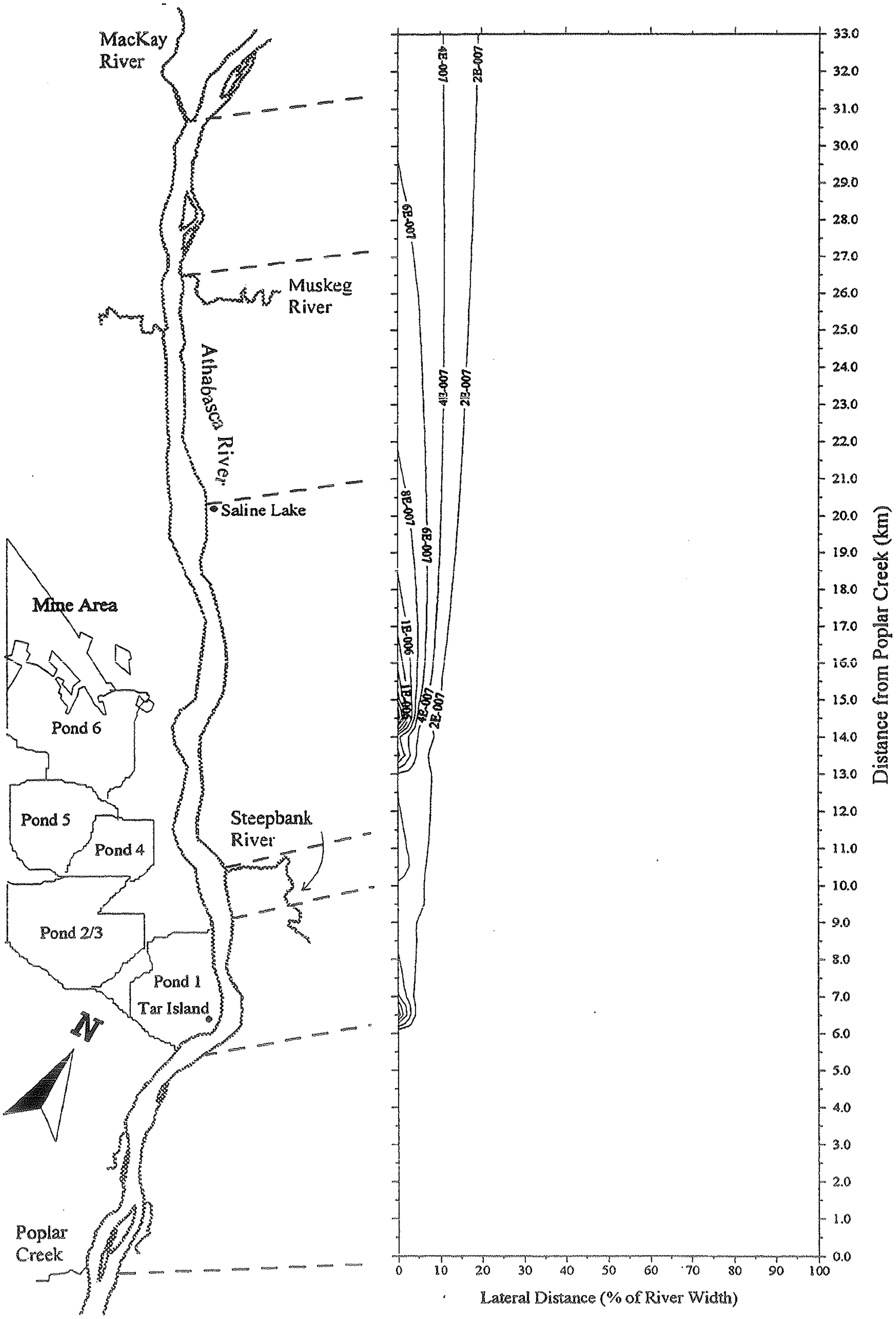

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Figure VI-39 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Nickel - Total, River Flow of 115 cms

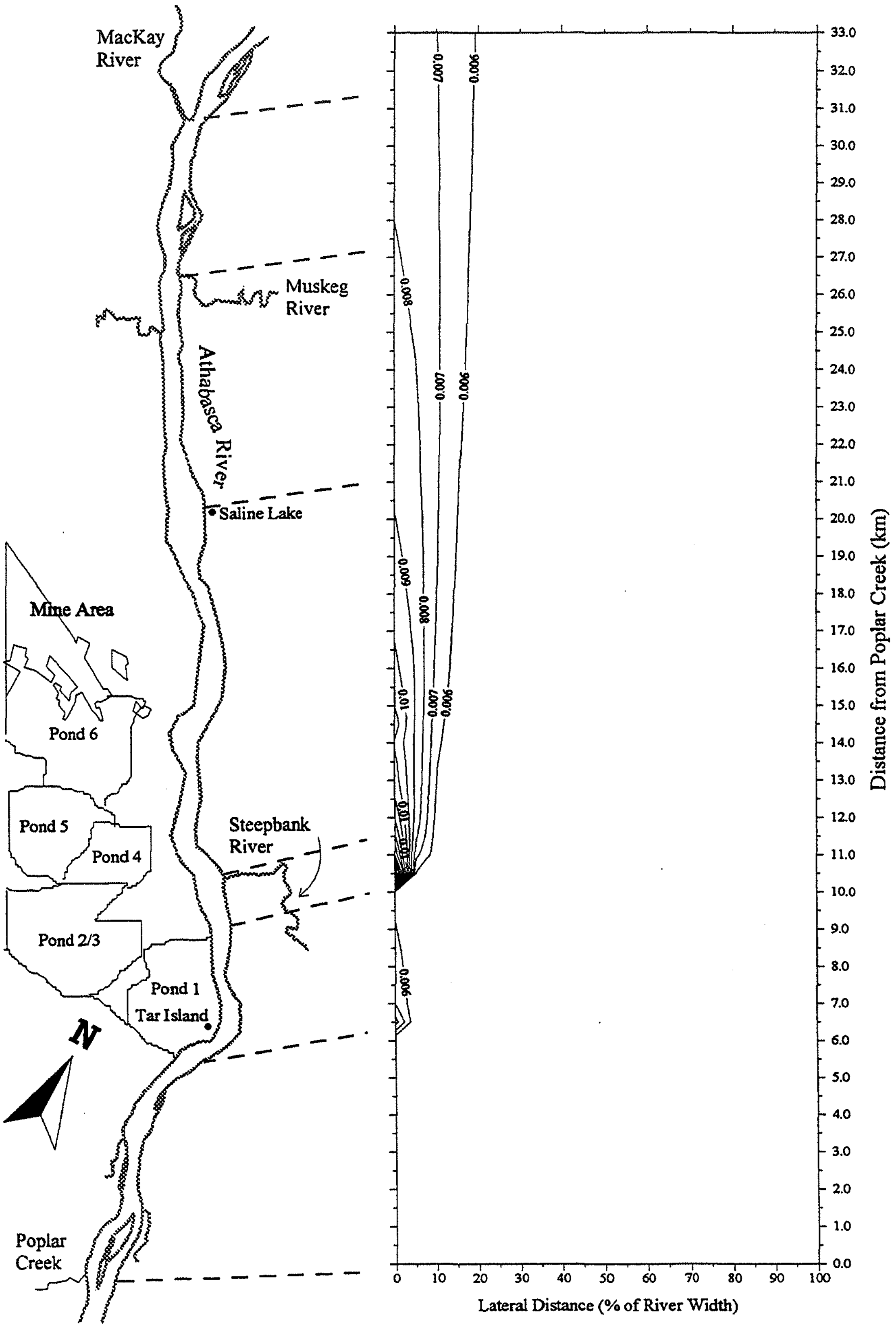

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Figure VI-40 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario o-xylene, River Flow of 115 cms

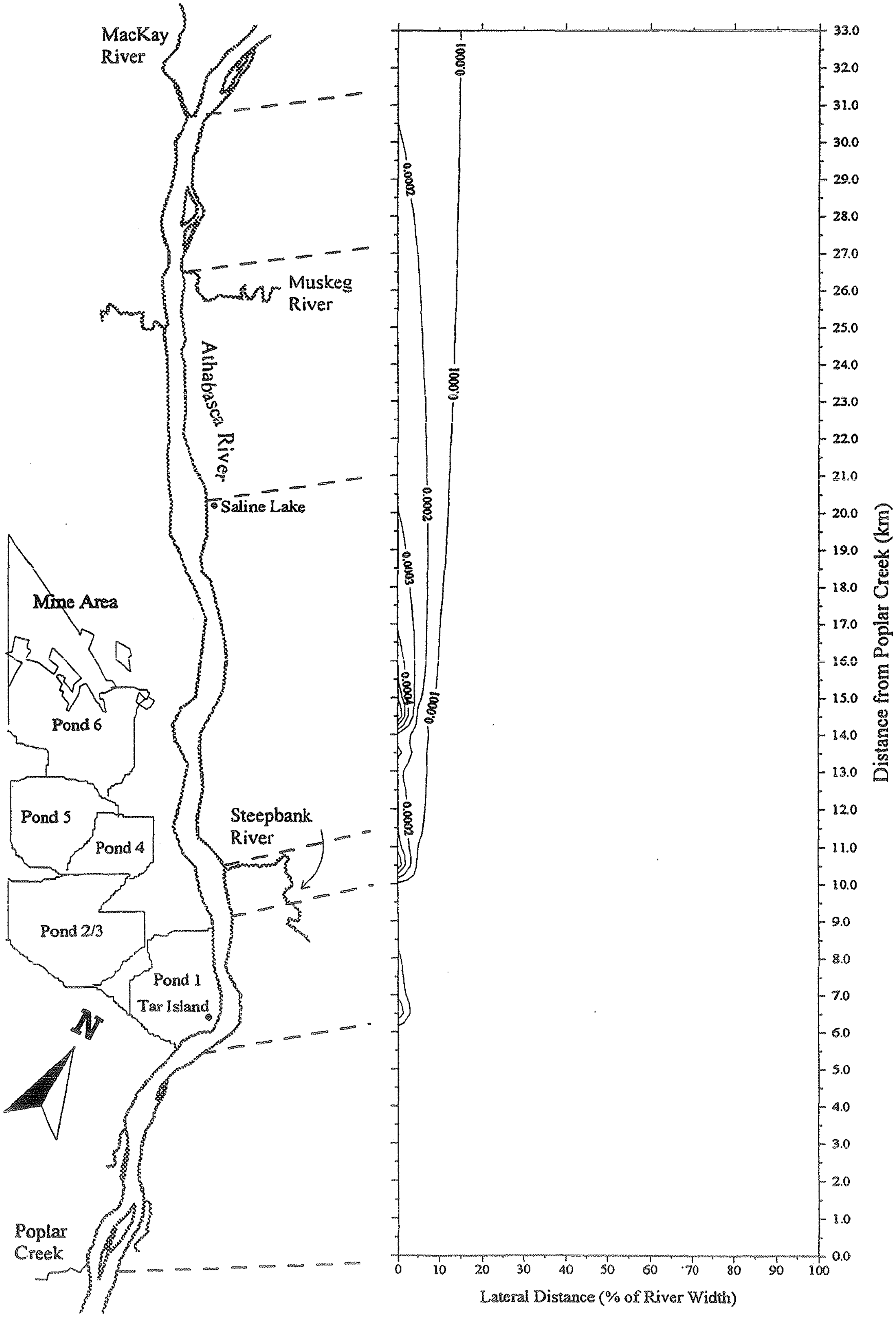

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Figure VI-41 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Phenols - Total, River Flow of 115 cms

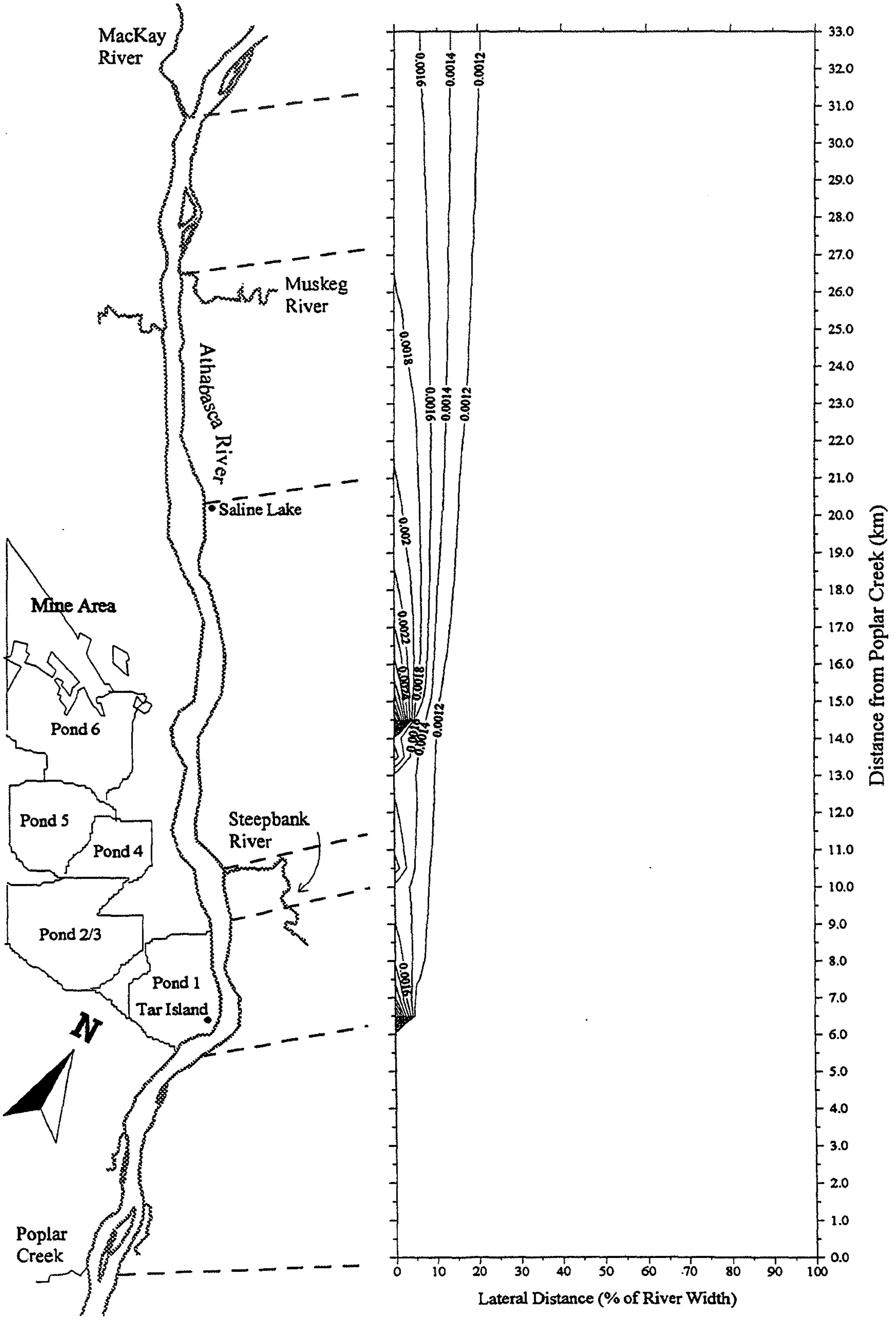

Figure VI-42 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Pyrene, River Flow of 115 cms

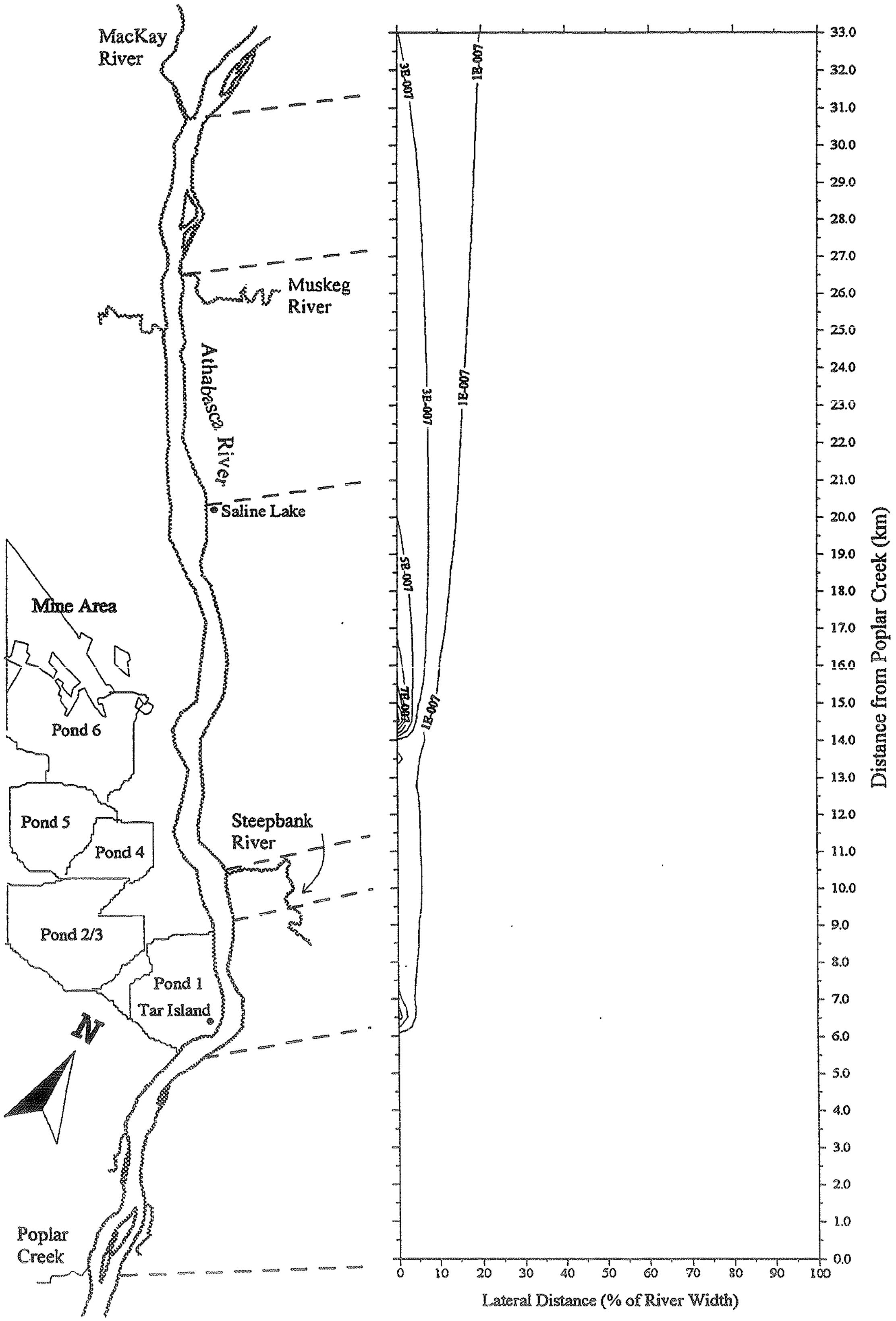

Figure VI-43 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Phosphorus-Total, River Flow of 115 cms

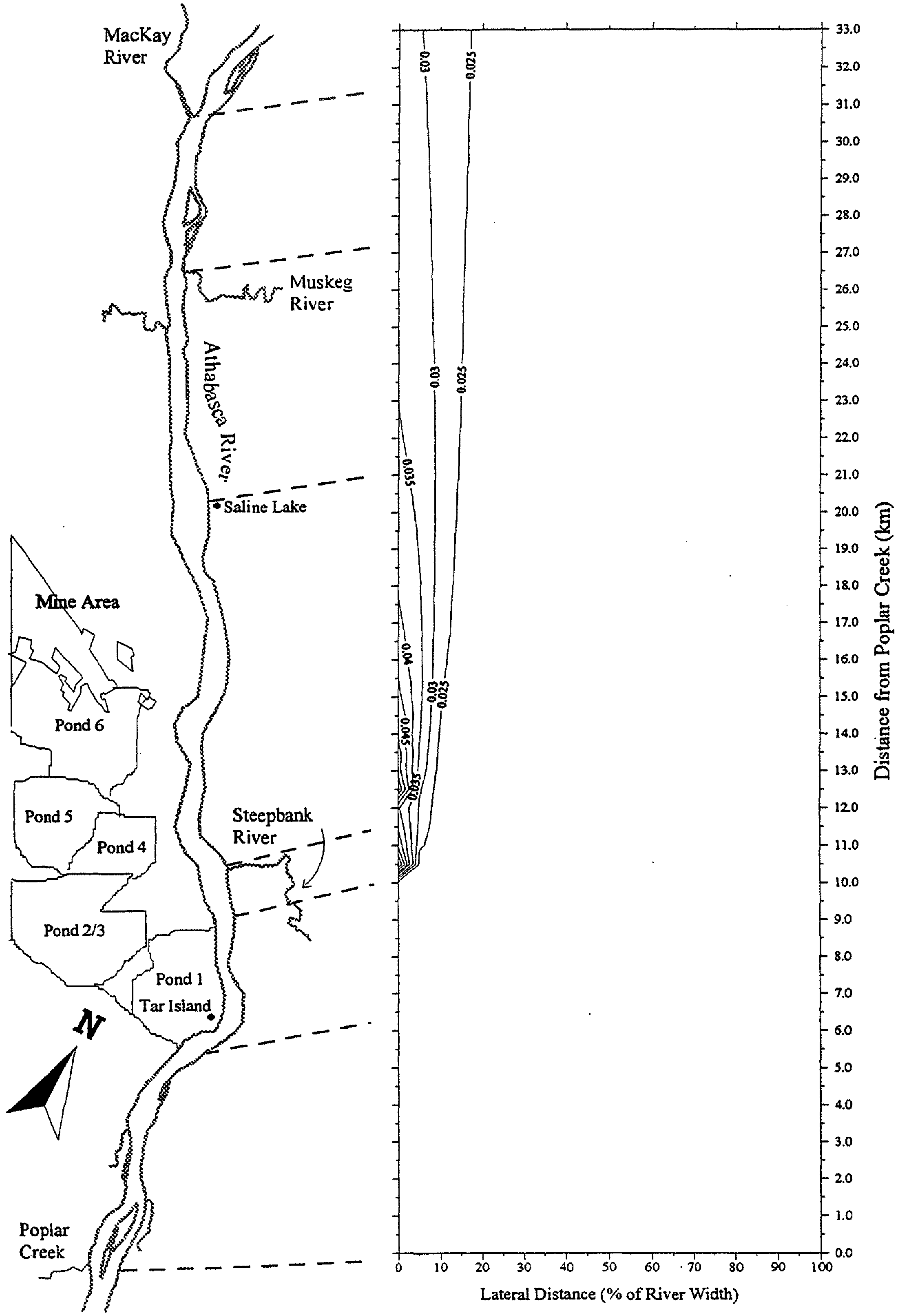

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Figure VI-44 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Selenium - Total, River Flow of 115 cms

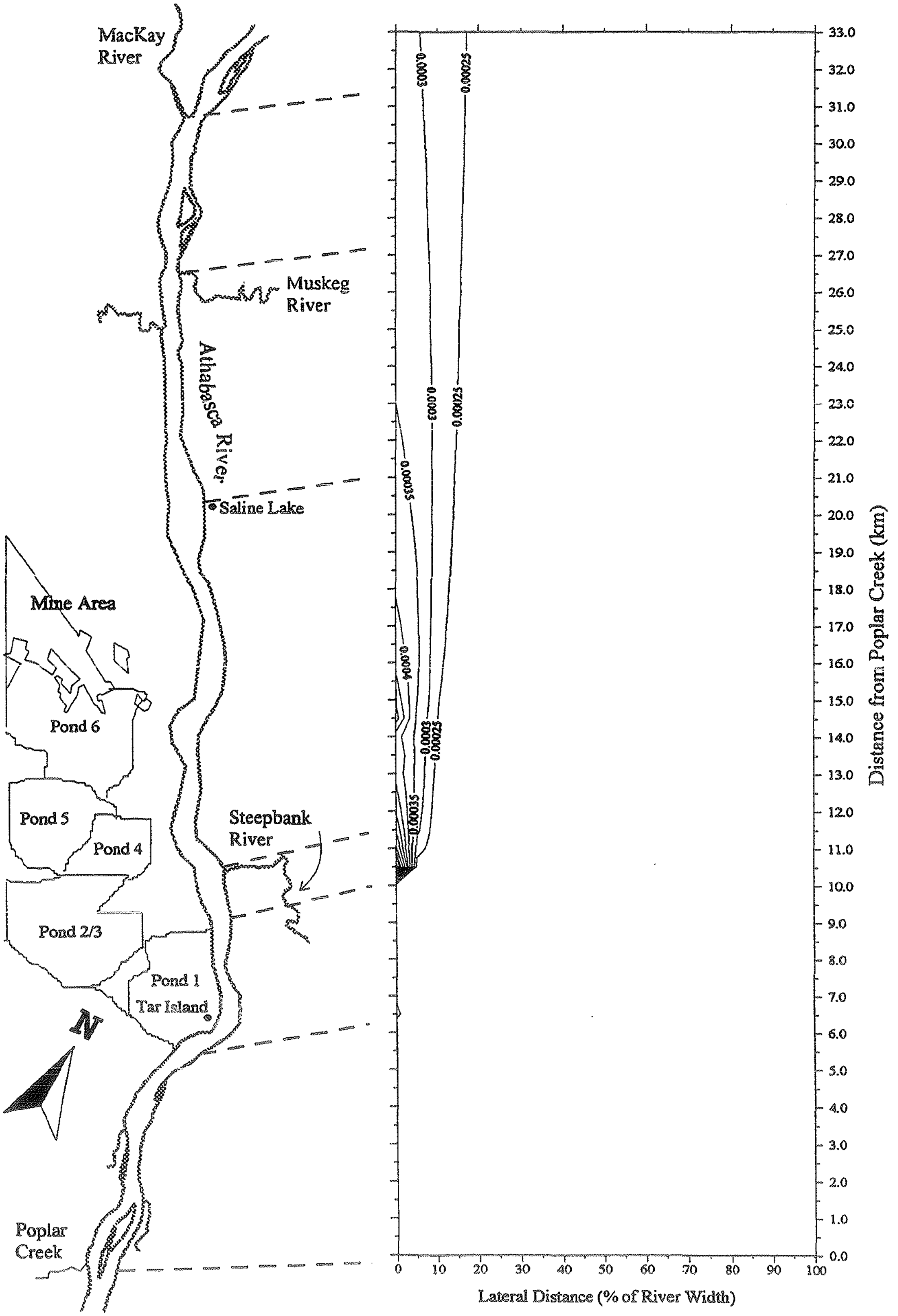

Figure VI-45 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Silver - Total, River Flow of 115 cms

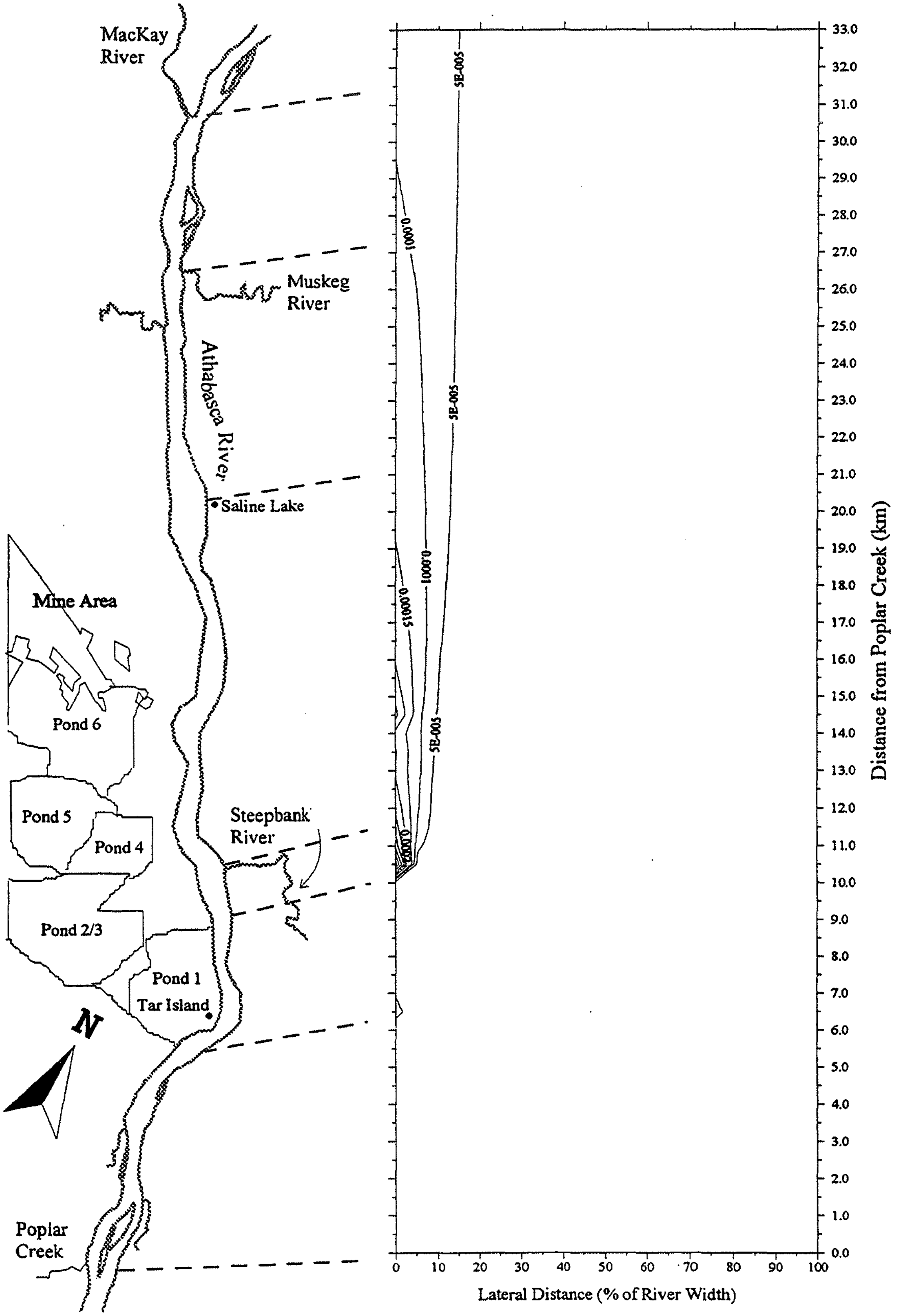

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Figure VI-46 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Strontium - Total, River Flow of 115 cms

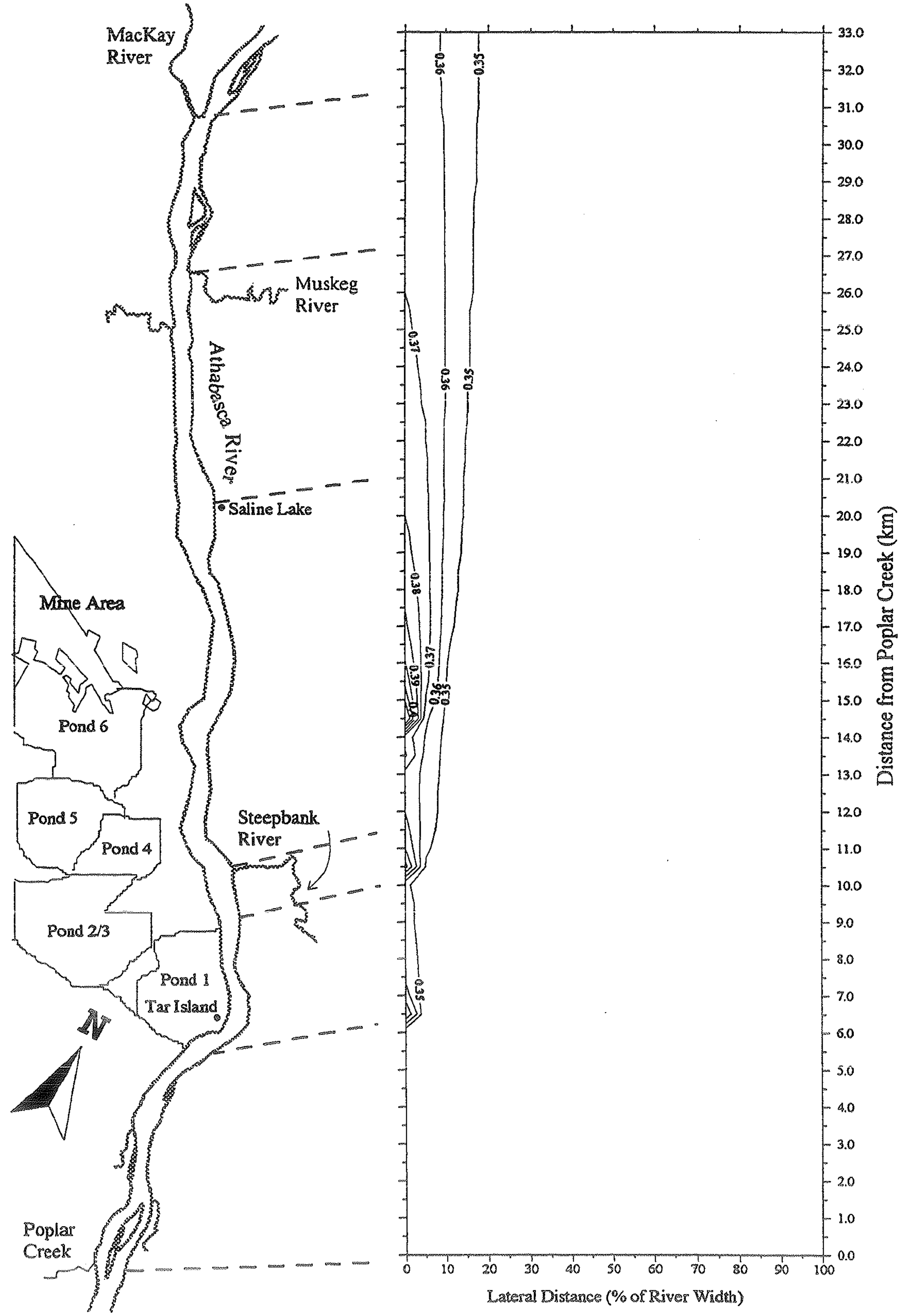

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Figure VI-47 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Sulphate, River Flow of 115 cms

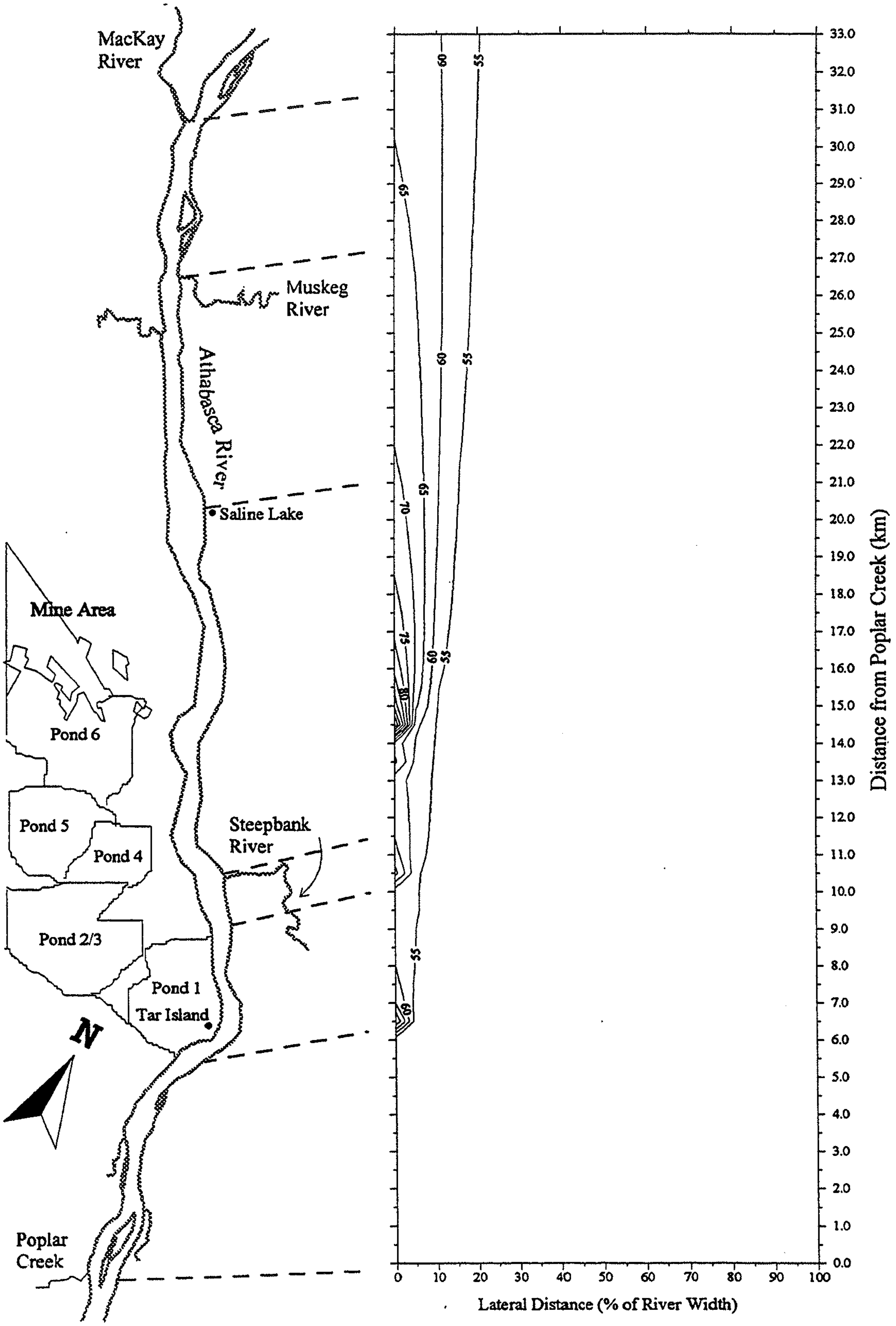

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Figure VI-48 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Thallium, River Flow of 115 cms

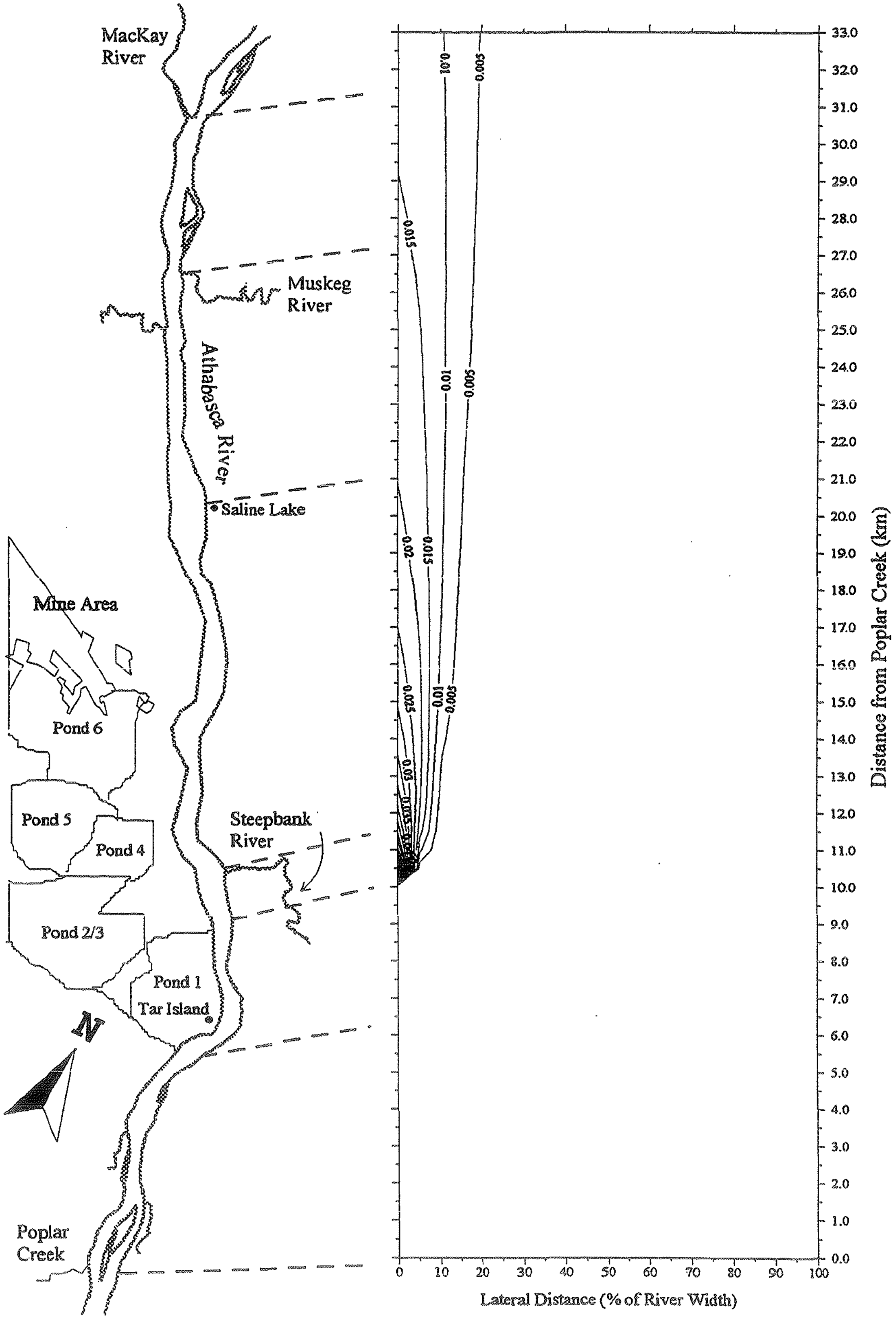

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Figure VI-49 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Toluene, River Flow of 115 cms

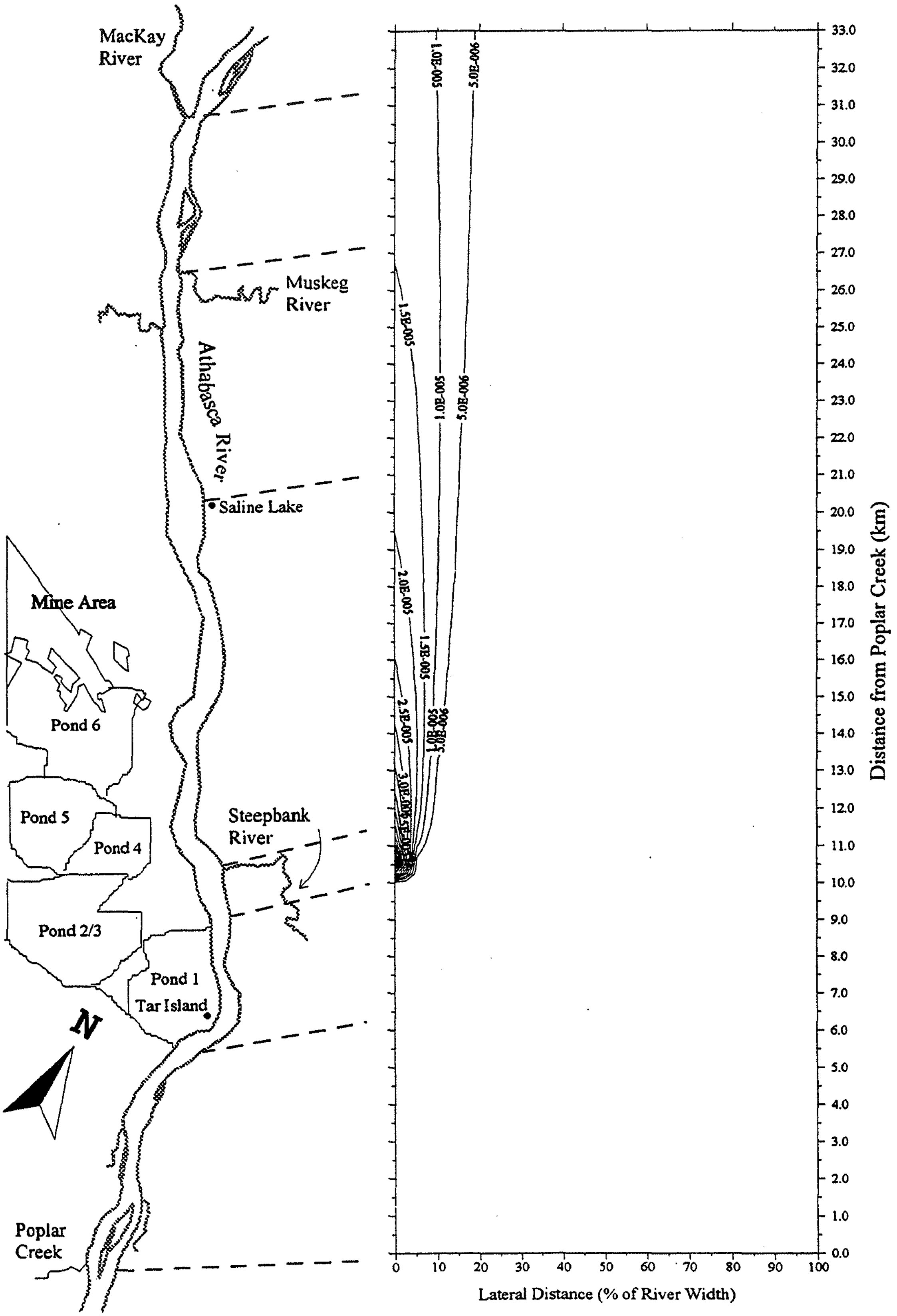

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Figure VI-50 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Total PAH's, River Flow of 115 cms

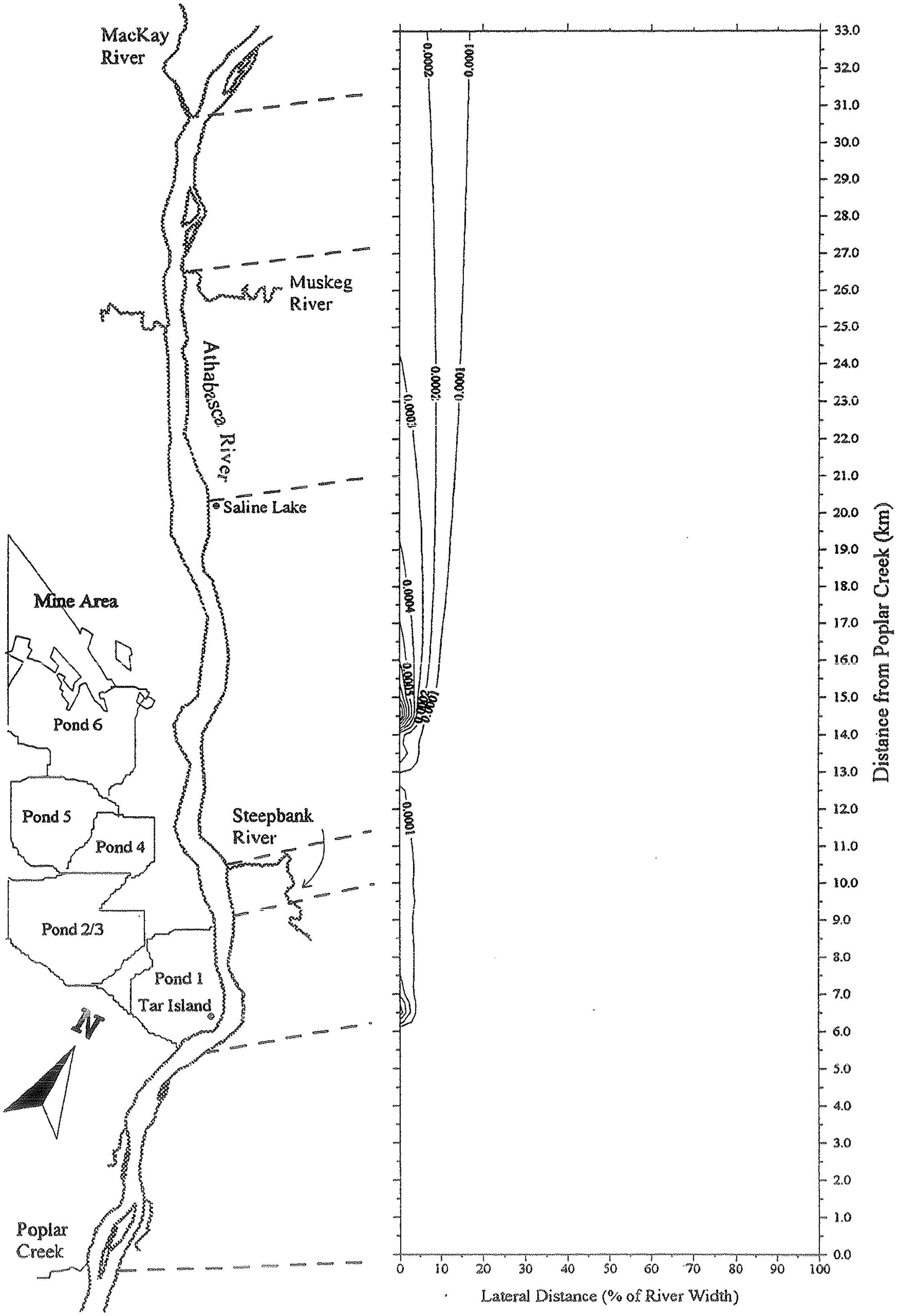

Figure VI-51 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
2,4,6-Trichlorophenol, River Flow of 115 cms

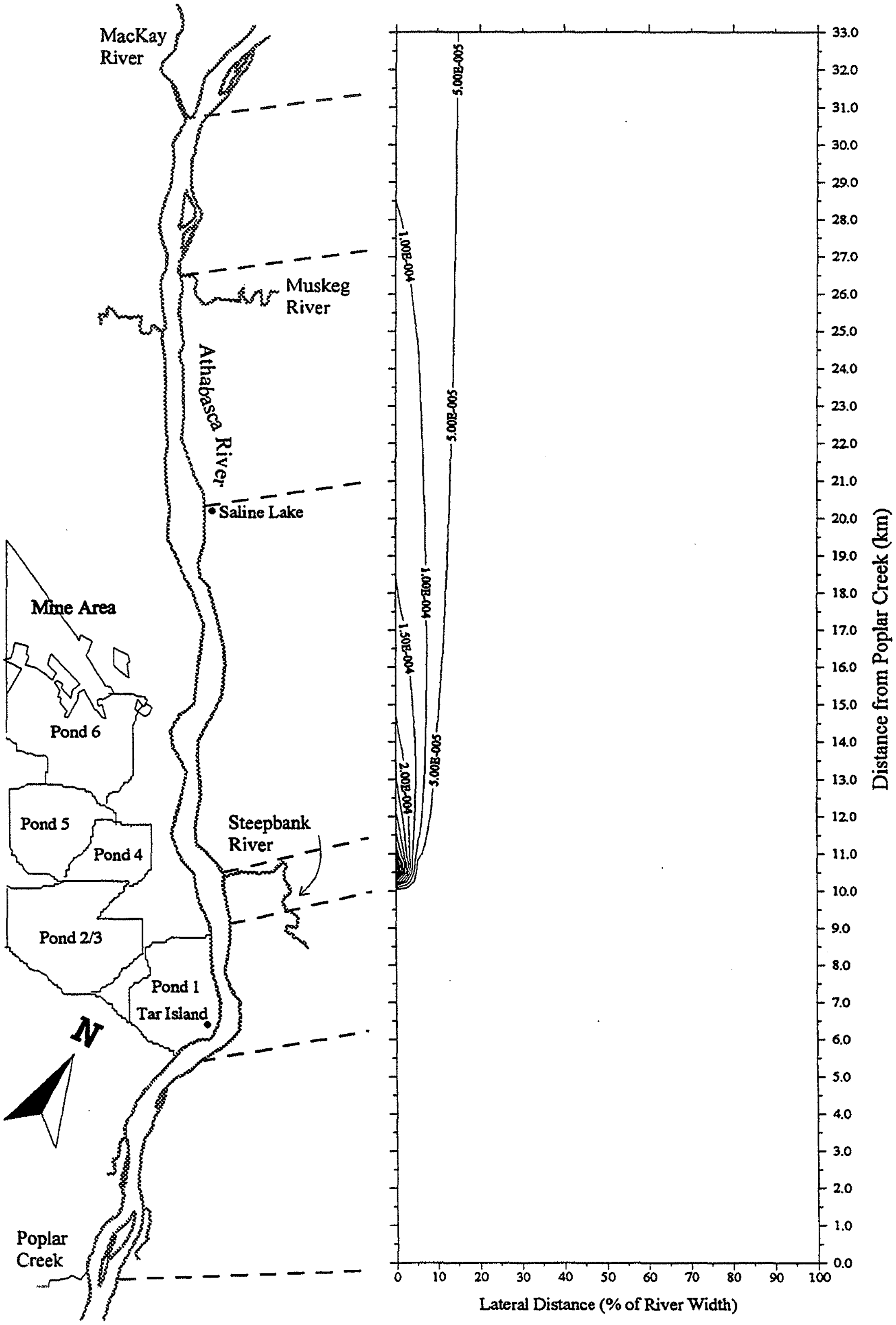

Figure VI-52 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
TSS, River Flow of 115 cms

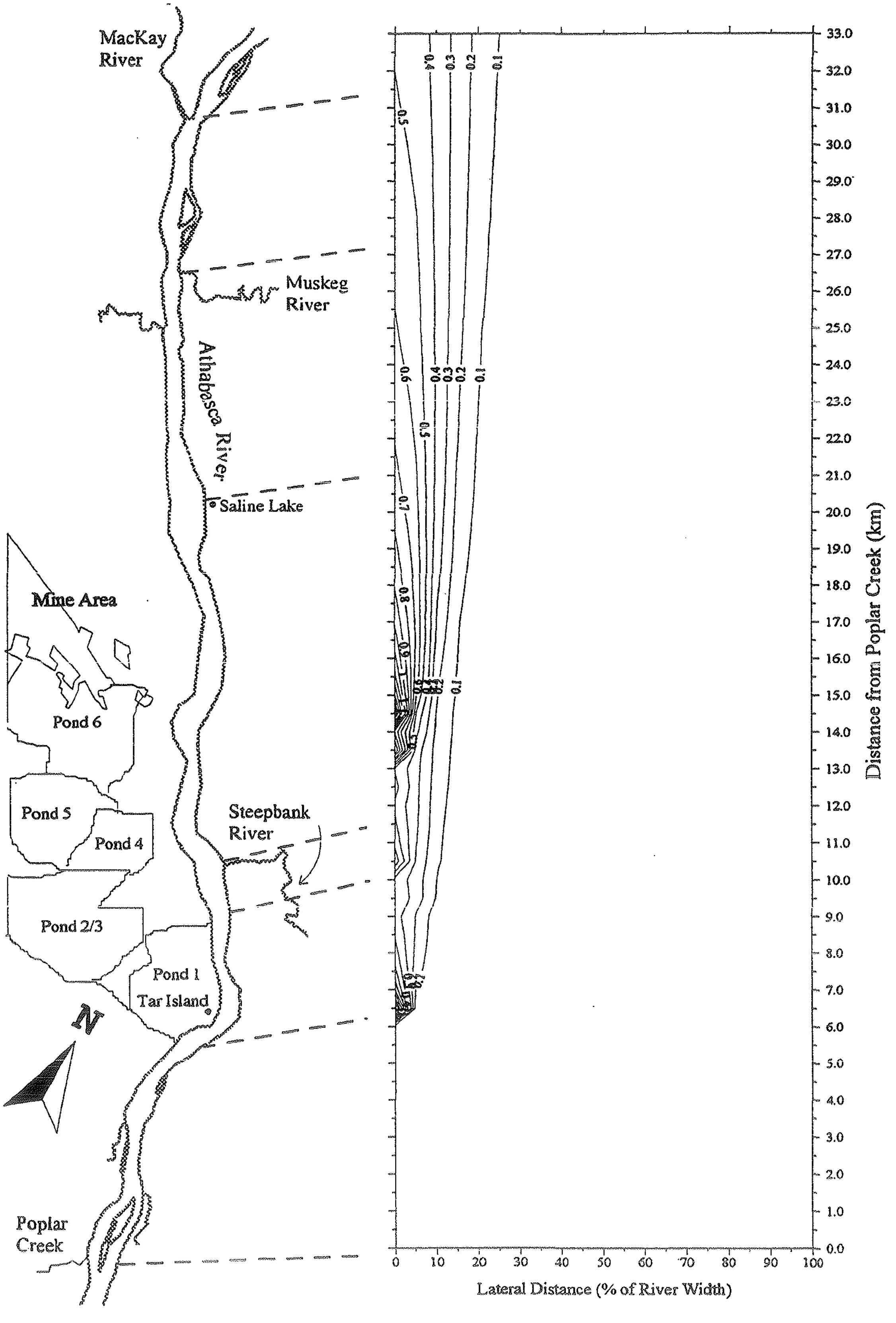

Figure VI-53 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario Uranium - Total, River Flow of 115 cms

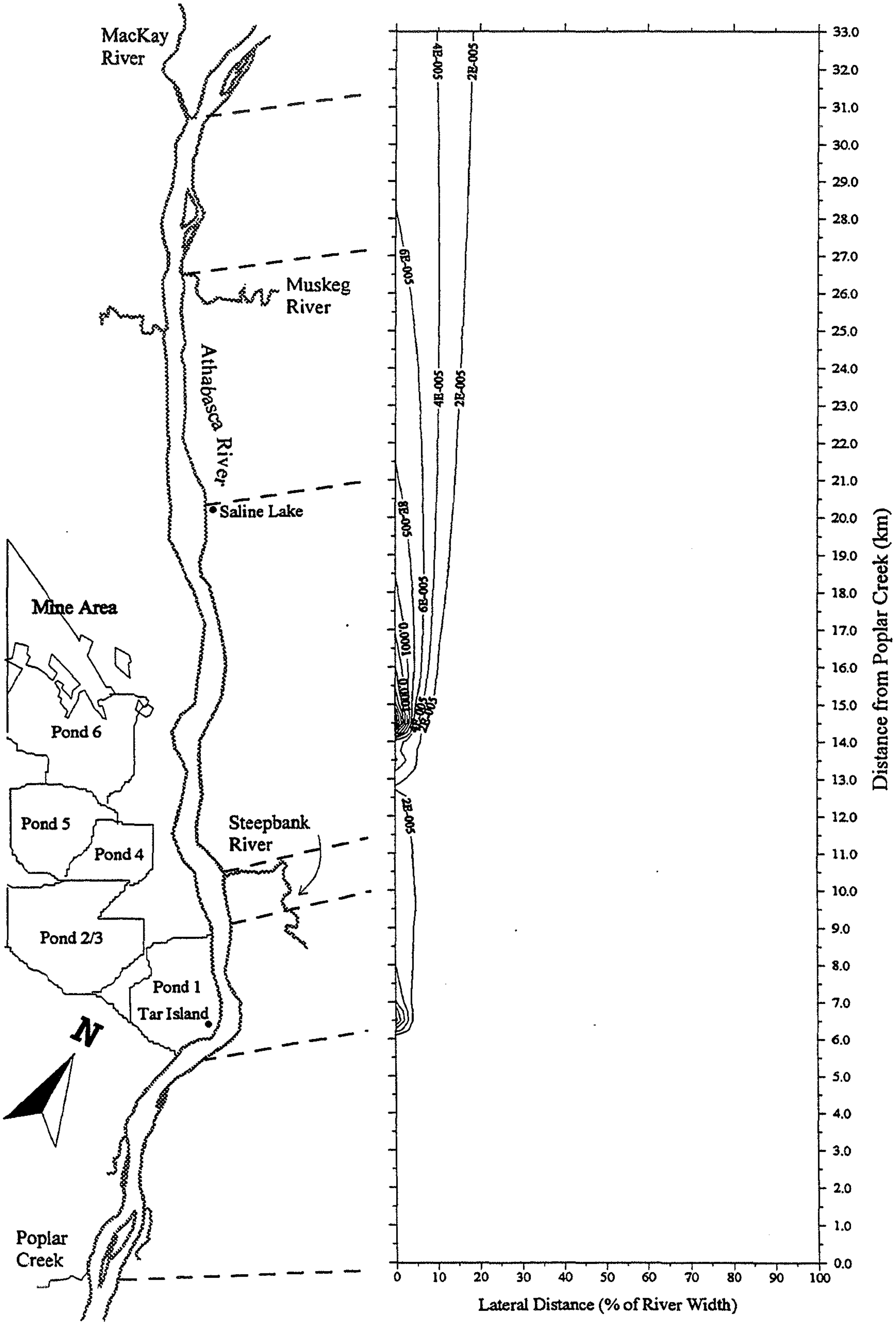

Figure VI-54 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Vanadium - Total, River Flow of 115 cms

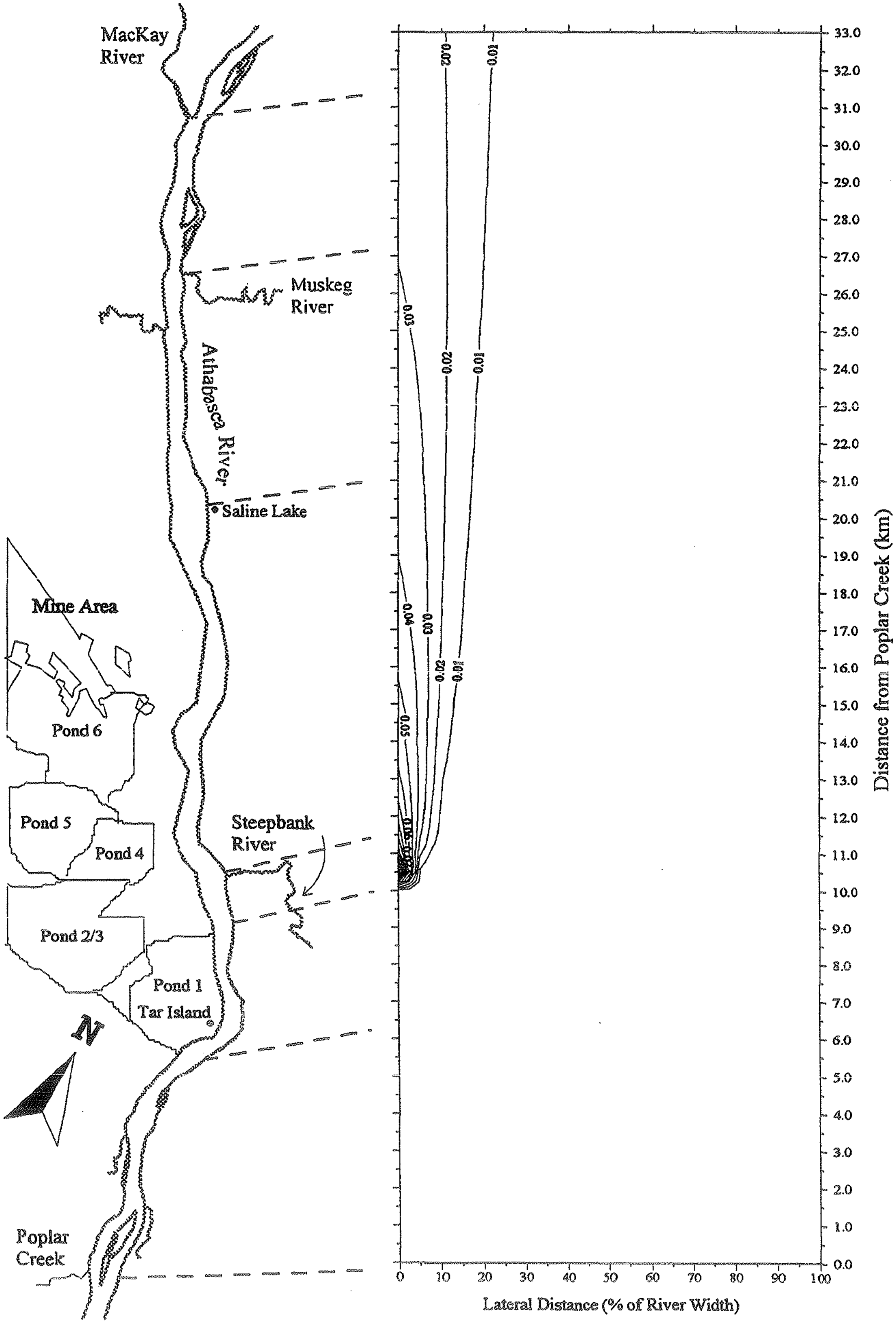

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Figure VI-55 Simulated Athabasca River Concentrations (mg/L) - Year 2020 Scenario
Zinc - Total, River Flow of 115 cms

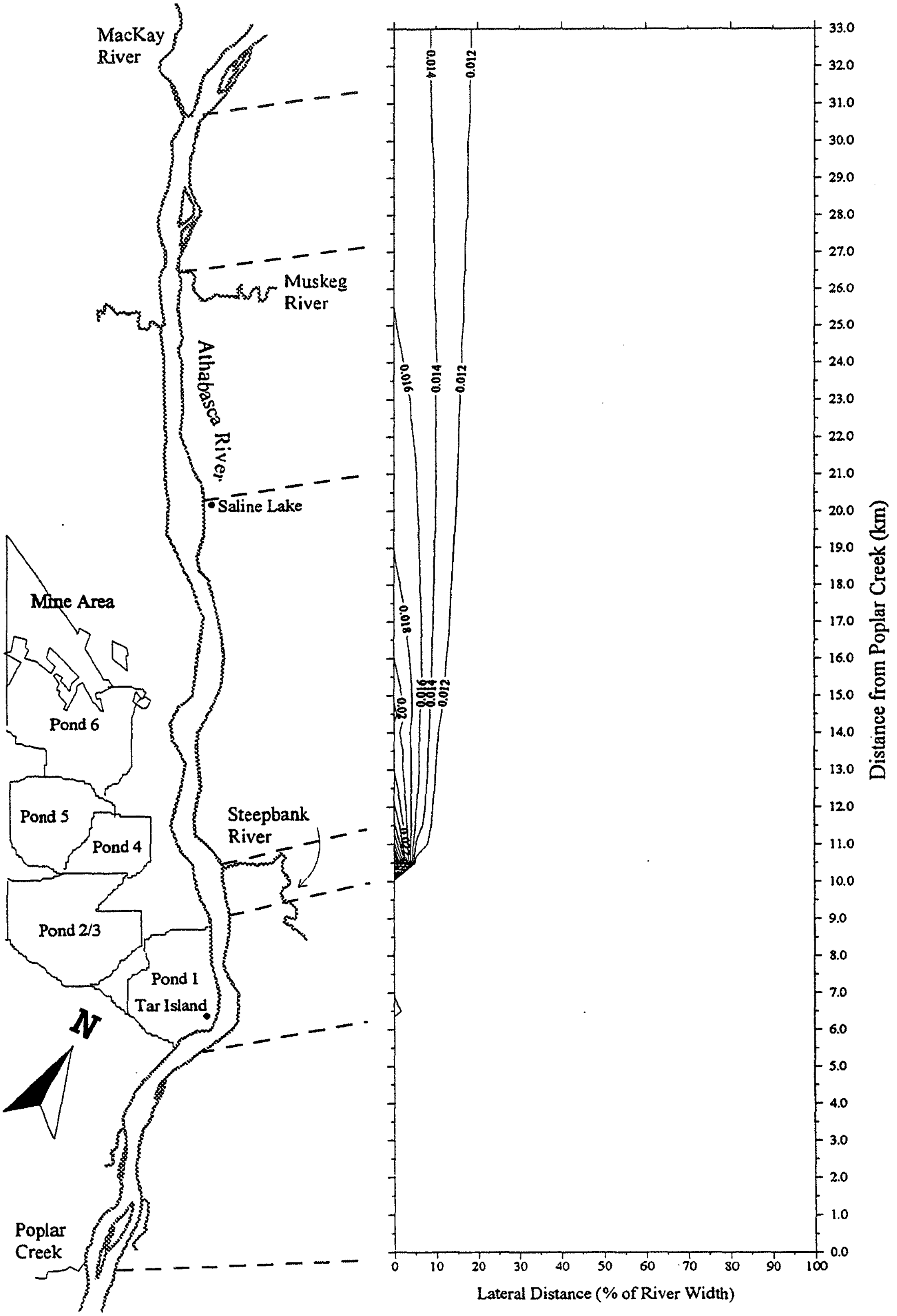
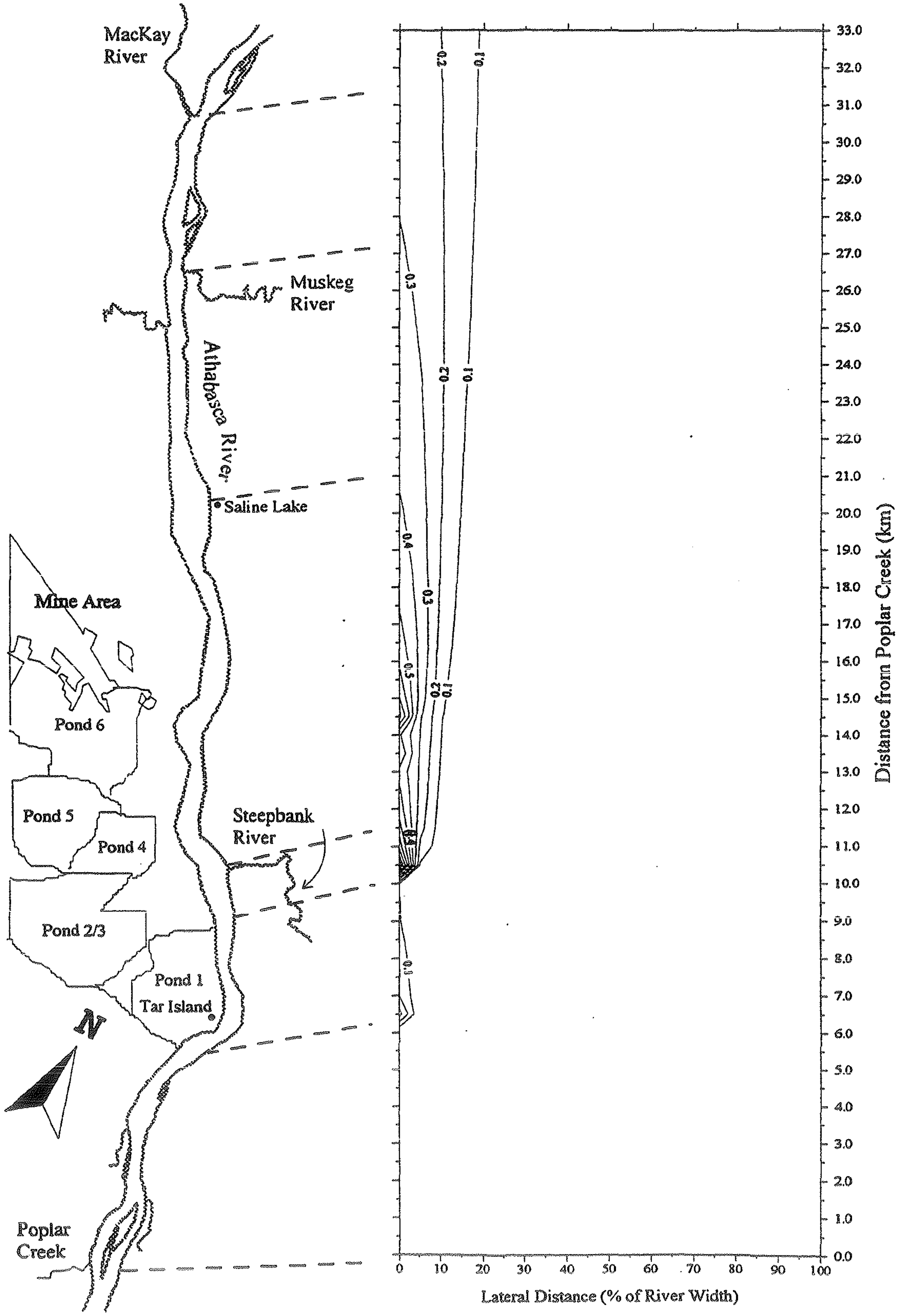


Figure VI-56 Simulated Athabasca River Chronic Toxicity (TUc) - Year 2020 Scenario River Flow of 115 cms



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