Impact Analysis of Human Health Issues Associated with the Steepbank Mine

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TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

APPENDICES

A INTRODUCTION

This report is one of a series that addresses potential human health, environmental and socio-economic impacts of Suncor Inc., Oil Sands Group's (Suncor) Steepbank Mine project and reclamation of Suncor's existing leases (Figure A-1). Specifically this report addresses potential impacts on people arising from construction, operation, extraction/upgrading and reclamation activities related to the Steepbank Mine and/or reclamation of Suncor's existing mine.

This impact assessment is based on testing specific hypotheses of potential impacts of the project on people's health and safety. In particular, three groups of people were considered. One group consists of workers on the site that might be exposed to chemicals, noise and/or other physical site hazards (e.g., heavy equipment). A second group includes people who live, work or engage in recreational activities recreate near Suncor's operations and who may be affected by air and water emissions that are not contained on-site. A third group includes those people who might use the existing mined-out areas following closure and reclamation. The interrelationship of the impact hypotheses investigated in the human health study is presented in Table A-1.

The remainder of this report outlines the impact assessment framework, describes the existing environmental characteristics that are pertinent to the impact assessment, presents the results of the impact analysis and discusses proposed activities to monitor and test specific impact predictions.

TABLE A-1
STEEPBANK MINE EIA IMPACT HYPOTHESES SUMMARY LIST

SOCIO-ECONOMIC	
1	The Steepbank Mine Project will contribute additional local, provincial and national benefits through additional employment, the procurement of goods and services required for the project and the payment of local, provincial and national taxes and royalties.
2	Construction-related activities and employment and the associated temporary increase in population will result in increased demands on services and infrastructure within the Regional Municipality of Wood Buffalo.
3	Operations-related employment and the associated increase in population will result in increased demands on services and infrastructure within communities in the Regional Municipality of Wood Buffalo.
4	The social stability and quality of life of communities within Wood Buffalo will be maintained as a result of the continued operation of the Suncor project, through development of the Steepbank Mine.
5	The Steepbank project will contribute to a loss in the traditional resource base of the Fort McKay community and displace some traditional activities.
6	The cumulative demands from the Suncor, Solv-Ex and Syncrude projects combined with the expected demands from existing populations within the Municipality will result in increased demands on local communities and affect the quality of life of those communities.
HUMAN HEALTH	
7	The health and well being of people who live, work or engage in recreational activities within the study area may be affected by changes to Athabasca and Steepbank River water quality caused by water releases resulting from extraction, processing and reclamation of oil sands from Suncor's existing and proposed mines.
8	The health and well being of people who live, work or engage in recreational activities within the study area may be affected by air emissions resulting from extraction, processing and reclamation of oils sands from Suncor's existing or proposed mines.
9	The health and well being of people who live, work or engage in recreational activities within the study area may be affected by cumulative exposure to chemicals associated with water and air emissions from Suncor's activities and other developments within the regional study area.
10	The health of people who in the future may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine may be affected by release of chemicals from the reclaimed landscapes.
11	The health and safety of Suncor employees may be affected by development and operations of the Steepbank Mine and related facilities.
TERRESTRIAL	
12	Valued Ecosystem Components in the Athabasca River valley could be affected by the development, operation and reclamation of the Steepbank Mine and Lease 86/17.
13	Existing and future use of the area's landscapes could be limited by the development, operation and reclamation of the Steepbank Mine and Lease 86/17.
14	Visual integrity of the Athabasca River Valley could be affected by the development, operation and reclamation of the Steepbank Mine and Lease 86/17.
15	Biodiversity could be affected by the development, operation and reclamation of the Steepbank Mine and Lease 86/17.

16	Peatlands could be affected by Lease 86/17 and Steepbank Mine development and operation, including mine dewatering, changes to subsurface drainage, and reclamation release water.
17	Air emissions from the Suncor operation could have an impact on vegetation and soils, as well as aquatic environments.
WILDLIFE	
18	Mine development will result in changes in the availability and quality of wildlife habitat which will bring about a reduction in wildlife populations
19	Disturbance associated with mechanical noise and human activity may result in reduced abundance of wildlife.
20	Direct mortality of wildlife caused by mine development could result in reduced abundance of wildlife.
21	Mine development will disrupt the movement patterns of wildlife in the vicinity of the Steepbank Mine, thereby reducing access to important habitat or interfering with population mechanisms, resulting in decreased abundance of wildlife.
22	Mine development could cause a reduction in wildlife resource use (hunting, trapping, non-consumption recreational use).
23	Development of the Steepbank Mine could contribute to a loss of natural biodiversity.
SURFACE AND GROUNDWATER RESOURCES	
24	Flows in the Athabasca and Steepbank Rivers could be significantly changed by mine development withdrawals for extraction, upgrading and/or reclamation
25	Ice jams, floods or other hydrological events could cause structure damage and flooding of facilities that will result in subsequent impacts to hydrological/aquatic systems and downstream uses.
26	Navigation along the Athabasca River could be affected by bridge construction.
27	Groundwater quality could be affected by contaminant migration from processing and extraction activities.
AQUATIC RESOURCES	
28	Construction, operational or reclamation activities might adversely affect aquatic habitat in the Steepbank River.
29	Construction, operational or reclamation activities might adversely affect aquatic habitat in the Athabasca River.
30	Water releases associated with construction, operational or reclamation activities might adversely affect aquatic ecosystem health in the Athabasca or Steepbank Rivers.
31	Water releases associated with construction, operational or reclamation activities might adversely affect the quality of fish flesh.
32	Construction, operational or reclamation activities might lead to changes in aquatic habitat and/or aquatic health which might result in a decline in fish abundance in the Athabasca or Steepbank Rivers.
33	Construction, operational or reclamation activities might lead to changes in fish abundance or quality of fish flesh which might result in a decreased use of the fish resource.
34	Construction, operational or reclamation activities might cause changes in Athabasca River water quality which limit downstream use of the water.

AIR	
35	Global climate change could be affected by increased release of greenhouse gases associated with production expansion related to the Steepbank Mine.
HISTORICAL RESOURCES	
36	Significant archaeological, paleontological or historical resources could be affected by the development and operation of the Steepbank Mine.

B STUDY BOUNDARIES

For any assessment of this type, it is essential to define boundary conditions, both spatial and temporal, that provide a context in which to base the analysis. Spatial boundaries for worker safety issues are restricted to the areas directly controlled by Suncor, i.e., existing and future mine and plant sites. Similar boundaries are applicable for evaluation of potential health impacts for people who might use the reclaimed lands. With respect to people who might be exposed to off-site water and air emissions, the Local Study Area has been defined to include an area immediately surrounding Suncor's leases (Figure B-1). This boundary includes sections of the Athabasca and Steepbank Rivers where worst-case water quality conditions apply, i.e., before significant mixing and decay processes act to reduce chemical concentrations in the rivers.

Suncor is one of several existing or proposed developments that may potentially affect the health of people who live, work or recreate in the region, primarily through changes in water or air quality associated with emissions from these developments. For example, a number of upstream municipalities and pulp and paper mills discharge wastewater to the Athabasca River, and other existing and proposed oil sands developments may also contribute to water quality and air quality issues in the region. Hence, the Regional Study Area was defined to encompass cumulative impacts from other significant developments in the region, such as air emissions from Syncrude's existing plant site and water emissions from the proposed Aurora Mine (Figure B-2).

In addition to spatial boundaries, it is essential to define temporal boundaries for this assessment. Four discrete time periods are included in this assessment: 1995 (present/baseline), 1997-2000 (construction), 2000-2020 (operation) and a long-term, post-reclamation period. These time periods were selected because each one includes unique conditions that may affect people's health. For example, 1995 represents baseline conditions prior to development of the Steepbank Mine and, thus, is indicative of existing conditions associated with Suncor's current operations. From 1997-2000 much of the construction activity for the Steepbank Mine will take place. The 2000-2020 time period represents the operational phase of the mine. Finally, long-term represents conditions expected following mine closure and complete reclamation of the existing mines, plant site and the Steepbank Mine.

C METHODS

The approach followed in this assessment is based on:

- Defining pertinent issues of concern to stakeholders;
- Developing impact hypotheses that describe the mechanisms through which project activities may affect human health;
- Collecting and analysing data to evaluate the hypotheses; and
- Quantifying the degree of concern of the potential impacts.

C1.0 IDENTIFICATION OF ISSUES

Identification of pertinent issues is the critical first step in conducting an assessment of potential impacts of the new mine development on the health and safety of people. Issues that are pertinent to stakeholders were identified from two separate activities:

- Public meetings and workshops for the general public and government regulators; and
- Review of historical data and reports pertinent to the study area.

Issues pertaining to human health identified during these workshops, from ongoing consultations with stakeholders and from review of pertinent reports are summarized in Table C1.0-1.

TABLE C1.0-1
RESPONSE TO ISSUES ON STAKEHOLDER DATABASE

Throughout the planning for the Steepbank Mine, stakeholders were invited to express their concerns about the project. Below is a listing of the issues that have been raised that are related to human health and how the concerns will be addressed. In most cases, the issue will be investigated in an Impact Hypothesis in the EIA document. A list of those Impact Hypothesis is attached. In other cases, Suncor is responding through other mechanisms (e.g., Aboriginal Affairs Policy), or the information is included in the project description and operating plan chapters of the Application.

ISSUE	IMPACT HYPOTHESIS	CORRESPONDING SECTION IN HUMAN HEALTH IMPACT ANALYSIS
SOCIO-ECONOMIC, HUMAN HEALTH AND HISTORICAL RESOURCES CONCERNS		
What are the project's implications to human health?	7, 8, 9, 10, 11	Section F
Studies must be tied into health studies, include health risks.	7, 8, 9, 10, 11	Section D
Concerns for human health from consumption of fish.	7, 9	Section D1.0
AQUATICS, SURFACE AND GROUNDWATER		
Is mercury a concern in fish?	7	Section D1.0
What will be the effects resulting from discharge of mine drainage water (i.e., water quality, flows); effects of water discharge from facilities (e.g., camp, plant runoff, extraction, upgrading); effects of shop/maintenance facility to water quality in wetlands, effects of sewage and garbage disposal, landfill contamination, storage and disposal of fuel, cleaners, run-off from sizers/surge bin/conveyors?	7, 10, 15, 16, 28, 29, 30, 31, 32	Section D1.0, D4.0
AIR QUALITY		
Will there be impacts from fugitive dust from coke piles, overburden dumps and tailings ponds?	8	Section D3.0
Air studies must be tied into human health.	8, 9	Section D2.0, D3.0
Particulates and heavy metals need to be addressed (e.g., $_{NH}(_{SOL})_2$).	8, 9	Section D2.0, D3.0

C2.0 DEVELOPMENT OF IMPACT HYPOTHESIS

As noted above, most issues related to human health pertain directly or indirectly towards changes in water or air quality. These issues can be subdivided into five primary categories that form the impact hypotheses for the human health assessment:

Hypothesis 7: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by changes to Athabasca and Steepbank River water quality caused by water releases resulting from extraction, processing and reclamation of oil sands from Suncor's existing and/or proposed mines.

Hypothesis 8: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by air emissions resulting from extraction, processing and reclamation of oil sands from Suncor's existing and proposed mines.

Hypothesis 9: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by cumulative exposure to chemicals associated with water and air emissions from Suncor's activities and other developments within the regional study area.

Hypothesis 10: The health of people who, in the future, may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine may be affected by release of chemicals from the reclaimed landscapes.

Hypothesis 11: The health and safety of workers may be affected by development and operation of the Steepbank Mine and related facilities.

Note that these impact hypotheses are presented as statements that assume the impacts occur and are tested to determine which issues are real and which are not. Development of testable hypotheses for evaluating the potential impacts of the mine life-cycle on human health requires:

1. Review of mine operations and development plans so that pertinent activities can be identified.

2. Development of linkage diagrams that illustrate how the mine operations and development activities are connected to the issues of concern.

3. Development of testable hypotheses to assess effects of mine operation and development activities on measurable endpoints.

A detailed description of mine operation and development plans is given in Section C of Suncor's Steepbank Mine Application.

The primary linkages among mine operations and development activities, modes of impact and the impact hypotheses are shown in Figure C2.0-1. The general approach followed in assessing potential impacts was to first confirm that a linkage exists or might exist between the mine activity (e.g., release of refinery wastewaters or fugitive air emissions) and mode of impact (e.g., change in river or air quality). Testable hypotheses were then developed to test whether changes in the modes of impact might affect human health. For instance, for the impact hypotheses related primarily to chemical exposures (Impact Hypotheses 7-10), the source emissions were first characterized and ambient concentrations in pertinent environmental media (water, air, soils, plants and/or animals) were measured and/or modelled. These ambient concentrations were then compared to health-based levels to identify those chemicals that might pose a potential risk to people's health and/or to identify data deficiencies. This information was then used to define degree of concern.

C3.0 DATA COLLECTION AND ANALYSIS

A large database of historical data and technical reports was reviewed and incorporated, where appropriate, into this assessment. The primary sources of pertinent information include:

- Air and water quality monitoring reports prepared by Alberta Environmental Protection;

- Water and fish quality studies completed for Northern River Basins Studies;
- Air and water quality monitoring reports and other technical reports prepared by Suncor and Syncrude;
- Human health studies completed for Syncrude's 1993 Expansion Application; and
- Industrial Hygiene Survey reports for Suncor's operations (1990 - 1996).

In addition, a number of specific data collection activities were carried out in 1995 to further document existing (baseline) conditions and to provide information for testing the hypotheses discussed above.

The primary reports prepared for Suncor's Steepbank Mine Application in which pertinent data for this human health assessment are presented and synthesized include:

- Air Emissions Impact Analysis (Bovar 1996a)
- Air Emissions Source Characterization (Bovar 1996b);
- Ambient Air Quality Observation (Bovar 1996c);
- Air Quality Modelling (Bovar 1996d);
- Steepbank Mine Baseline Aquatics Study (Golder 1996a);
- Aquatics Impact Analysis (Golder 1996b);
- Athabasca Water Releases Impact Assessment (Golder 1996c); and
- Suncor Reclamation Landscape Performance Assessment (Golder 1996d).

All work conducted for the Suncor Environmental Impact Assessment was carried out under a detailed Quality Assurance Project Plan (QAPP). The QAPP is presented in a separate document (Golder 1995a) and specific details are provided in appendices to the reports listed above.

C4.0 DEFINING DEGREE OF CONCERN

Selecting appropriate criteria for defining and quantifying the degree of concern of potential impacts is an important component of the assessment. For this assessment, degree of concern is based exclusively on whether or not the activity might adversely affect human health. Degree of concern was based on quantitative criteria for Hypothesis 7 (impacts associated with water emissions) and 10 (impacts associated with use of reclaimed landscape), since, for these hypotheses, risk assessments were used to quantify potential impact. In particular, Exposure Ratios (ER) form the basis for defining degree of concern. Exposure Ratios are commonly used to assess health risks and are an expression that compares the predicted daily rate of intake for a chemical or group of chemicals (typically based on worst-case, protective assumptions) to a reference dose (i.e., dose of chemical that is safe over a long-term; Health Canada 1995, U.S. EPA 1989). 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 1 per 100,000 ($1x10^{-5}$), which does not pose a significant health risk to exposed individuals (Health Canada 1995). Values greater than one represent scenarios that pose a potential concern. However, since many conservative factors are typically used to derive both the intake rates and the reference doses, the ER estimates will tend to overestimate the potential for risk. This is consistent with a protective approach to risk evaluation. Thus, an ER value of greater than one indicates a potential health concern that needs to be further evaluated to identify the reason for the elevated ER; this may lead to additional data collection to more accurately quantify risks. Hence, degree of concern has been defined as follows:

Nil ER $\leq$ 1 and no data gaps.

Low No ER because of lack of data, although enough evidence to suggest that exposure unlikely to adversely affect health; additional information necessary to support this conclusion.

Moderate ER > 1, with mitigating factors that would likely result in exposures or toxic pathways to be less than used in the ER calculations, but additional information needed to support this conclusion.

High ER > 1, without mitigating factors; hence exposure has potential to adversely affect people's health.

For the impact hypotheses where ERs were not computed, the degree of concern was defined as follows:

Nil No increase over background health impacts is probable and conclusion defensible based on existing information.

Low Health impact unlikely but additional information needed to confirm this conclusion.

High Activity has potential to affect people's health or insufficient information to draw any firm conclusions.

The attributes listed above are defined for each impact hypothesis.

D IMPACT HYPOTHESES

D1.0 OFF-SITE HEALTH IMPACTS ASSOCIATED WITH WATER RELEASES

Hypothesis 7: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by changes to Athabasca and Steepbank River water quality caused by water releases resulting from extraction, processing and reclamation of oil sands from Suncor's existing and/or proposed mines.

D1.1 VALIDITY OF LINKAGE BETWEEN ACTIVITY AND MODE OF ACTION

Figure D1.0-1 shows the linkages among mine life-cycle activities, mode of action and the primary impact hypothesis. As noted in this figure, there are four primary activities that might result in changes to river water quality that might subsequently affect human health: (1) discharge of operational waters, (2) release of reclamation waters, (3) accidental releases and (4) changes in surface and subsurface flow patterns. These activities potentially result in changes to river water quality and fish tissue quality, thereby creating potential concerns for people using water and/or fish from the Athabasca or Steepbank Rivers. The validity of the linkage between these activities and mode of actions are described below.

D1.1.1 Operational Waters (Link 1)

The Oil Sands Water Release Technical Working Group (OSWRTWG) which consisted of government and industry representatives, was established in 1995 to evaluate the issue of releases of water from oil sands operations to the Athabasca River. OSWRTWG (1996) classed water releases into two groups: operational and reclamation waters. Operational waters are those 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:

- consolidated tailings (CT);
- drainage water collected from dykes and structures;
- mine drainage;
- upgrading process - Wastewater Treatment system;
- cooling water; and
- sewage treatment facility.

An overview of the quality of these waters is given in Table I-1 (see Appendix I). Levels of trace organics (PAHs), naphthenic acids and some metals are considerably higher in some of these waters than in either the Athabasca or Steepbank Rivers. An overview of the discharge volumes from these sources is given in Table D1.0-1 and the location of the discharge points shown in Figure D1.0-2. Given the elevated concentrations for some chemicals noted in operational waters plus the numerous discharges to the Athabasca River, there is potential that operational discharges will affect the water quality of the Athabasca River. There are, however, no plans to discharge any operational waters to the Steepbank River. Thus a link between release of operational waters and changes in water quality exists for the Athabasca River but not the Steepbank River. The linkage between operational water releases and potential changes in water quality will extend over the operational life of the plant.

D1.1.2 Reclamation Waters (Link 2)

Reclamation waters are defined according to OSWRTWG (1996) as those waters that are:

- non-point source diffuse waters, which may be directed through wetlands, streams or lakes prior to discharge into the Athabasca or Steepbank River;
- 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);

TABLE D1.0-1

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.

- not amenable to conventional end-of-pipe licensing requirements; and
- primarily an on-site water management system and a component of a maintenance-free reclamation landscape.

Sources of reclamation waters include surface runoff and ground water seepage from:

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

An overview of water quality of these waters compared to natural surface waters is given in Appendix I, Table I-1. Levels of trace organics (PAHs), naphthenic acids and some metals are considerably higher in some reclamation waters than in either the Athabasca or Steepbank Rivers, particularly in the case of dyke drainage water and CT release water. An overview of the discharge volumes from these sources is given in Table D1.0-1 and locations of the discharge points shown in Figure D1.0-2. With the exception of very low volumes of CT drainage waters, no reclamation waters will flow into the Steepbank River. However, the changes in Steepbank River concentrations associated with CT drainage waters is negligible (Golder 1996b), thus, the focus of this assessment was directed towards the Athabasca River. The linkage between release of reclamation waters and changes in Athabasca River water quality will extend well into the future, as a result of long-term leaching of chemicals from reclamation soils.

D1.1.3 Accidental Releases (Link 3)

Three types of accidental releases need to be considered with respect to impacts on the aquatic environment:

- catastrophic releases related to failure of an engineered structure, e.g., breaching of a tailings dyke;
- spills associated with hydrotransport, pipeline transport, or accidents on the bridge or barge; and

- releases related to upset conditions, e.g., flooding of storage ponds, failures in the wastewater treatment system.

a) Catastrophic Releases

In the more than thirty years of lease operations, Suncor has maintained the stability of all retention structures including tailing dykes, waste dumps and other facilities. These structures have been designed and operated to accepted Canadian standards for fluid retention structures, and the design and safe operating conditions have been supported by an extensive monitoring program and reviewed by independent review boards and regulatory agencies. In the very unlikely event of a major instability, Suncor has developed an Emergency Response Plan which would provide warning to those who may be affected.

In addition, the stability of all structures will improve with time due to two important factors. Firstly, the removal of fluid-like mature fine tails and the replacement with consolidated tailings will assist in improving stability. Secondly the pore water pressures in the foundation and other elements of the structure will slowly decrease with time further increasing stability from the already acceptable conditions. When the removal of fine tailings and the infilling of the ponds is complete, these structures are no longer fluid retention structures. In addition, the seismic activity of this region is very low; thus the long term stability of all lease components with respect to earthquake considerations is also assured. A detailed discussion of the stability of existing and reclamation landforms is given in Suncor's Steepbank Mine Application.

b) Spills

Spills associated with hydrotransport and pipeline transport across the bridge, accidents on the bridge or barge and construction activities in or near watercourses could potentially affect river water quality. Several types of materials will be piped across the bridge: slurried oil sands prior to extraction, mine tailings, natural gas, diesel fuel and hot water. Shop facilities will include storage areas for diesel fuel, gas and oil. Hence the most likely types of spills associated with hydrotransport, pipeline activities and shop facilities are from petroleum products.

Several features have been incorporated into the bridge design and into the design of the shop facilities to prevent and contain spills. The bridge is designed with a solid bridge deck below the pipes and a containment curb that will contain spills. Also, a gradient away from the centre of the river (i.e., to each bank) would direct a spill to shoreline containment structures that are designed to contain the entire volume of the pipelines. Since the most likely place a pipe will burst is at the joints, a steel ring enclosure shroud is placed around each pipe joint to prevent spray into the river should the pipe burst. Also, in the event of a breakage, isolation valves at each end of the bridge ensure that the maximum volume released from the pipes would be the volume contained in the portion of the pipeline that extends across the bridge. As well, mitigation measures to prevent spills will be followed during nearshore and instream construction (see Golder 1996b for details of these mitigation measures).

Shop facilities will also have features to prevent contamination of surface water. The shop facilities will have an independent surface water drainage system which will collect and contain surface runoff and sediment. Also, areas with high potential for contamination such as fuel islands, will have individual collection systems.

c) Upset Conditions

The potential for flooding of the Steepbank Mine drainage system is discussed in detail in Klohn-Crippen (1996). There is a possibility of flooding during the construction phase (1997 to 2001) prior to completion of Dyke 10 construction. The Mine Drainage System (Basins A, B, C and D) is designed to accommodate the 1 in 10 year annual runoff. This storage capacity is large enough to contain a 1 in 100 year flood (Klohn-Crippen 1996). Thus, overflow of storage basins would only occur under runoff conditions in excess of the 1 in 100 year flood or the 1 in 10 year annual runoff. Overflow of storage basins A, B and C flows into the Athabasca River, whereas overflow from Basin D flows into Shipyard Lake. In 2005, when Dyke 10 is complete, overflow can be diverted into Pit 1. Thus, flooding would only occur under extreme conditions (runoff in excess of the 1 in 100 year flood) during the early stages of mine development (1997 to 2005).

Suncor has undertaken numerous activities to prevent or mitigate any unauthorized water releases or contamination of surface water or groundwater from the existing plant site. These activities are outlined in detail in Suncor's 1996 Fixed Plant Expansion Project Approval Application (Section 9.4).

In summary, the potential for accidental releases to the Athabasca River is low given the features discussed above. In the event of an accidental release, Suncor's Environmental Management Plan provides a protocol for dealing with these events. Suncor has a fully trained in-house emergency response team and specialized equipment for handling oil spills. Mutual aid agreements with

Fort McMurray and Syncrude provide immediate additional backup should it be necessary. Hence, given the low probability of accidental releases of chemicals coupled with Suncor's emergency response time, this pathway has been excluded from further investigation.

D1.1.4 Changes in Surface and Subsurface Flow Patterns (Link 4)

As noted above there will be a number of different sources of operational and reclamation waters that will be released to the Athabasca and/or Steepbank Rivers. In addition, changes in natural drainage patterns and/or hydraulic gradients may potentially affect the volumes of water in the Athabasca and Steepbank Rivers. This in turn has the potential to affect water quality because of changes in dilution and mixing of chemicals within the rivers. However, the total volumes of Suncor's operational and reclamation waters that may be released to the Athabasca River are small relative to flow conditions in the river. For example, current flows from the wastewater effluent (1995: 0.33 m^3/s; Table D1.0-1) are only 0.3% of 7Q10 flows (the lowest mean flow over a seven day-period that occurs, on average, once every ten years: 114 m^3/s; Noton and Shaw 1989) and only 0.05% of mean annual flows (667 m^3/s; Environment Canada 1991). Similarly, the sum of all other operational and reclamation water releases (0.68 m^3/s; Table D1.0-1) are only 0.6% of 7Q10 flows and only 0.1% of mean annual flows. Hence, the linkage between changes in river flow rates and potential changes in river water quality does not exist.

D1.1.5 Changes in Water Quality (Link 5)

The primary mode of action in which all of the above activities are expressed is the potential for changes in water quality in the Athabasca and Steepbank Rivers. Given the wide range in both water quality and discharges from operational and reclamation water, the cumulative loads from these and other upstream and future sources need to be accounted for in the predictions of changes in river water quality.

Two different approaches were used to identify whether water emissions from Suncor's facilities might adversely affect human health:

- A wasteload allocation study was completed to in accordance with Alberta Environmental Protection (1995) guidelines to identify specific chemicals that might affect human health.

- A human health risk assessment was conducted in accordance with Health Canada (1995) guidelines to identify specific chemicals that might affect human health and to quantify the risks to human health associated with exposure to those chemicals.

a) <u>Wasteload Allocation Study</u>

Details of the wasteload allocation analysis are given in Golder (1996c) and summarized below. 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 wasteload allocation study identified three parameters as potential health issues: arsenic, benzo(a)anthracene, and total polycyclic aromatic hydrocarbons (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 D1.2. 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.

b) <u>Risk Assessment - Chemical Screening</u>

In addition to the wasteload allocation, a quantitative risk analysis was conducted to determine which chemicals might pose a risk to people. This study is presented in Golder (1996c) and summarized here. Risk assessment provides a much more thorough analysis of potential health issues than the wasteload allocation approach. The first step in the analysis was to conduct a thorough screening of chemicals associated with the operational and reclamation waters to identify chemicals that need further analysis.

A number of protective assumptions were incorporated into the screening process to ensure that the chemicals eliminated from further analysis pose no incremental risk to human health over that from exposure to naturally-occurring levels of these chemicals.

The chemical screening process followed a methodical, step-wise process as shown schematically in Figure D1.0-3 and outlined below. It is based on the screening protocol suggested by Health Canada (1995).

Step 1: Water quality data were collected, evaluated and appropriate concentrations were selected for the screening process. For this assessment, the maximum concentrations that have been measured in pertinent operational and reclamation water were used as a conservative estimate of the chemical concentrations released to the Athabasca River. Six types of wastewaters were screened here: Suncor refinery wastewater, cooling Pond E water, mine drainage water, dyke drainage water, CT release water and Plant 4 drainage water (Appendix I, Table I-1). These waters represent the major groups of water that are currently released, or might in the future be released to the Athabasca River.

Step 2: Human health criteria were compiled from various published sources and used to identify Screening Level Criteria (SLC). For drinking water, the published health-based criteria included Health and Welfare Canada (HWC 1993), U.S. Environmental Protection Agency (U.S. EPA as cited in CRWQCB 1995); and B.C. Environment (BCE 1994). The lowest values of the above criteria were selected as the SLC for chemicals in drinking water.

Step 3: Observed background concentrations for the Athabasca River were compared to the SLC (as defined in Step 2) to determine the relevance of regulatory criteria for this site. If the observed maximum background concentrations were greater than the SLC, then the applicability of the criterion was reviewed.

Step 4: Each chemical identified in Step 1 and measured at concentrations above the analytical detection limit was compared to the SLC. If the maximum recorded concentration did not exceed the SLC, then the chemical was removed from further consideration. Chemicals that were not measured above analytical detection limits were not included in the screening process. Detection limits for chemicals that were excluded at this step were all below health-based criteria.

Step 5: If measured concentrations exceeded SLCs in Step 4, then the concentrations were compared to background concentrations within the Athabasca River. If the maximum chemical concentrations measured for the release waters site were less than or equal to the maximum concentrations measured in Athabasca River, then these chemicals were assumed to be natural in origin and typical of the area and were removed from further analysis.

Step 6: If the measured release water concentrations exceeded background concentrations in Step 5, then release water concentrations were compared to risk-based concentrations (RBCs). The list of chemicals for which RBCs are defined is more extensive than for SLCs. These RBCs were set at levels at which no adverse effects would be expected for a person drinking water containing that level of chemical, on a daily basis over a long-term period. If the RBC was not exceeded, then the chemical was eliminated from further consideration.

Step 7: If a chemical did not have an RBC or exceeded the RBC in Step 6, the chemical was evaluated as to its importance as a dietary component, status as an essential nutrient or general lack of toxic effects. If the chemical was considered to be a required nutrient or essentially non-toxic, it was eliminated from further evaluation. Otherwise, it was retained.

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

- 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).
- The SLC were based on published criteria that are designed to prevent any adverse health effects.
- If no SLC was available for a chemical, it was retained and carried forward to the next chemical screening step.

- RBCs were based on conservative exposure scenarios (e.g., assumed people drink the water and or eat the fish 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 do not necessarily pose a risk to people's health. Further analysis is needed to determine if these chemicals pose a health risk. Based on this screening, the following chemicals were identified as ones that required more detailed investigation with respect to people that might drink water from the Athabasca River downstream of Suncor's operations:

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

Hence, a linkage exists between discharge of operational and reclamation waters and changes in Athabasca River water quality for the chemicals listed above. This linkage may extend well into the future as a result of long-term loading from reclamation waters. 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.

D1.1.6 Changes in Fish Tissue Quality (Link 6)

A combined field and laboratory study was completed to address the question as to the potential for accumulation of chemicals in fish flesh. These data are given in Golder (1996a) and HydroQual (1996), synthesized and analyzed in Golder (1996c), and summarized below.

Walleye (*Stizostedion vitreum*), goldeye (*Hiodon alosoides*) and longnose sucker (*Catostomus catostomus*) were collected as part of the 1995 baseline aquatics study (Golder 1996a). Walleye and goldeye were captured in the Athabasca River near Suncor and longnose sucker were captured as they moved up the Muskeg River (a tributary to the Athabasca River) to spawn. All three species spend part of the open water season in the vicinity of Suncor. Composite (by sex and species) samples of fish fillets were analyzed for organic chemicals and metals (Appendix I, Table I-2). Samples from longnose sucker contained trace concentrations of naphthalene (0.02 to 0.04 μg/g) and methylnaphthalene (<0.02 to 0.03 μg/g); however, other PAHs were not detectable (detection limits range from 0.02 to 0.04 μg/g). No PAHs were detected in walleye and goldeye samples. Levels of trace metals in fish tissue were generally low. However, the mercury level in the walleye sample (0.45 μg/g) was only marginally below the 0.5 μg/g Health and Welfare Canada (1995) guideline for fish consumption.

Uptake of oil sands-related chemicals into fish tissue was also investigated during a laboratory fish health study where juvenile walleye and rainbow trout (*Oncorhynchus mykiss*) were exposed to a variety of waters, including a dilution series of water collected from the Tar Island Dyke drainage system (0.1 to 10% strength), laboratory control water and Athabasca River water collected upstream of Suncor. The fish were exposed to these waters in a flow-through system for 28 days, sacrificed and their tissues analyzed for PAHs and trace metals (HydroQual 1996). PAH concentrations in juvenile walleye and rainbow trout were below detection for nearly all chemicals; naphthalene and methyl naphthalene levels in rainbow trout were at or just above the detection level in both control and treatment samples (0.02 to 0.03 μg/g; Table I-2). Levels of most metals were generally below detection limits in both treatment and control samples. The only notable exceptions were for arsenic and mercury where concentrations of <0.1-2.3 μg/g and 0.03-0.45 μg/g, respectively, were measured. However, the highest concentrations were associated with control fish exposed to the Athabasca River. Thus, no significant accumulation of PAHs or metals (relative to detection limits or levels in control fish) is indicated by either laboratory exposure of fish to Tar Island Dyke water or from fish captured in the Athabasca River. A comparable study is currently underway (spring 1996) using Suncor's refinery wastewater to confirm the lack of bioaccumulation of organic compounds and metals associated with exposure of fish to this source of water. It should be noted that there may be changes in fish flesh quality with respect to chemicals that create off-flavours in fish flesh, and these chemicals might be present at concentrations below analytical detection limits. Although tainting is an important issue from the perspective of use of the fish resource, it is not a health issue. Therefore, the potential for tainting of fish flesh is discussed in the Aquatic Impact Analysis (Golder 1996b).

Notwithstanding the lack of evidence of accumulation of chemicals in fish tissue, a chemical screening was conducted on the data presented above to determine whether ingestion of fish from the Athabasca River might potentially pose a hazard to people's health. The chemical screening process followed essentially the same screening protocol as for drinking water (Figure D1.0-3) and is outlined in detail in Golder (1996d). Based on this analysis, no chemicals of concern were identified in fish tissues that could be attributed to Suncor's operations. However, as noted above, 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).

As noted in the discussion of water quality changes, the results of a separate AEP screening protocol based on a wasteload allocation approach indicated that arsenic poses a potential hazard for people who might eat fish from the river. However, there is no direct evidence either from the 1995 field study or the 28-day laboratory study that arsenic is accumulating in fish flesh as a result of Suncor's operations. The laboratory study currently underway will provide data on potential for arsenic accumulation associated with exposure to Suncor's refinery wastewater effluent.

In summary, Suncor's release waters do not appear to contribute to increases in chemical concentrations in fish within the Local or Regional Study Area. Hence, a linkage between changes in fish tissue quality associated with Suncor's operations and risks to human health does not exist.

D1.2 TEST OF IMPACT HYPOTHESIS

A human health risk assessment was conducted to quantify risks to human health associated with exposure to the chemicals of concern identified above related to water emissions from Suncor's existing and proposed operations (Golder 1996c). This assessment focused on pertinent pathways in which people using the Athabasca River, immediately downstream of Suncor's operations, might be exposed to these chemicals, i.e., through drinking water or direct contact activities such as swimming. Five time periods were examined: existing (1995), 2001, 2010, 2020 and post-reclamation.

The following analysis considered the cumulative impacts associated with all existing upstream sources (municipal and pulp mill effluent plus non-point sources such as runoff from agricultural lands) and future oil sands developments proposed by Syncrude and Solv-Ex. The contribution from existing upstream sources was directly accounted for by data collected from the Athabasca River, immediately upstream of Suncor. It was assumed that these existing data also provide a reasonable estimate of future background conditions, given that the chemicals identified above are primarily associated with oil sands deposits and no oil sands projects have been proposed upstream of the Steepbank Mine.

Future oil sands developments might contribute additional loads of PAHs and naphthenic acids to the river downstream of Suncor. However, both Solv-Ex and Syncrude's Aurora mine developments are on the east side of the river and water release from those developments will be along that side of the river. In contrast, most of Suncor's existing and future water releases are along the west side of the river. However, the Athabasca River takes more than 100 km to fully mix from bank to bank, and there will be little contribution from potential releases associated with other oil sands operations on concentrations in the mixing zone (Golder 1995b). Thus, maximum concentrations will still occur in the mixing zone immediately below all of Suncor's discharges and concentrations will decrease with distance downstream of Suncor because of lateral mixing and degradation processes.

The drainage plan for Syncrude's proposed water-capped, fine-tails lakes (Base Mine and North Mine) involves discharge of water through wetlands into the old Beaver River channel and ultimately into the Athabasca River well downstream of Suncor. However, these lakes have retention times in the order of tens of years, thus natural degradation processes are expected to keep levels of these compounds low, e.g., predicted long-term concentrations of naphthenic acids range from 100 to 1,000 μg/L and concentrations of phenanthrene range from 0.005 to 0.01 μg/L (EMA 1993). Concentrations of benzo(a)anthracene and benzo(a)pyrene have not been estimated for these lakes, however concentrations of these PAHs in fine tails are only about 2 to 20% of phenanthrene concentrations (Golder 1994). Since consolidation of fine tails is the primary source of these chemicals within the lakes, it is reasonable to conclude that levels of benzo(a)anthracene and benzo(a)pyrene in water that is ultimately released to the Athabasca River will be even lower than that predicted for phenanthrene. Further, benzo(a)anthracene and benzo(a)pyrene are less soluble in water than phenanthrene. Even so, a value of 0.005 μg/L was assumed for concentrations of these PAHs from this source of water.

Table D1.0-1 gives flow rates and Appendix I, Table I-1 supplies concentrations for all water releases. A river mixing model, which is described in Golder (1996c) was used to predict concentrations in the Athabasca River at two locations; one immediately below all of Suncor's discharges and the other further downstream below the discharge point from Syncrude's reclaimed landscape (Figure D1.0-2). The predicted concentrations for the chemicals of interest are given in Table D1.0-2. These river concentrations provide exposure point concentrations for estimating chemical doses to current and future users of the river.

Risk analysis involves two major components: (1) estimating the daily intake rate (dose) of a chemical to a person under a given exposure scenario and (2) determining the reference value or intake rate at which the health of sensitive individuals is protected. Exposure Ratios (ERs) are then 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.

Two scenarios were evaluated related to exposure to Athabasca River water: recreational use and swimming in the river at the two locations shown in Figure D1.0-2. 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. 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). The equations used to calculate intake rates are summarized in Table D1.0-3 and chemical-specific input data given in Table D1.0-2.

TABLE D1.0-2

CHEMICAL-SPECIFIC EXPOSURE PARAMETERS FOR WATER RELEASE SCENARIOS

Chemical	Water Concentrations[1] (mg/L)					Dermal Permeability Const.[2], Kp (m/hr)	Reference Values[3] (mg/kg BW/day)	Reference Value Effects
	1995	2001	2009	2020	Long-Term			
Benzo(a)anthracene	0.000012	0.0000034	0.0000081	0.0000085	0.00000062	0.0081	0.000014	stomach tumors
Benzo(a)pyrene	0.0000017	0.0000010	0.0000009	0.0000016	0.00000093	0.012	0.0000014	stomach tumors
Naphthenic Acids	0.24	0.20	0.28	0.59	0.36	–[4]	–[4]	–[4]
Molybdenum	0.013	0.011	0.013	0.014	0.013	0.00001	0.005	painful joints, increased uric acid
Vanadium	0.0053	0.000077	0.0035	0.0031	0.00042	0.00001	0.007	growth, serum cholesterol

[1] Predicted upper 95 percentile concentrations in the Athabasca River, immediately downstream of Suncor's operations (Golder 1996c).

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

[3] Dose below which adverse effects on human health are not expected to occur (see Golder 1996c for details).

[4] Dermal permeability, reference values and associated effects are not available for naphthenic acids.

TABLE D1.0-3
EQUATIONS FOR ESTIMATING INTAKE RATES

Pathway	Equation and Equation Parameters
SWIMMING RECEPTORS	
Dermal Exposure	$$EDI_{dermal} = \frac{SA x C_{water} x K_p x ET x ED x 10^{-3} L/m^3}{BW x AT}$$
	EDI_{dermal} = dermal intake while swimming (mg/kg-BW/day) C_{water} = water concentration (mg/L) SA = surface water available for contact while swimming (m^2) K_p = permeability constant in water (chemical-specific; metre/hour) ET = total time of exposure event (hours/event) EF = frequency of exposure events (events/year) ED = duration of exposure (years) BW = body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)

Pathway	Equation and Equation Parameters
Water Ingestion	$EDI_{water} = \frac{C_{water} R_{water} x ET x ED x EF x BA_{ing}}{BW x AT}$
	EDI_{water} = incidental water consumption while swimming (mg/kg-BW/day) C_{water} = water concentration (mg/L) R_{water} = water ingestion rate (L per hour) ET = time of exposure (hours/event) EF = frequency of exposure (events per year) ED = duration of exposure (years) BA_{ing} = bioavailability of ingested chemicals (chemical-specific, unitless) BW = body weight (kg) AT = averaging time (ED for noncarcinogens; 70 years for carcinogens)
RECREATIONAL RECEPTOR	
	$EDI_{water} = \frac{C_{water} R_{water} x ED x EF x BA_{ing}}{BW x AT}$
	EDI_{water} = intake from water consumption (mg/kg-BW/day) C_{water} = water concentration (mg/L) R_{water} = water ingestion rate (L/day) EF = frequency of exposure (events per year) ED = duration of exposure (years) BA_{ing} = bioavailability of ingested chemicals (chemical-specific, unitless) BW = body weight (kg) AT = averaging time (ED for noncarcinogens; 70 years for carcinogens)

Reference values are daily exposure rates that could occur over the 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).* Reference values for chemicals that are not carcinogenic and exhibit a dose-response threshold (i.e., effects only occur after a particular minimum dose is exceeded) are usually based on a No-Observable-Adverse-Effect-Level (NOAEL) from animal studies divided by an uncertainty factor. This calculation produces a the Reference Dose (RfD), below which no adverse effect is expected in people. 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 = 1×10^{-5}/chemcial-specific slope factor).

An RfD was calculated for molybdenum and vanadium, and RsDs were calculated for benzo(a)anthracene and benzo(a)pyrene. To date, there are insufficient mammalian toxicological data to calculate a defensible RfD for naphthenic acids. 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.

A series of protective assumptions was incorporated into the assessment to ensure that the final risk estimates would not underestimate health risks. All input parameter values for the dose equations were biased in a way that tends to overestimate the calculated values. Concentrations were based on the upper 95 percentile of modelled levels (Table D1.0-2) (Golder 1996c). Exposures were assumed to occur within the mixing zone, immediately downstream of Suncor's water releases as well as 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 of 100%. Exposure parameters for people (i.e., body weight, body surface area, etc.) are summarized in Table D1.0-4 and were based on values recommended by Health Canada (1994).

Exposure ratios for each scenario and for each time period are shown in Table D1.0-5. 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; M. MacKinnon, Syncrude Research, pers. comm.), 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; M. MacKinnon, Syncrude Research, pers. comm.). 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.

TABLE D1.0-4

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 (1992).
[3] Golder (1996c).

TABLE D1.0-5

EXPOSURE RATIOS FOR THE WATER RELEASE SCENARIOS

Scenario	Chemical	Adult ER[1]	Child 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

TABLE D1.0-5

EXPOSURE RATIOS FOR THE WATER RELEASE SCENARIOS

Scenario	Chemical	Adult ER[1]	Child ER[1]
	benzo(a)pyrene	0.005	0.001
	naphthenic acids	--	--
	molybdenum	0.02	0.05
	vanadium	0.003	0.008
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.

D1.3 HYPOTHESIS IMPACT CLASSIFICATION

D1.3.1 Degree of Concern

Based on the information presented above, one can conclude that the health and well being of people who live, work or engage in recreational activities within the study area is very unlikely to be affected by water releases associated with Suncor's existing and/or proposed mines. However, there is some uncertainty with this conclusion because of the lack of mammalian toxicological data for naphthenic acids and lack of direct information on bioaccumulation of chemicals in fish exposed to Suncor's refinery wastewater. Hence, the degree of concern is rated as low, i.e., incomplete data for certain chemicals although enough evidence to suggest that exposure is unlikely to adversely affect health.

D1.3.2 Certainty

The assessment of potential impacts to users of the Athabasca River was based on a number of highly protective assumptions. The protective assumptions related to chemical screening are discussed in Section D1.2. These assumptions provide assurances that no chemicals were excluded from the screening step except those that clearly pose no incremental risk to people's health. Risk calculations were done deterministically to provide single value estimates of Exposure Ratios; however, a significant degree of uncertainty is associated with most ER values. To ensure that this assessment yields a sufficiently protective answer in light of this uncertainty, the assessment was based on protective input values. Hence, the actual risks to people's health will likely be even lower than those suggested by ER estimates, and may in fact be as low as zero because of the multiple protective assumptions as outlined below:

- exposure point concentrations were set at the upper 95 percentile of concentrations measured (existing conditions) or predicted (future conditions) for the Athabasca River, immediately downstream of all of Suncor's water releases;
- exposure location was set within the mixing zone, downstream of all potential water emissions;
- exposure parameter values represent reasonable maximum exposure values;

- bioavailability was set to a maximum of 100%; and
- reference values were set to be protective of sensitive subpopulations under chronic exposure conditions.

As such, there is a high degree of confidence in the results of the assessment with the exception of three potential issues:

- lack of a reference value for naphthenic acids;
- lack of information on bioaccumulation of chemicals in fish exposed to Suncor's refinery wastewater; and
- possible interactions in chemicals mixtures (e.g., additive and synergistic effects).

As noted above, it is unlikely that either of the first two issues will affect the conclusions presented above. Even so, studies have been initiated to address these issues.

With respect to chemical mixtures, interactions may occur that may increase or decrease toxic effects. For example additive effects occur when the combined effect of chemicals are equal to the sum of each agent alone; this is believed to be the most common type of chemical interaction (Health Canada 1995). Synergistic effects occur when the combined effect of chemicals are greater than the sum of each agent alone. In contrast, antagonistic effects occur when chemicals interfere with each other thereby decreasing adverse effects associated with each chemical acting separately. Because of the complexity of these interactions, the potential for these interactions are rarely taken into account in risk assessments. We have, however, explicitly incorporated the potential for additive effects among PAHs by grouping PAHs into functional groups based on those with similar molecular structure and modes of toxicity (Golder 1996c). In addition, the conservative nature of both the screening and risk estimates serve to provide additional protection against possible toxicological interactions among other chemicals.

D1.3.3 Cumulative Impacts

This assessment was based on taking into account all current upstream sources (i.e., all pulp mills, municipal effluents and non-point discharges) and proposed developments such as Solv-Ex and Syncrude that might contribute to cumulative impacts to human health. In particular, upstream developments are accounted for directly by measuring water quality in the Athabasca River immediately upstream of Suncor. Both Solv-Ex and Syncrude's proposed Aurora mine are located on the opposite side of the river from most of Suncor's discharges, so they will not contribute to increased concentrations within Suncor's mixing zone (where maximum in-stream concentrations are expected). Release water associated with reclamation from Syncrude's existing leases may contribute an additional load to the Athabasca River from the old Beaver River channel, and this extra load was accounted for in the simulation of post-reclamation conditions. Thus, the above conclusions have taken into account future oil sands developments.

D2.0 OFF-SITE HEALTH IMPACTS ASSOCIATED WITH AIR EMISSIONS

Hypothesis 8: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by air emissions resulting from extraction, processing and reclamation of oil sands from Suncor's existing and proposed mines.

D2.1 VALIDITY OF LINKAGE BETWEEN ACTIVITY AND MODE OF ACTION

Figure D2.0-1 shows the linkages among mine life-cycle activities, mode of action and the primary impact hypothesis. As noted in this figure, there are five primary sources of air emissions: mining, extraction, plant operations, fugitive sources and reclamation. These sources potentially contribute to changes in off-site air quality. The validity of the linkage between these activities and mode of actions are described below.

D2.1.1 Mining (Link 1)

Oil sands are mined using shovels and trucks and the mined oil sands are carried to the extraction plant by a conveyor belt system. Sources of emissions associated with mining include:

- pre-mine slash burning;
- diesel fuel combustion from mine vehicle exhausts;
- mine vehicle traffic;

- vents from the hydrotransport system;
- volatilization of hydrocarbons from freshly exposed bitumen/oil sands; and
- wind erosion from mine surfaces.

The primary emissions derived from these sources include NO_x, CO, HC and CO_2 and PM_{10} (Table D2.0-1) (Abbreviations are defined in Section H). With the exception of CO_2, these constituents may potentially affect human health, so a linkage exists between mining activities and changes in off-site air quality.

TABLE D2.0-1
SUNCOR SOURCE-EMISSION MATRIX

Source	Emission							
	SO_2	H_2S	TRS	NO_x	CO	HC	CO_2	PM_{10}
Mining								
Mine surfaces						✓		✓
Mine equipment								✓
Mine equipment exhausts	✓			✓	✓	✓	✓	✓
Extraction								
Extraction plant			✓			✓		
Vapour recovery unit						✓		
South tank farm						✓		
Tailings pond		✓	✓			✓		
Upgrading								
Incinerator stack	✓		✓	✓	✓		✓	
Secondary combust. stacks	✓			✓	✓	✓	✓	✓
Hydrocarbon flares	✓			✓	✓	✓	✓	
Acid gas flare	✓						✓	
North tank farm						✓		
Fugitive emissions			✓			✓		
Utilities								
Powerhouse stack	✓			✓	✓	✓	✓	✓
Coke storage	✓				✓			✓

D2.1.2 Extraction (Link 2)

Bitumen is separated from the oil sands by the Clark hot water process. The water and sand mixture (which contains unrecovered bitumen) is disposed of in tailings ponds; and the bitumen/diluent mixture is transported to upgrading facilities and stored in the south tank farm area. Sources of emissions associated with extraction include:

- vents from the primary extraction plant;
- vents from the froth treatment plants;
- naphtha recovery unit stack;
- vents from the tank farm; and
- ponds.

The primary emissions derived from these sources include SO_2, H_2S, TRS, NO_x, CO, HC and CO_2 (Table D2.0-1). With the exception of CO_2, these constituents may potentially affect human health, so a linkage exists between extraction activities and changes in off-site air quality.

D2.1.3 Plant Operations (Link 3)

Sources of emissions associated with the upgrading of bitumen to various crude oil products and with the utilities facilities have been documented by BOVAR (1996a). The major sources include the main stack that services the sulphur recovery plant and boilers associated with the utility operations, vents from process heaters, the flare systems and the powerhouse stack. The primary emissions derived from these sources include SO_2, TRS, NO_x, CO, HC, CO_2 and PM_{10} (Table D2.0-1). With the exception of CO_2, these constituents may potentially affect human health, so a linkage exists between plant operational emissions and changes in off-site air quality.

D2.1.4 Fugitive Emissions (Link 4)

Sources of fugitive emissions include:

- process piping, valves, joints;
- leaks, upset conditions, breaks, flares;

- open processing systems;
- maintenance or change-out operations that enter closed systems; and
- coke and sulphur storage

Fugitive emissions that are involved with normal site operations are usually included in occupational health and industrial hygiene monitoring programs and will be discussed further in Section D4.0.

Fugitive emissions from normal operating conditions are usually not considered a major contributor to off-site exposures because they are diluted and dispersed within a short distance of the site (in this case well before reaching populous areas). However, fugitive emissions from upset or emergency conditions may not be sufficiently diluted or dispersed before reaching populous areas. Therefore, a linkage exists between fugitive emissions and changes in off-site air quality.

D2.1.5 Reclamation (Link 5)

Future sources of emissions from the reclaimed landscape include:

- windborne particulates from CT deposits and tailings sand structures and
- volatilization of hydrocarbons from CT deposits.

However, there is little potential for either of these sources to affect off-site air quality. The primary source of chemicals of potential concern in the reclaimed landscape are associated with CT deposits (mixture of fine tails, tailings sand and gypsum). The potential for erosion by wind will be extremely low since the CT deposits will be capped with a layer of sand and muskeg and then reclaimed with a variety of plants. Atmospheric release of volatile organic carbons from CT deposits is expected to be lower than from existing tailings ponds since:

- water in the existing tailings ponds are exposed directly to the atmosphere whereas CT deposits are buried and over time the water table will decline substantially;
- effective transfer to air of chemicals absorbed to soils is limited unless mediated by pore water, thus the depth of the water table is an important factor controlling transfer of chemicals from soil to water to air;

- diffusion and biodegradation processes will occur in the unsaturated zone (i.e., zone within the soil surface down to the water table) of the CT units, which will reduce concentrations of volatile chemicals prior to release to the atmosphere; and
- volatile organics in the CT deposits will be depleted over time as a result of volatilization and biodegradation, hence, emissions from the CT deposits will continuously decline over time.

As discussed below in Section D2.2, it is unlikely that emissions of VOCs from the existing tailings ponds adversely affect off-site air quality. Since emissions from CT deposits will be even lower than from existing tailings ponds, it is reasonable to conclude that a linkage will not exist between the reclaimed landscape and off-site air quality. Potential health implications associated with use of the reclaimed landscape are discussed in Section D 4.0.

D2.1.6 Changes in Air Quality (Link 6)

Ambient air quality data in the local and regional study areas are summarized by BOVAR (1996c) and predicted changes associated with air emissions projected for Suncor, Syncrude and Solv-Ex are given in BOVAR (1996a).

A number of major facility improvements over the next five years have been initiated to reduce air emissions such that:

- SO_2 emissions will decrease to 22% of current levels;
- NOx emissions will decrease to 97% of current levels;
- VOC emissions will decrease to 31% of current levels; and
- particulates from source emissions will decrease to 22% of current levels.

Thus, for these parameters off-site air concentrations will decline from current conditions.

D2.2 TEST OF IMPACT HYPOTHESIS

From a human health perspective, the chemicals that are of most interest are those associated with VOC and particulate emissions. Off-site chemical speciation data for VOCs and particulates 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 Risk-Based Concentrations (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 D2.0-2). 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 engage in recreational activities 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 air-borne 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 exisiting 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 from 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.

TABLE D2.0-2

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 ($\mu g/m^3$)
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

TABLE D2.0-2

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 ($\mu g/m^3$)
Thiophene	15.9	170	8	4.7	-
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 (1996c).

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

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

- 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 that 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 sands are representative of relative concentrations in the 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 D2.0-3.
- Compare predicted, worst-case exposure concentrations to Risk-Based Concentrations (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 (TableD2.0-3). As is evident from Table D2.0-3, predicted concentrations are considerably lower than RBCs. Considering the multiple protective assumptions 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.

TABLE D2.0-3

PREDICTED DUST AIR CONCENTRATIONS COMPARED TO RISK-BASED CONCENTRATIONS

Chemical	Concentration[1] in Tailings sand (mg/kg)	Predicted Concentration in Air (µg/m^3)	EPA Risk-Based[2] Concentration (air) (µg/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).

D2.3 HYPOTHESIS IMPACT CLASSIFICATION

D2.3.1 Degree of Concern

In summary, there are indications that suggest that Suncor's air emissions pose little health risk, at least with respect to volatile organics and particulates generated by dust. However, there are insufficient data to fully assess health risks associated with off-site exposure. Hence, degree of concern during the operational phase of the mine-life cycle is rated as low, i.e., health impact unlikely but additional information needed to confirm this conclusion. Since a linkage will not exist between the reclaimed landscape and off-site air quality, degree of concern following reclamation is rated as nil.

D2.3.2 Certainty

There is uncertainty associated with the conclusion about off-site health impacts because of the lack of chemical-specific data for VOCs and particulates at probable off-site exposure points. However, a monitoring program is under design to collect these data. These data can then be compared to risk-based concentrations to determine whether off-site exposures currently pose an unacceptable risk to people's health.

In addition, the Alberta Oil Sands Community Exposure and Health Effects Assessment Program ("Regional Community Health Study") is currently in the protocol development stage and will be initiated later in 1996 under the direction of Alberta Health. This program will collect information to provide a baseline for the health status of area residents with respect to air quality.

With respect to future operational conditions, the process changes, upgrades and control systems currently being installed or planned for installation as part of the expanded or new operations at Suncor are reducing and will continue to reduce SO_2, NO_x, particulates and VOCs emissions. These changes will all reduce Suncor's contribution to the off-site airshed, and thus will reduce potential exposures of people living off-site to Suncor's emissions. Reducing the potential of exposure also reduces the associated health risk.

D2.3.3 Cumulative Impacts

The conclusions presented above are based on existing data plus predicted changes associated with air emissions projected for Suncor, Syncrude and Solv-Ex. Thus, the primary oil sands sources that are presently contributing or in the future might contribute to regional air quality issues are accounted for in this assessment.

D3.0 OFF-SITE CUMULATIVE EXPOSURES

Hypothesis 9: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by cumulative exposure to chemicals associated with water and air emissions from Suncor's activities and other developments within the Regional Study Area.

D3.1 VALIDITY OF LINKAGE BETWEEN ACTIVITY AND MODE OF ACTION

Figure D3.0-1 shows the linkages among mine life-cycle activities, mode of action and the primary impact hypothesis. As noted in this figure, the health of people who live, work or engage in recreational activities within the study area may be potentially affected by the cumulative exposure to both water and air emissions arising from Suncor's developments and other existing and proposed developments in the region.

D3.1.1 Water Emissions (Link 1)

As discussed in detail in Section D1.1, a linkage exists between water emissions and changes in river water quality.

D3.1.2 Air Emissions (Link 2)

As discussed in detail in Section D2.1, a linkage exists between air emissions and changes in off-site air quality during the operational phase of the mine life-cycle, but not following reclamation.

D3.1.3 Water Quality (Link 3)

As discussed in detail in Section D1.1, five parameters associated with water emissions from Suncor's facilities pose a potential hazard to human health:

- benzo(a)anthracene group,
- benzo(a)pyrene group,
- naphthenic acids;
- molybdenum; and
- vanadium.

D3.1.4 Fish Tissue Quality (Link 4)

As discussed in detail in Section D1.1, no chemicals associated with Suncor's wastewater bioaccumulate in fish tissues to concentrations that pose a hazard to human health or to levels greater than in fish exposed to Athabasca River water. Thus, there is no linkage between release of Suncor's wastewaters and health impacts associated with consumption of fish from the Athabasca River.

D3.1.5 Air Quality (Link 5)

As discussed in Section D2.1, it is unlikely that concentrations of VOCs from plant operations or PAHs associated with dust-generated particles pose a health hazard with respect to off-site exposure. Data collected near Suncor's plant are required to validate this conclusion and to provide chemical-specific data from other sources of particulates (e.g., utilities and upgrading facilities).

D3.2 TEST OF IMPACT HYPOTHESIS

As noted above, it is unlikely that concentrations of VOCs in air at off-site locations are present at levels that pose a health hazard. Concentrations of VOCs in water emissions are also low and these chemicals do not bioaccumulate in fish tissue. Thus, it is unlikely that the cumulative exposures to VOCs from breathing air, drinking and/or swimming in river water and eating fish from the river will affect people's health, even for people who might live, work or engage in recreational activities immediately adjacent to Suncor's leases.

Thus, the potential for health impacts from cumulative exposure would likely be restricted to those chemicals associated with air-borne particulate matter that might also be present in Suncor's water emissions. Of primary interest are PAHs and metals. Chemical-specific air quality data are required at probable off-site exposure locations before health risks from multiple exposure can be quantified. However, given the extremely low risks calculated for water-based exposure to these chemicals and probable low risks associated with air-based exposures, exposure to multiple pathways for these chemicals does not likely pose a significant health risk.

With respect to naphthenic acids, data for this group of chemicals are restricted to water samples. They are considered non-volatile (Morales et al. 1993) so inhalation of air vapours is probably an insignificant pathway for this group of chemicals. In addition, they are present as highly soluble sodium salts in tailings pond, e.g., concentrations in tailings pond water are greater than 100 mg/L (FTFC 1995). Naphthenic acids also have a low affinity to lipids as compared to hydrophobic chemicals such as PAHs: e.g., log K_{ow} at pH 8 is only 2.0 for naphthenates (M. MacKinnon, Syncrude Research, 1995 pers. comm.) compared to 3.7 to 7.0 for PAHs (Moore and Ramamoorthy 1984). Hence, naphthenates are unlikely to be stored in fish flesh or present at high concentrations in soils, so exposure via ingestion of fish flesh or inhalation of dust particles are not expected to be important off-site exposure pathways for this group of chemicals.

D3.3 HYPOTHESIS IMPACT CLASSIFICATION

D3.3.1 Degree of Concern

Based on the discussion presented above it is unlikely that cumulative exposure from both air and water poses an unacceptable risk to people's health. Thus, the degree of concern associated with this hypothesis is rated as low, i.e., unlikely to affect people's health but additional information needed to confirm this conclusion.

D3.3.2 Certainty

The qualifications associated with the above conclusion are comparable to those associated with conclusions pertaining to off-site health impacts from water and air emissions. The additional data collection activities discussed in Section D1.3.2 and D2.3.2 will provide the information necessary to confirm the conclusion that cumulative exposure from both air and water poses no risk to people's health.

D3.3.3 Cumulative Impacts

The conclusions presented above are based on existing data plus predicted changes associated with water and air emissions projected for Suncor and other proposed oil sands facilities. Thus, the existing and proposed facilities that might contribute to regional water and air quality issues are accounted for in this assessment.

D4.0 USE OF RECLAIMED LANDSCAPE

Hypothesis 10: The health of people who in the future may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine may be affected by release of chemicals from the reclaimed landscapes.

D4.1 VALIDITY OF LINKAGE BETWEEN ACTIVITY AND MODE OF ACTION

Figure D4.0-1 shows the linkages among activities, mode of action and the primary impact hypothesis. As noted in this figure, there are three primary modes of action in which chemicals from the reclaimed areas might be released to the environment: release of reclamation waters, exposure of reclamation materials, and fugitive air emissions from the reclaimed site. In turn, these pathways may potentially affect the quality of environmental media (water, soil, food, air) to which people may be exposed (Figure D4.0-2).

The following assessment is based on a number of assumptions:

- The analysis conducted here is based on reclamation plans for Suncor's existing Leases 86 and 17; however, a similar reclamation concept is being applied to the Steepbank Mine so that the findings also apply to the Steepbank Mine;
- Nearby oil sands mining activities have stopped, so water or air emissions from extraction or processing of oil sands do not contribute to exposure of people who might use the reclaimed landscape;

- Suncor's plant site has been decommissioned and reclaimed and poses no hazard to peoples' health;
- Access to the reclaimed landscapes will be controlled until stable and self-sustaining plant communities have been established;
- The end land use for the site is based on the assumption that it might be used for activities such as hunting, gathering and trapping.

A detailed human and ecological risk assessment of the reclaimed landscape was performed by Golder (1996c) and is summarized below.

D4.1.1 Reclamation Waters (Link 1)

The primary sources of reclamation waters that will be affected by oil sands processing are (Figure D4.0-2):

- Exfiltration water is associated with consolidation of CT deposits and will contain elevated concentrations of organics and inorganic chemicals compared to natural surface waters in the region (Table I-1). However, consolidation rates decline over time, so that the rate of evapotranspiration is expected to exceed the rate of water expressed during consolidation within tens of years following filling (L. Sawatsky, AGRA, pers. comm). Hence, in the longer-term this pathway will cease to exist.
- Surface runoff will be the primary pathway for transport of water from the reclaimed landscape to the Athabasca River. Surface runoff water will be derived from two primary sources: exfiltration water and precipitation falling directly onto the reclaimed landscape (i.e., rainfall and snowmelt). As noted above, exfiltration water is expected to affect surface runoff quality for only a relatively short period of time following reclamation. Thus, over the longer term the primary source of surface runoff water will be from precipitation. Given the precipitation will be isolated from the CT deposits by a capping layer of sand, muskeg and vegetation, it is unlikely that significant amounts of chemicals will be leached from the subsurface CT deposits. In addition, all surface runoff will be routed through a series of wetlands prior to discharge to the Athabasca River, where biodegradation and other processes within the wetlands will act to reduce chemical levels prior to discharge to the river.

- Groundwater will ultimately be the largest single pathway for transport of process-affected waters to the Athabasca River. In particular, groundwater derived from CT deposits and tailings dykes will seep into wetlands along the base of these structures and also directly into the Athabasca River.

Hence, a linkage exists between release of waters from the reclaimed landscape, primarily via groundwater seepage, and changes in river water quality.

D4.1.2 Reclamation Deposits (Link 2)

The reclamation plans for Suncor's operations are described in detail in Section D of the Steepbank Mine Application. Two types of reclamation materials will be associated with the reclaimed landscape: (a) consolidated tailings and (b) tailings sand (Figure D4.0-2). Consolidated tailings form the subsurface deposit for reclamation of most mined-out pits and is formed from fine tails that have been stabilized through gypsum and sand treatments. Consolidated tailings will be placed in mined-out pits and capped with a layer of sand and muskeg and then reclaimed with a variety of plants. The CT will consolidate within a reasonable time into a trafficable surface, which can be shaped and reclaimed to form the base for a healthy ecosystem. It is, therefore, unlikely that people will be exposed directly to CT. Tailings sand form the dykes surrounding some of the CT pits and will be similarly reclaimed. Hence, there will be no linkage between buried reclamation deposits and chemical concentrations in surficial soils of the reclaimed landscapes.

D4.1.3 Air Emissions (Link 3)

Potential sources of air emissions from the reclaimed landscape include (Figure D4.0-2):

- volatilization of hydrocarbons from CT and tailings sand deposits; and
- windborne particulates from the reclamation structures.

The proposed capping scheme should prevent wind erosion from CT or tailings sand structures. As discussed in detail in Section D2.1, volatilization of hydrocarbons from reclaimed CT deposits is expected to be considerably lower than for the existing tailings ponds and will decline over time. Even so, hydrocarbons will be released to the atmosphere via volatilization, although the emission rates and expected effect on air quality have not yet been assessed. Hence, a possible linkage exists between air emissions and potential changes in air quality of the reclaimed landscape.

D4.1.4 Drinking Water Quality (Link 4)

Potential sources of drinking water associated with the reclaimed landscape include groundwater, surface water associated with wetlands, snow and nearby rivers and streams such as the Athabasca River. Groundwater derived from tailings sands deposits was excluded as a source of drinking water since the associated hydrocarbon odours would deter potential users. In addition, CT deposits are of low permeability so it is unlikely that they would produce sufficient quantities of water. Wetlands are expected on sections of the top of CT deposits and also along sections of the base of the reclamation structures. However, these wetlands are expected to be intermittently dry and stagnant and would not offer good quality water considering the potential for anoxia, warm temperatures and naturally-occurring pathogens. Snow is a potential source of good quality water but only during winter. Thus, it was assumed that the primary source of drinking water would be from the Athabasca River, since it offers a constant and accessible source of water near the reclaimed landscape.

A quantitative risk analysis was conducted to determine whether any chemicals present in drinking water might pose a risk to people's health. The chemical screening process followed the conservative, step-wise process previously described in Section D1.1. Based on this screening, the following chemicals were identified as ones that need to be investigated in more detail with respect to people drinking water from the Athabasca River adjacent to the reclaimed landscape:

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

Hence, a linkage exists between discharge of reclamation waters and changes in Athabasca River water quality for the chemicals listed above.

D4.1.5 Food Quality (Link 5)

Potential food items for traditional land users of the reclaimed landscapes include numerous herbs, berries, shrubs, water tolerant plants, trees, big game animals, fur-bearers, migratory and predatory birds, upland game birds and fish (Fort McKay Environment Services Ltd. 1996).

Mammals and birds exposed to the reclamation deposits may accumulate certain chemicals, thus providing an exposure pathway for people who might eat wild game. Limited tissue data are available from bison pastured on tailings sand and ducks and muskrat exposed to CT release water within wetlands. These data were screened in an analogous manner to that described in Section D1.1 for water. The results of that screening indicated that additional analysis was required for only two metals:

- copper
- manganese

Thus, these chemicals were retained and analyzed as part of the quantitative risk assessment.

Plants might potentially accumulate process-affected chemicals via root uptake, particularly those plants with roots that might penetrate through the capping soils into the CT deposits. There are limited data from laboratory and field experiments that suggest that wetlands and terrestrial plants grown directly in CT soils accumulate concentrations of metals to levels slightly above plants grown in control soils (Xu 1995, 1996). However, it is expected that this pathway will be effectively eliminated for most plants by the proposed capping sequence using sand and muskeg. Even so, for the purpose of this assessment it was assumed that plants are a potential exposure pathway to people using the reclaimed site. Chemical screening was not done on these plant data since appropriate control data were not collected.

D4.1.6 Soil Quality (Link 6)

It is unlikely that people will be directly exposed to CT since these deposits will be buried below a capping layer of sand, muskeg and vegetation. Therefore, soil concentrations that people will be exposed to will be comparable to natural background levels; hence incidental ingestion of soils will not be a significant source of process-affected chemicals to end users of the site and was eliminated from further consideration in this assessment.

D4.1.7 Air Quality (Link 7)

As noted above, there is potential for release of volatile chemicals through the ground and into the air above CT deposits. There are insufficient data to test whether this exposure route poses any health risks to people. However, during 1996 Suncor intends to create a CT reclamation demonstration site. This site will provide opportunities to directly monitor air emissions from a reclaimed CT landscape so that potential effects on air quality can be assessed.

D4.2 TEST OF IMPACT HYPOTHESIS

A risk assessment was conducted to evaluate risks from exposure of people to chemicals associated with the reclaimed landscape. The risk assessment framework that was used is consistent with approaches developed by Environment Canada (1994), Health Canada (1995) and U.S. EPA (1994). Details of the assessment are given in Golder (1996d) and the findings are summarized below.

The risk assessment was completed for the chemicals identified above from the chemical screening of water and food:

- benzo(a)anthracene group;
- benzo(a)pyrene group;
- naphthenic acids;
- copper,
- manganese; and
- molybdenum.

Benzo(a)anthracene and benzo(a)pyrene are classified as carcinogens and copper, manganese and molybdenum are classified as noncarcinogens. Although naphthenic acids were identified as a chemical of concern, there is currently insufficient toxicity information with which to assess health hazards (see Section D1.2).

It was assumed that people might be exposed to these chemicals via three routes:

- drinking water collected from the Athabasca River at a point immediately downstream of all reclamation water discharge points;
- eating plants gathered on the site and assuming that these plants were growing directly in CT; and
- eating wild game harvested on the site.

It was further assumed that an adult trapper would be the end user receiving the highest exposure to the reclaimed site. In particular, it was assumed that the hypothetical trapper would:

- reside on the site 365 days/year;
- live on the site from ages 20 to 70 (51 years);
- obtain 25% of all food (both meat and plants) directly from the site; and
- obtain all drinking water from the Athabasca River.

The equations used to calculate intake rates are summarized in Table D4.0-1 and input values given in Table D4.0-2. Protective assumptions used in these calculations of intake rates included:

- exposure point concentrations for drinking water were set at the upper 95 percentile for predicted concentrations in the Athabasca River, immediately downstream of water releases from the reclaimed landscape;
- chemical concentrations in plant tissues were based on upper 95 percentile values recorded from plants grown directly in CT;
- exposure parameter values were set to represent reasonable maximum exposure values; and
- bioavailability was set to a maximum of 100%.

Exposure Ratio (ER) values are summarized in Table D4.0-3. Exposure Ratios are defined in Section D1.2; value of less than one represents exposure scenarios that do not pose a significant health risk to exposed individuals while values greater than one represent scenarios that pose a potential concern and require further investigation (Health Canada 1995).

Pathway	Equation and Equation Parameters
RECREATIONAL RECEPTOR	
Plant Ingestion	$$EDI_{plant}=\frac{C_{plant}R_{plant}xEDxEFxSCxBA_{ing}}{BWxAT}$$
	EDI_{plant} = estimated daily intake from plant ingestion (mg/kg-BW/day) C_{plant} = plant concentration (mg/kg) R_{plant} = plant ingestion rate (kg/day) EF = frequency of exposure (events per year) ED = duration of exposure (years) BA_{ing} = bioavailability of ingested chemicals (chemical-specific, unitless) BW = body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)
Meat Ingestion	$$EDI_{meat}=\frac{C_{meat}R_{meat}xEDxEFxSCxBA_{ing}}{BWxAT}$$
	EDI_{meat} = estimated daily intake from plant ingestion (mg/kg-BW/day) C_{meat} = plant concentration (mg/kg) R_{meat} = plant ingestion rate (kg/day) EF = frequency of exposure (events per year) ED = duration of exposure (years) BA_{ing} = bioavailability of ingested chemicals (chemical-specific, unitless) BW = body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)

TABLE D4.0-1
EQUATIONS FOR ESTIMATING INTAKE RATES FOR RECLAIMED LANDSCAPE

Pathway	Equation and Equation Parameters
Water Ingestion	$$EDI_{water} = \frac{C_{water} R_{water} x ET x ED x EF x BA_{ing}}{BW x AT}$$
	EDI_{water} = estimated daily intake from water consumption (mg/kg-BW/day) C_{water} = water concentration (mg/L) R_{water} = water ingestion rate (L per hour) EF = frequency of exposure (events per year) ED = duration of exposure (years) BA_{ing} = bioavailability of ingested chemicals (chemical-specific, unitless) BW = body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)

TABLE D4.0-2

EXPOSURE PARAMETERS FOR RECLAMATION LANDSCAPE SCENARIO

Parameter	Value	Source
Exposure Parameters		
Body Weight (kg)	70	Health Canada (1994)
Water Ingestion Rate (L/d)	1.5	Health Canada (1994)
Site Contribution (unitless)	1.0	For drinking water
Meat Ingestion Rate (kg/d)	0.183	Health Canada (1994)
Plant Ingestion Rate (kg/d)	0.436	Health Canada (1994)
Site Contribution (unitless)	0.25	For meat and plants
Exposure Frequency (events/year)	365	Golder (1996d)
Exposure Duration (years)	50	Golder (1996d)
Averaging Time- Non-carcin. (years)	50	Golder (1996d)
Averaging Time- Carcinogens (years)	70	Health Canada (1994)
Drinking Water Concentrations (mg/L)		
Benzo(a)anthracene/Chrysene	0.00000062	Predicted Athabasca River Concentrations (Golder 1996c)
Benzo(a)pyrene	0.00000093	Predicted Athabasca River Concentrations (Golder 1996c)
Naphthenic Acids	0.36	Predicted Athabasca River Concentrations (Golder 1996c)
Copper	0.0090	Predicted Athabasca River Concentrations (Golder 1996c)
Manganese	0.24	Predicted Athabasca River Concentrations (Golder 1996c)
Molybdenum	0.013	Predicted Athabasca River Concentrations (Golder 1996c)
Concentrations in Meat (mg/kg)		
Benzo(a)anthracene/Chrysene	0	Bison liver tissue (Pauls et al. 1995)
Benzo(a)pyrene	0	Bison liver tissue (Pauls et al. 1995)
Naphthenic Acids	--	No data available
Copper	52.4	Bison liver tissue (Pauls et al. 1995)
Manganese	12.4	Bison liver tissue (Pauls et al. 1995)
Molybdenum	4.7	Bison liver tissue (Pauls et al. 1995)
Concentrations in Plants (mg/kg)		
Benzo(a)anthracene/Chrysene	0.025	Predicted concentrations (Golder 1996d)
Benzo(a)pyrene	0.0046	Predicted concentrations (Golder 1996d)
Naphthenic Acids	--	No data available
Copper	7.28	Willow and poplar tissue (Xu 1995 and 1996)
Manganese	234	Willow and poplar tissue (Xu 1995 and 1996)
Molybdenum	8.05	Willow and poplar tissue (Xu 1995 and 1996)

TABLE D4.0-3

EXPOSURE RATIOS FOR THE RECLAMATION LANDSCAPE SCENARIO

Chemical	Reference Value[1] (mg/kg BW/day)	Adult		Exposure Limit Effect
		Total Dose[2] (mg/kg-BW/day)	ER[3]	
benzo(a)anthracene	0.000014	0.000028	2.0	stomach tumors
benzo(a)pyrene	0.0000014	0.0000051	3.7	stomach tumors
naphthenic acids	--	0.0055	--	no exposure limit has been set
copper	0.04	0.033	0.8	gastrointestinal irritation
manganese	0.145	0.38	2.6	CNS effects
molybdenum	0.005	0.016	3.2	painful joints, increased uric acid

1 Dose below which adverse effects on human health are not expected to occur (see Golder 1996c for details).

2 Calculated daily intake rates as outlined in Table D4.0-1

3 For non-carcinogens, exposure ratio = Intake rate / exposure limit. For carcinogens, exposure ratio = risk / acceptable risk.

The exposure Ratio value for copper is below one, therefore, this chemical 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. Even so, as noted in Section D1.2, it is unlikely that exposure to copper poses a health risk at the low levels predicted for the scenario assessed here.

Exposure Ratio values were slightly greater than one for the other chemicals. These relatively high values are attributable primarily to ingestion of plants. However, it is probable that this exposure pathway will be effectively eliminated by the proposed capping sequence using sand and muskeg. In addition, because this assessment was based on multiple conservative assumptions, the actual health risks are likely to be considerably lower than those suggested by the ER values and may be as low as zero. Notwithstanding these mitigating factors, ER values above one indicate that intake of plant food from the reclaimed landscape is an issue that requires further scrutiny.

D4.3 HYPOTHESIS IMPACT CLASSIFICATION

D4.3.1 Degree of Concern

Based on the information presented above, one can conclude that the health and well being of people who in the future may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine is not likely to be affected by release of chemicals from the reclaimed landscapes. However, there is some uncertainty with this conclusion because of:

- lack of reference value for naphthenic acids;
- uptake of chemicals uncertainties associated with by plants; and
- volatilization of hydrocarbons and the subsequent affect on air quality.

Hence, the degree of concern is rated as moderate, i.e., ER values greater than one, with mitigating factors that would likely result in exposures to be substantially reduced, but additional work needed to support this conclusion.

D4.3.2 Certainty

The assessment of potential impacts to users of Suncor's reclaimed landscape was based on a number of highly protective assumptions. The protective assumptions related to chemical screening are discussed in Section D1.1. These assumptions provide assurances that no chemicals were excluded from the screening step except those that clearly pose no incremental risk to people's health. Risk calculations were done deterministically to provide single value estimates of Exposure Ratios; however, a significant degree of uncertainty is associated with most ER values. To ensure that this assessment yields a sufficiently protective answer in light of this uncertainty, the assessment was based on conservative input values. Hence, the actual risks to people's health are likely to be even lower than those suggested by ER estimates and may in fact be as low as zero because this assessment uses multiple conservative assumptions as outlined in the preceding section.

As such, there is a high degree of confidence in the results of the assessment with the exception of four potential issues:

- lack of a reference value for naphthenic acids;
- lack of information on bioconcentration of chemicals in plants grown on the reclaimed soils;
- lack of data on emissions of volatile hydrocarbons; and
- possible interactions in chemicals mixtures (e.g., additive and synergistic effects).

As noted above, it is unlikely that either of the first two issues will affect the conclusions presented above. Even so, studies have been initiated to collect appropriate data to address these issues. In particular, an experiment is currently being designed to determine the subchronic toxicity of naphthenic acids to mammalian species. In addition, in 1996 Suncor intends to create a CT reclamation demonstration site. This site will be used to demonstrate the integrity of the CT consolidation process and will provide a small-scale experimental platform to quantify (1) bioaccumulation of chemicals in edible plants and (2) air emissions from reclaimed CT deposits. The issue of chemical mixtures is addressed in Section 1.3.

D4.3.3 Cumulative Impacts

The assessment was based on cumulative exposure to chemicals from various pathways, including drinking water and eating native plants and wild game. The only other exposure pathway of potential importance is inhalation of air. However, the chemicals associated with that pathway would be restricted to volatile hydrocarbons and would not be expected to provide an incremental dose of the chemicals investigated here.

The above analysis was based on the assumption that off-site emissions related to other oil sands facilities were negligible with respect to exposure of end users of the reclaimed landscape. Hence, no other anthropogenic sources were included in the assessment.

D5.0 WORKER SAFETY

Hypothesis 11: The health and safety of Suncor employees may be affected by development and operation of the Steepbank Mine and related facilities.

The evaluation of on-site occupational health and safety was accomplished through first-hand observations at the Suncor site, review of industrial hygiene monitoring and safety records, interviews with Suncor health and safety staff, and review of the specific changes proposed in operations for the current site for increased production, for expansion to the Steepbank Mine and for reclamation.

D5.1 CURRENT PLANT OPERATIONS

Suncor has an industrial hygiene monitoring program for airborne vapours and dusts and for physical hazards (heat, vibration, etc.). Included in the program are:

- air quality surveys by operational areas;
- personal and area monitoring (e.g., benzene, naphtha, etc.) for specific chemical exposure;
- noise surveys;
- heat stress surveys;
- smoke and welding fumes surveys;
- ventilation surveys;

- environmental emissions surveys (e.g, ponds, tanks, storage pads, etc.);
- lighting surveys;
- fume hood performance surveys;
- particulate and flyash surveys;
- asbestos surveys;
- safety audits; and
- ergonomic audits.

In addition, Suncor has on-site personnel for medical emergencies and routine medical monitoring programs. Suncor also has an in-house Emergency Response Team (ERT) comprised of fire fighters, rescue personnel, first-aid trained staff and nurses. Major emergencies are handled through a mutual aid agreement with Fort McMurray and Syncrude Canada Ltd.

D5.1.1 Mining Operations

The major mining operations on Lease 86/17 are scheduled to close in 2001 and start-up on the Steepbank Mine across the Athabasca River is scheduled to be in full production either prior to or to coincident with that date. The Steepbank Mine is expected to operate until 2020, with additional leases brought into production beyond that date.

Each mining operation produces noise, dust and fugitive emissions. Noise is mitigated by use of individual ear sound mufflers in areas where measurements exceed safe limits. The dust from digging and hauling operations is monitored to conform to nuisance dust standards and dust masks are worn where needed to mitigate exposure. Fugitive emissions are monitored as part of the personal industrial hygiene monitoring program and appropriate personal protective gear is used, if needed.

D5.1.2 Extraction Operations

Fugitive emissions and spills can potentially occur anywhere in the extraction process:

- vapours discharged along with excess sparge steam in the heating processes;
- spills from the conveyors;
- piping leaks;

- during routine maintenance (one of the five trains is always in a maintenance stage);
- during pump train shut-down;
- during centrifugation;
- during naphtha recovery; and
- during all tailings operations.

In the process trains, all spills and leaks are collected via sumps, which reinject the materials back into the process line. During upsets, emergencies, or when the sump system is not available, the spillage goes to an emergency holding pond and subsequently to the tailings ponds. Naphtha (light hydrocarbon) vapours above the centrifuges are captured and condensed to minimize atmospheric emissions. Hydrogen sulphide collected in the naphtha recovery process is scrubbed to minimize atmospheric releases. Fugitive emission controls are being installed in the tank farm to reduce atmospheric release.

Routine industrial hygiene monitoring is done on employees in the bitumen extraction operations and proper protective equipment is used to minimize exposures to chemicals and physical hazards.

D5.1.3 Upgrading Operations

Fugitive emissions and spills can occur anywhere in the upgrading process:

- vapours discharged in the heating processes;
- piping leaks;
- during routine maintenance;
- during process shut-down;
- during trucking coke to the coke stockpile storage area;
- during naphtha recovery, sour gas stripping, sulphur recovery, acid gas stripping; and
- during flaring of excess acid gas and hydrocarbons.

As with the extraction operation, routine industrial hygiene monitoring is done on employees working in the upgrading operations and proper protective equipment is used to minimize exposures and physical hazards.

D5.1.4 Utilities

Fugitive emissions and spills can occur anywhere in the energy production operation. The emissions are similar to those from extraction and upgrading operations and are routinely measured by industrial hygiene monitoring programs.

D5.1.5 Miscellaneous Operations

Although operationally each of the following areas falls within one of the three main operations at the site, they are discussed here as a group because the fugitive emissions and potential exposures to employees are similar. These areas are:

- tailings ponds;
- tank farms for storage;
- wastewater ponds;
- waste holding areas;
- sulphur pit/pad for storage; and
- coke stockpile/storage area.

Fugitive emissions occur from the ponds, dykes and pipes from process areas and between tailings ponds. Dust particles become entrained in air as they pass over the dykes. Routine industrial hygiene monitoring is done on employees working around the tailings ponds and proper protective equipment is used, when required, to minimize exposures to chemicals and physical hazards.

Fugitive emissions and spills can occur from the tanks themselves and from the pipes connecting the process areas and the tank farm. Dykes are present to contain potential spills and some tanks are equipped with emission control devices to minimize atmospheric releases (e.g, slop oil tanks, naphtha tanks). Routine industrial hygiene monitoring is done on employees working in tank storage areas and proper protective equipment is used to minimize exposures to chemicals and physical hazards.

Fugitive emissions and spills can occur from the piping between the processes and ponds and from the ponds themselves. Routine industrial hygiene monitoring is done on employees working around wastewater ponds and pipes and proper protective equipment is used, when required, to minimize exposures and physical hazards.

Fugitive emissions and spills can occur during the truck filling process, piping liquid sulphur to the underground pit, blocking the sulphur on the temporary pad and storing sulphur on the pad. A liner in the sulphur pad area minimizes ground water contamination and diverts water back into the wastewater treatment system. Routine industrial hygiene monitoring is done on employees working in the sulphur handling and storage areas and proper protective equipment is used, when required, to minimize exposures and physical hazards.

Fugitive emissions, smoke and spills can occur during transport and storage. Flare-ups occur in the coke stockpile and dust can become entrained in air passing over the stockpile. Water from the stockpile area enters the wastewater treatment system. Routine industrial hygiene monitoring is done on employees working in coke handling and stockpile areas and proper protective equipment is used, when required, to minimize exposures and physical hazards during normal operations and flare-ups.

D5.2 EXPANDED CAPACITY OPERATIONS/PLANNED OPERATIONAL CHANGES/ NEW MINE

Suncor is planning to increase its daily capacity from 79,500 bbl/cd to 107,000 bbl/cd at full capacity. This expansion will also include several process upgrades and installation of new emissions control systems to reduce atmospheric releases.

The following changes are currently under construction, or planned:

- add flue gas desulphurization plant to reduce SO_2 emissions;
- upgrade coke fired boilers to make them more reliable and to reduce NO_x emissions;
- add condensate filtration capacity;
- add boiler feed water pumping capacity;
- provide cleaner and cooler once-through water to reduce draw from Athabasca River and improve quality of return water;
- add deaeration capacity;
- add condensate surge pumping capacity;

- add steam pressure letdown station;
- add condensate line;
- add new diluent recovery unit to increase recovery efficiency;
- add vacuum unit to delayed coking unit;
- initiate new consolidated tailings process (hydrocyclone separation and combination with existing mature tailings);
- add steam line;
- move and cap coke stockpile;
- upgrade waste heat recovery operation; and
- wastewater, spill control systems and emissions control system upgrades to handle process changes.

The net impact of these changes will be to reduce fugitive emissions, operational emissions and potential occupational exposures. Each expansion or process change will be reviewed and a worker safety analysis will be performed. All protective equipment required during the construction, modification, or start-up phases will be provided. Industrial hygiene monitoring will be conducted to minimize potential impacts on worker health and safety.

Construction and operation of the new Steepbank Mine will incorporate several changes to current operations. During construction, the only substantive difference from current operations is that temporary river crossings will be used from 1996-1999 (ice bridges in winter and barges in summer). These activities will be closely monitored through Suncor's current comprehensive industrial hygiene program and proper personal protective equipment will be used, when required.

Operations at the new mine will be similar to those currently in place for Lease 86/17. The only major changes will be the addition of a hydroslurry transport system to move water-diluted oil sands across the river to the extraction area (conveyors will be used in the Steepbank Mine, but not for the entire length of the transport system) and the construction of dykes from overburden rather than tailings. The hydroslurry will eliminate fugitive dust exposures from that portion of the transport system and will reduce noise and the overburden dyke construction will reduce fugitive emission and sand exposures from the dykes.

As new technology becomes available to reduce fugitive emissions and dust, it will be evaluated for inclusion into the construction and operation phases of the new Steepbank Mine.

The Steepbank Mine emergency response time is an issue that will be addressed as mining activities move further from the bridge being constructed and from the existing plant site. This will be addressed as part of the development of the site.

D5.3 RECLAMATION

Reclamation activities are not considered different from activities currently underway on Lease 86/17 site. These activities will continue to be monitored through the existing industrial hygiene programs.

D5.4 SUMMARY

The current operations meet all local, Provincial and Federal rules and regulations for protection of worker safety and health. In addition, changes proposed or in progress to the plant during both expansion and operation of the current site and the new mine will have a positive impact in reducing potential exposures through reducing fugitive emissions, dust, physical hazards and atmospheric releases.

The current industrial hygiene program is aggressive toward reducing exposures to workers and must remain so as the mining shifts from Lease 86/17 to the new Steepbank Mine. Emerging issues, such as a reduction in any current permissible exposure level or physical hazard standard, must be dealt with as soon as they become evident. Proactive occupational health and safety surveillance will assist in maintaining a healthy and productive workforce.

It is expected that occupational health and safety conditions will continue to improve in the future. Thus the degree of concern for this hypothesis is rated as negligible, i.e., improvement from existing condition.

E RESIDUAL IMPACTS AND NET BENEFITS SUMMARY

The degree of concern for each of the five impact hypotheses pertaining to effects on human health is defined in detail in Section D and the residual impacts summarized below:

Hypothesis 7: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by changes to Athabasca and Steepbank River water quality caused by water releases resulting from extraction, processing and reclamation of oil sands from Suncor's existing or proposed mines.

A human health risk assessment was conducted to quantify risk to people's health related to water emissions from Suncor's existing and proposed operations. The assessment focused on pertinent pathways in which people using the Athabasca River, immediately downstream of Suncor's operations might be affected by Suncor's operations via drinking water, swimming in the river or eating fish from the river. Results of this analysis indicated that Suncor's water emissions do not pose a significant health risk to people using the Athabasca River. Hence, the degree of concern is rated as low, i.e., incomplete data for certain chemicals although enough evidence to suggest that exposure is unlikely to adversely affect health.

Hypothesis 8: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by air emissions resulting from extraction, processing and reclamation of oil sands from Suncor's existing or proposed mines.

Suncor has initiated a number of facility improvements to reduce air emissions from its operations. These changes will all reduce Suncor's contribution to the off-site airshed and thus, will reduce potential exposures of people living off-site from Suncor emissions. Reducing the potential of exposure may also reduce the associated health risk. Although data are limited, there are no indications that suggest that Suncor's air emissions pose a health risk, at least with respect to volatile organics and particulates generated by dust. Hence, degree of concern during the operational phase of the mine-life cycle is rated as low, i.e., health impact unlikely but additional information needed to confirm this conclusion. Since a linkage will not exist between the reclaimed landscape and off-site air quality, degree of concern following reclamation is rated as nil.

Hypothesis 9: The health and well being of people who live, work or engage in recreational activities within the study area may be affected by cumulative exposure to chemicals associated with water and air emissions from Suncor's activities and other developments within the Regional Study Area.

Based on the information reviewed coupled with the exceedingly low risks associated with exposures to these chemicals from water, it is unlikely that cumulative exposure from both air and water affects people's health. Thus, the degree of concern associated with this hypothesis is rated as low, i.e., unlikely to affect people's health but additional information needed to confirm this conclusion.

Hypothesis 10: The health of people who in the future may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine may be affected by release of chemicals from the reclaimed landscapes.

Based on information reviewed, the health and well being of people who in the future may occupy and/or use the land reclaimed from Suncor's Lease 86/17 and Steepbank Mine is not likely to be affected by release of chemicals from the reclaimed landscapes. The degree of concern is rated as moderate, i.e., ER values greater than one with mitigating factors that would likely result in exposures to be substantially reduced, but additional information needed to support this conclusion.

Hypothesis 11: The health and safety of Suncor employees may be affected by development and operation of the Steepbank Mine and related facilities.

Based on the information assessed and on-site surveys, changes proposed or in progress at the plant during both expansion and operation of the current site and the new mine will have a positive impact in reducing potential exposures through reducing fugitive emissions, dust, physical hazards and atmospheric releases. Thus, the degree of concern has been rated as nil.

F ENVIRONMENTAL MONITORING

Predictions of potential health impacts based on natural systems and inhabitants of those systems are subject to uncertainty as a result of the inherent variability and our incomplete knowledge of natural systems. In addition, the ultimate success of proposed mitigation measures can only be assessed following their implementation. Therefore, an environmental monitoring program is recommended to validate impact predictions and to monitor the success of mitigation measures.

F1.0 OFF-SITE WATER EMISSIONS

Suncor has approval to discharge operational waters into the Athabasca River. Water quality sampling associated with this approval will continue. Therefore, additional water quality monitoring is not required. In addition to water quality monitoring, several aquatic biota monitoring studies will be conducted in the area including surveys on migratory fish in the Athabasca River, resident fish species in the Steepbank River and benthic invertebrate communities. These studies can be more sensitive than water quality monitoring because they can detect subtle changes in fish and benthic community health as well as bioaccumulation effects that might be associated with slight changes in water quality.

An experimental study is currently being designed to collect additional information to help determine whether low levels of naphthenic acids pose a risk to human health. In addition, a laboratory study is currently underway to test bioaccumulation and tainting potential of Suncor's refinery wastewater.

F2.0 OFF-SITE AIR EMISSIONS

Suncor has an air emission approval, and air quality sampling associated with this approval will continue. However, additional chemical-specific data for VOCs and particulates at off-site exposure points should be obtained.

In addition, Suncor is a sponsor and active participant in the Alberta Oil Sands Community Exposure and Health Effects Assessment Program being led by Alberta Health. This program is designed to measure exposure during a 24-hour cycle, which will include in-home, environmental and occupational exposures. Three hundred participants from Fort McMurray will be enrolled in the study, including all levels of income and job types. The study will collect information about exposures throughout a 1-year period, which will provide information about seasonal variations and behaviour. Daily records of events during the sample collection period will be made into a personal diary. A questionnaire will provide background medical histories of participants, as well as demographic information. The program will be continued for a period of years to permit assessment of changes in community health over time.

The samples collected will be analyzed for sulphur dioxide, oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and total reduced sulphur (TRS) in an accredited laboratory with validated protocols. The information will be used to establish a baseline health status for the Fort McMurray community for air quality, as well as to determine the relative contribution to exposure of indoor (in-home), outdoor (environmental) and occupational environments.

F3.0 CUMULATIVE EFFECTS

The monitoring programs discussed above will provide the required information to test the conclusions concerning exposure to both air and water.

F4.0 RECLAMATION LANDSCAPE

For the reclamation landscape, improvements need to be made in the predictions of chemical exposures. Continual monitoring of CT water quality and soil quality is required to enhance the CT database. In 1996, Suncor intends to create a CT reclamation demonstration site. This site will be used to demonstrate the integrity of the CT consolidation process and will provide a small-scale experimental platform to quantify bioaccumulation of chemicals in edible plants and air emissions from reclaimed CT deposits.

F5.0 ON-SITE OCCUPATIONAL HEALTH AND SAFETY

Suncor has an industrial hygiene and safety program, which generates data pertaining pertaining to potential exposures of the workforce to a variety of normal operational and upset conditions. This information, coupled with information from medical health programs, forms the basis of a workforce monitoring program to identify trends or signals that may indicate potential problems, i.e., a health surveillance program. This program can be an early warning system for possible adverse effects in the workforce, as well as a tool for continuing to show the effectiveness of systems, controls and administrative procedures that are currently in place or are planned.

G REFERENCES

AGRA Earth & Environmental. 1996. Technical basis for preliminary water balance analysis of Suncor's mine closure drainage system. Updated January 11, 1996. Submitted to Suncor Inc., Oil Sands Group. Calgary, Alberta.

Alberta Environmental Protection. 1995. Water quality based effluent limits procedures manual. Environmental Regulatory Service. December 1995.

BOVAR Environmental. 1996a. Impact Analysis of Air Emissions Associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

BOVAR Environmental. 1996b. Sources of atmospheric emissions in the Athabasca Oil Sands region (Report 1). Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd. Calgary, Alberta.

BOVAR Environmental. 1996c. Ambient air quality observations in the Athabasca Oil Sands region (Report 2). Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd. Calgary, Alberta.

BOVAR Environmental. 1996d. Air quality modelling for the Athabasca Oil Sands region. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd. Calgary, Alberta.

BCE (British Columbia Environment). 1994. Approved and working criteria for water quality - 1994. Water Quality Branch, Environmental Protection Department, Ministry of Environment, Lands and Parks.

CRWQCB (California Regional Water Quality Control Board, Central Valley Region). 1993. A compilation of water quality goals. May 1993.

EMA (Environmental Management Associates). 1993. End-Cap Lake water quality assessment. Final report. Prepared for Syncrude Canada. Ltd. Calgary, Alberta.

Environment Canada. 1991. Historical streamflow summary: Alberta (1990). Inland Waters Directorate, Water Resources Branch, Water Survey of Canada. Ottawa, Ontario.

Environment Canada. 1994. A framework for ecological risk assessment at contaminated sites in Canada: Review and recommendations. Prepared by EVS Environmental Consultants and ESSA. National Contaminated Sites Remediation Program, Scientific Series No. 199. Ecosystems Conservation Directorate, Evaluation and Interpretation Branch, Ottawa, Ontario.

ETL (EnviroTest Laboratories). 1993. Alumina fractionation and GC/MS characterization of potential reclamation materials from oil sands operations. Series: E3-02-125. Contract # 93-0691. Submitted to Alberta Environment, Land Reclamation Division. Edmonton, Alberta.

FTFC (Fine Tailings Fundamentals Consortium). 1995. Advances in oil sands tailings research. Alberta Department of Energy, Oil Sands and Research Division. June 1995.

Fort McKay Environment Services Ltd. 1996. The community of Fort McKay traditional uses of the renewable resources on the proposed Suncor Steepbank Mine site. Prepared for Suncor Inc., Oil Sands Group. January 1996.

Golder Associates Ltd. 1994. Oil sands tailings preliminary ecological risk assessment. Prepared for Oil Sands Reclamation Research Program, Alberta Conservation and Reclamation Management Group. (Reclamation Research Technical Advisory Committee). RRTAC OF-7. Calgary, Alberta.

Golder Associates Ltd. 1995a. Suncor Steepbank Mine EIA: Quality assurance needs and database management plan. Prepared for Suncor Inc., Oils Sands Group and Suncor Canada Ltd. Calgary, Alberta.

Golder Associates Ltd. 1995b. Mixing characteristics of the Suncor effluent discharge to the Athabasca River. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Golder Associates Ltd. 1996a. Aquatic baseline report for the Athabasca and Steepbank Rivers in the vicinity of the Steepbank and Aurora Mines. Prepared for Suncor Inc., Oil Sands Group and Syncrude Canada Ltd. Calgary, Alberta.

Golder Associates Ltd. 1996b. Impact analysis of aquatic issues associated with the Steepbank Mine. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Golder Associates Ltd. 1996c. Athabasca River water release impact assessment. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Golder Associates Ltd. 1996d. Suncor reclamation landscape performance assessment. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Health Canada. 1994. Human health risk assessment for priority substances. Canadian Environmental Protection Act. Ottawa, Ontario.

Health Canada. 1995. Human health risk assessment of chemicals from contaminated sites: Volume 1, risk assessment guidance manual. Prepared by Golder Associates, Ltd. and CanTox Inc., for Environmental Health Directorate, Health Canada, Ottawa, Ontario.

HWC (Health and Welfare Canada). 1993. Guidelines for Canadian drinking water quality. Minister of Supply and Services Canada. Ottawa, Ontario.

HWC (Health and Welfare Canada). 1995. Guidelines/Limits for various chemical contaminants in Canada. Fax from John Salminen. March 14, 1995.

HydroQual Laboratories Ltd. 1996. Laboratory studies on trophic level effects and fish health effects of Suncor Tar Island Dyke wastewater. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Klohn-Crippen. 1996. Impact Analysis Steepbank Mine EIA Surface Water and Groundwater. Prepared for Suncor Inc., Oil Sands Group. Calgary, Alberta.

Moore, J.W. and S. Ramamoorthy. 1984. Organic chemicals in natural waters. Applied Monitoring and Impact Assessment. Springer-Verlag. New York, New York. 289 pp.

Morales A., S.E. Hrudey and P.M. Fedorak. 1993. Mass spectrometric characterization of naphthenic acids in oil sands wastewaters: Analysis, biodegradation and environmental significance. Prepared for Fine Tailing Fundamentals Consortium. 92 pp plus Attachments.

Noton, L.R. and R.D. Shaw. 1989. Winter water quality in the Athabasca River System, 1988-1989. Prepared for Environmental Quality Monitoring Branch, Environmental Assessment Division, Environmental Protection Services, Alberta Environment, Edmonton, Alberta.

NRBS (Northern River Basins Study). 1996. River views. Winter 1996.

OSWRTWG (Oil Sands Water Release Technical Working Group). 1996. Approaches to oil sands water releases. Prepared by the Oil Sands Water Release Technical Working Group. March 1996.

Pauls, R., J. Peden and S. Johnson. 1995. Syncrude/Fort MacKay wood bison project, 1994 research report. Syncrude Canada Ltd. July 1995. pp 57-59.

Smith, R.L. 1995. EPA region III risk-based concentration table. Background Information. U.S. Environmental Protection Agency.

Syncrude Canada Ltd. 1993. Qualitative human health risk assessment for recreational exposures to chemicals predicted to occur in End-Cap Lake water and fish. Prepared by CanTox, Inc.

U.S. EPA (United States Environmental Protection Agency). 1989. Risk assessment guidance for Superfund, Volume I: Human health evaluation manual (Part A). Interim Final. U.S. Environmental Protection Agency. EPA/540/1-89/002.

U.S. EPA (United States Environmental Protection Agency). 1992. Dermal exposure assessment: Principles and applications. Interim report. United States Environmental Protection Agency. Washington, D.C. January 1992. EPA/600/8-91011B

U.S. EPA (United States Environmental Protection Agency). 1994. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. Environmental Response Team. U.S. Environmental Protection Agency. Edison, New Jersey.

Xu, J.G. (editor). 1995. Plant growth and metal uptake from two kinds of oil sands fine tailings (a progress report on greenhouse experiment). Alberta Environmental Protection Centre, Vegreville, AB. AECV 2600-M6*Cx10-2[R1.

Xu, J.G. (editor). 1996. Plant growth dewatering and contaminant uptake from oil sands fine tails and tailings (a progress report on 1995 field experiment). Alberta Environmental Protection Centre, Vegreville, AB. AECV 2600-M6*Cx10-3[R1.

H GLOSSARY OF TERMS

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.
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.
Background	An area not influenced by chemicals released from the site under evaluation.
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 toxicants, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.
Bioavailability	The amount of chemical that enters the general circulation of the body following administration or exposure.
Bioconcentration	A process where there is a net accumulation of a chemical directly from an exposure medium into an organism
CO	Carbon monoxide

CO_2	Carbon dioxide
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 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 exposures that are greater than seven years to be chronic).
Chronic Toxicity	The development of adverse effects after an extended exposure to relatively small quantities of a chemical.
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.
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 chemcially stabilized to prevent segretation of the fine and coarse mineral soilids using gypsum ($CaSO_4$).

DL	Detection Limit. 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.
Dose	A measure of integral exposure. Examples include (1) the amount of chemical ingested, (2) the amount of a chemical taken up and (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.
Ecosystem	An integrated and stable association of living and nonliving resources functioning within a defined physical location.
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.
Exposure	The contact reaction between a chemical and a biological system, or organism.
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 one hundred thousand). May be expressed as a Reference Dose (RfD) for threshold-response chemicals or as a Risk Specific Dose (RsD) for non-threshold response chemicals.
Exposure Pathway or Route	The route by which a receptor comes into contact with a chemical or physcial agent. Examples of exposure pathways include the ingestion of water, food and soil, the inhalation of air and dust, and dermal absorption.
Exposure Ratio (ER)	A comparison between total exposure from all predicted routes of exposure and the exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit.
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.
Golder	Golder Associates Ltd.
HC	Hydrocarbon
Habitat	The place where an animal or plant naturally or normally lives and grows, for example, a stream habitat or a forest habitat.

Human Health Risk Assessment	The process of defining and quantifying risks and determining the acceptability of those risks to human life.
m^3/s	Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.
Media	The physical form of the environmental sample under study (e.g., soil, water, air).
NO_x	Nitrogen Oxides.
NPH	Naphthalene. A metabolite of PANH that accumulates in body tissues and fluids, specifically bile, following PAH biotransformation. See BaP.
Nutrients	Environmental substances (elements or compounds), such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
PAH(s)	Polycyclic Aromatic Hydrocarbon. 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. See PAH.
PASH	Polycyclic Aromatic Sulphur Heterocycles.
PM_{10}	Particulate matter less than 10 μm in diameter.

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.
QAPP	Quality Assurance Project Plan.
Receptor	The person or organism subjected to exposure to chemcials or physical agents.
RfD (Reference Dose)	The maximum recommended daily exposure for a chemical exhibiting a threshold (highly nonlinear) dose-response based upon the NOAEL determined for the chemical from human and/or animals studies and the use of an appropriate uncertainty factor.
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 not risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.
Risk Assessment	The process tha 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 Management	The managerial, decision-making and active hazard control process used to deal with those environmental agents for which risk evaluation has indicated that the risk is too high.

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., q_1^* ÷ target level of risk); for example, the RsD for a lifetime cancer risk of one in one-million would equal to $q_1^* \div 1 \times 10^{-6}$.
SO_2	Sulphur Dioxide.
Screening	The process of filtering and removal of implausible or unlikely exposure pathways, chemicals or substances, or populations from the risk assessment process to focus the analysis on the chemicals, pathways and populations of greatest concern.
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.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Subchronic toxicity	The adverse effects occurring as a result of the repeated daily exposure to a chemical for a short time. In Canada, human exposures lasting between two weeks and three months may be termed subchronic while in the U.S. human exposures lasting between two weeks and seven years may be termed subchronic.
Suncor	Suncor Inc., Oil Sands Group
Syncrude	Syncrude Canada Ltd.
TID	Tar Island Dyke

TRS	Total Reduced Sulphur.
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 concentration where they can 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.
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 the 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 into the body.
U.S. EPA	U.S. Environmental Protection Agency.

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 in a specific population.

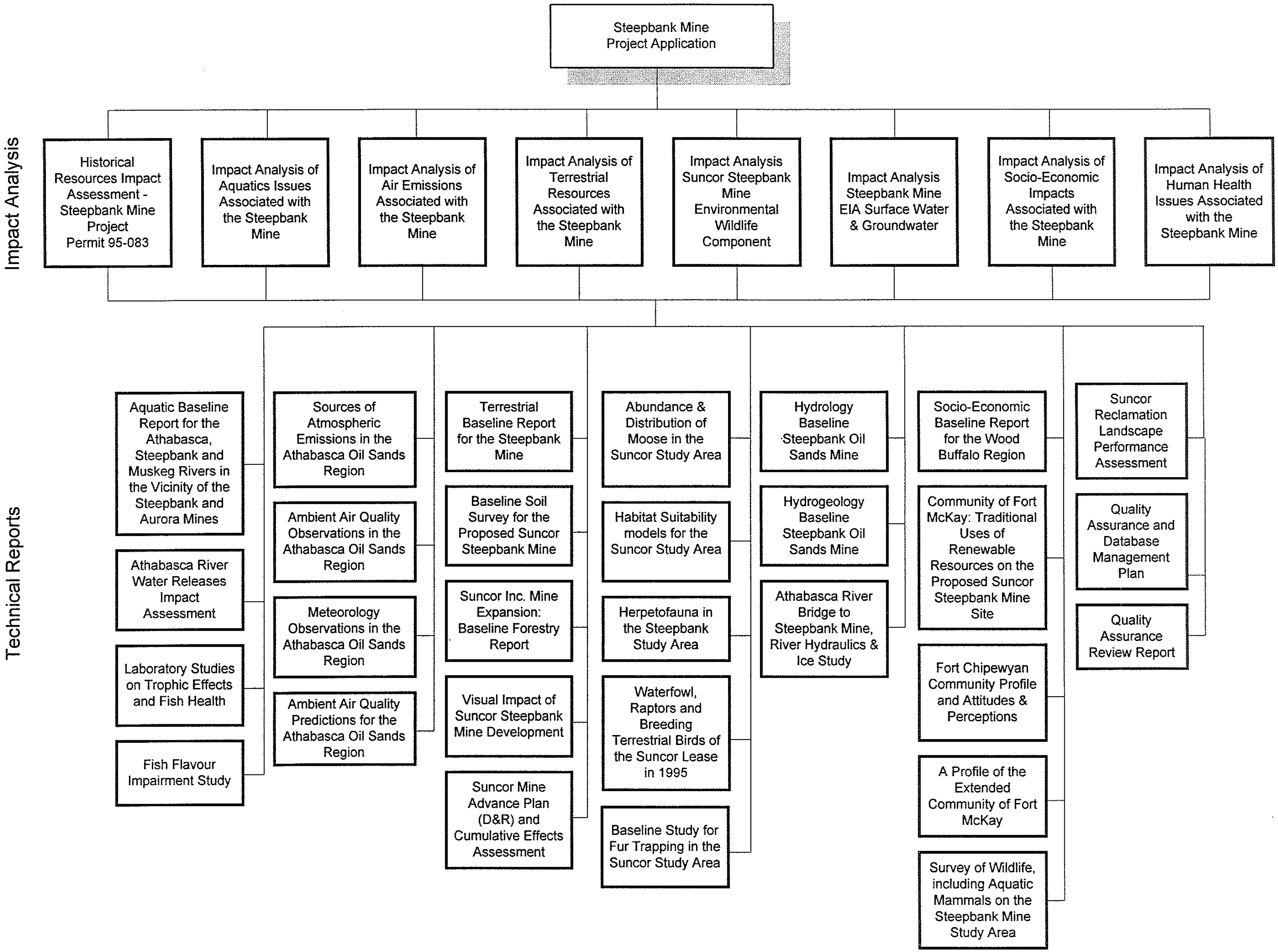

Figure A-1 Reports Prepared for the Steepbank Mine Environmental Assessment

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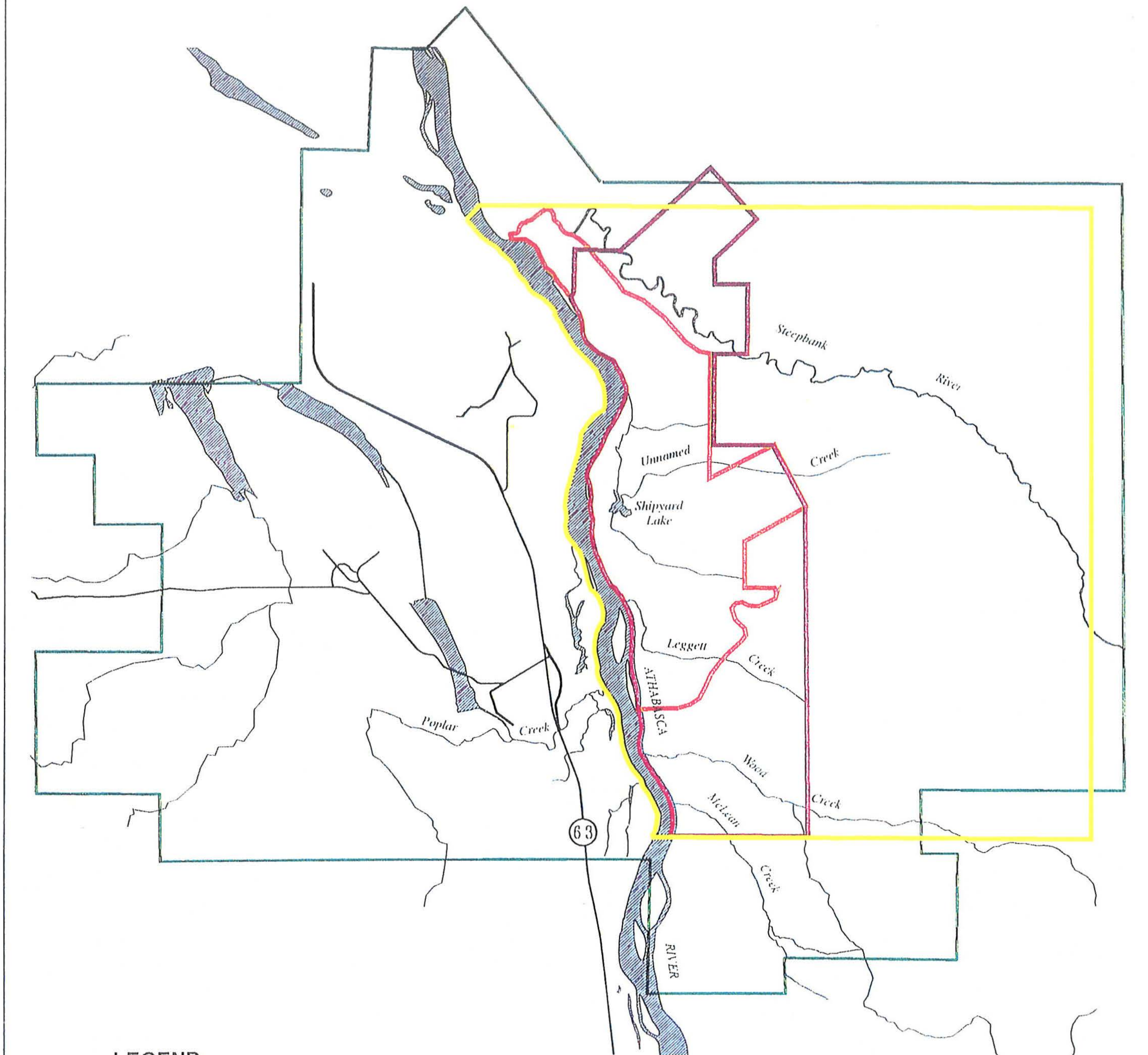

LEGEND

- Terrestrial and Wildlife Resources
- Hydrology and Hydrogeology
- Forestry
- Archaeological Local Study Area

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KILOMETRES

N

Suncor Inc.
Oil Sands Group

LOCAL STUDY AREA BOUNDARIES
FOR THE STEEPBANK MINE

SCALE: AS SHOWN	Steepbank Mine Application	REVIEWED BY:
DATE: 18 APR 96		REVISION No.: 1
DRAWN BY: RP		FIGURE No.: B-1

Figure B-2
SUNCOR REGIONAL AND APPROXIMATE
LOCAL STUDY AREA

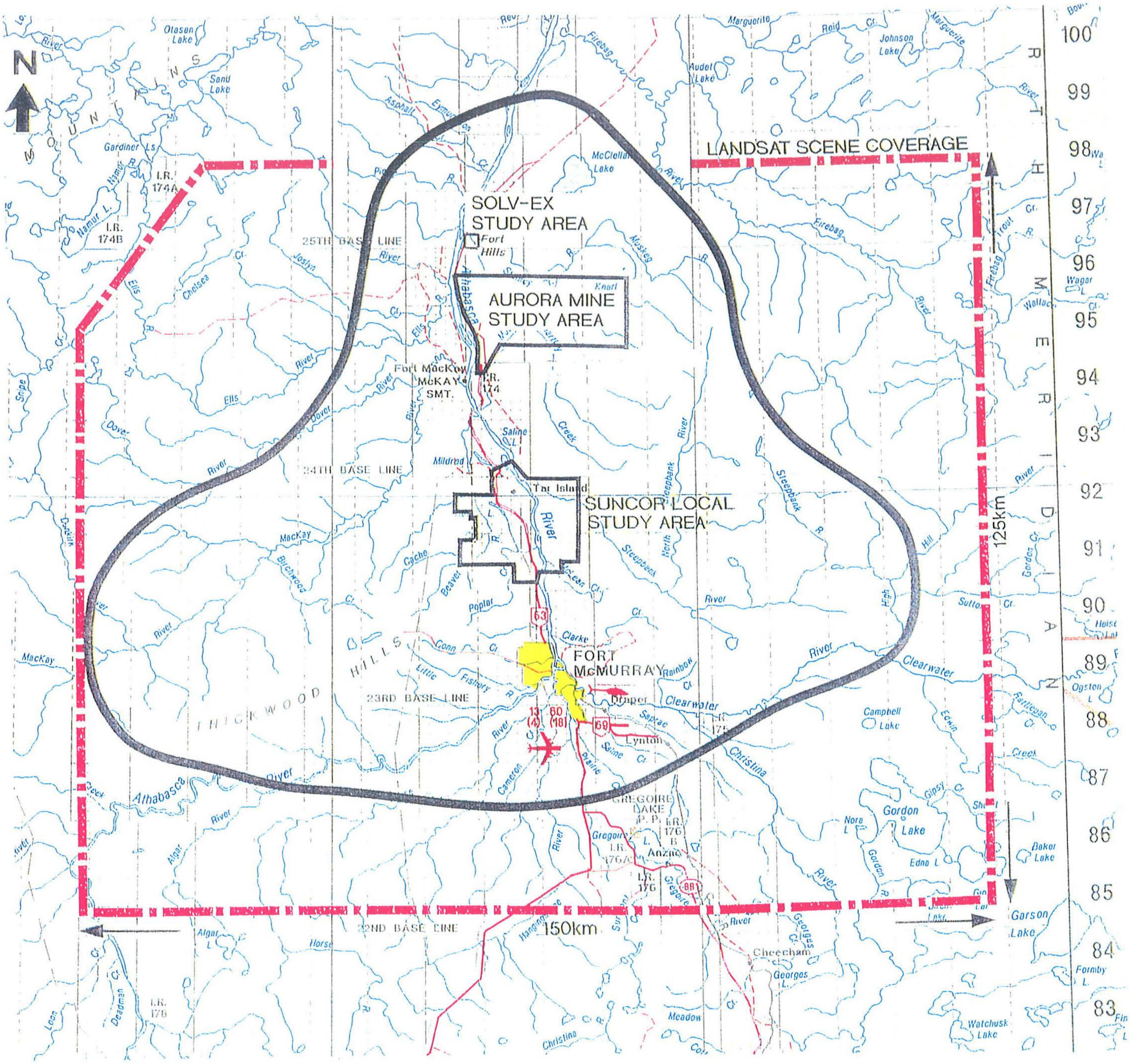

Figure C2.0-1
Linkages Among Mine Life Cycle Activities, Mode of Action and Potential Impacts on Human Health

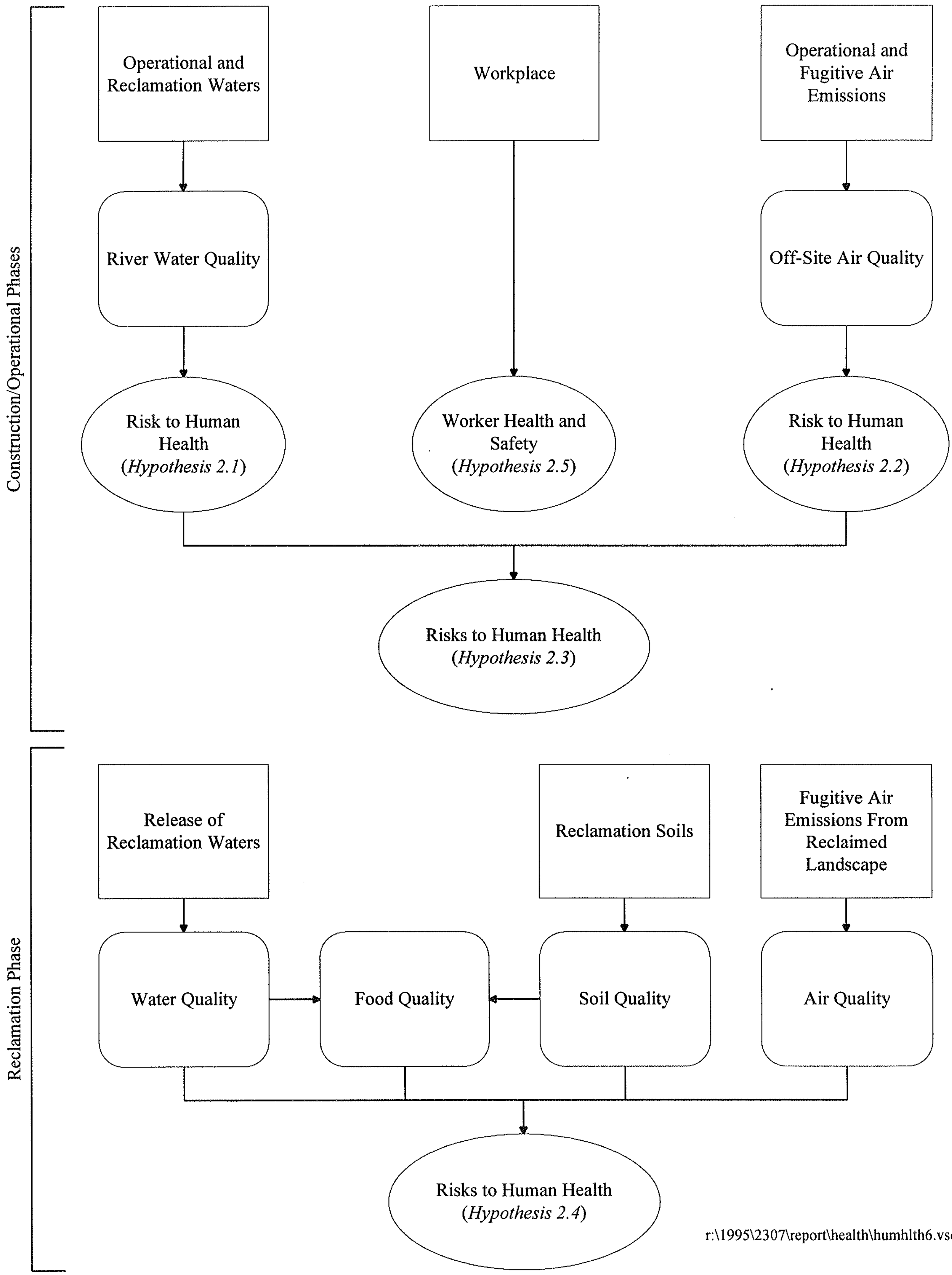

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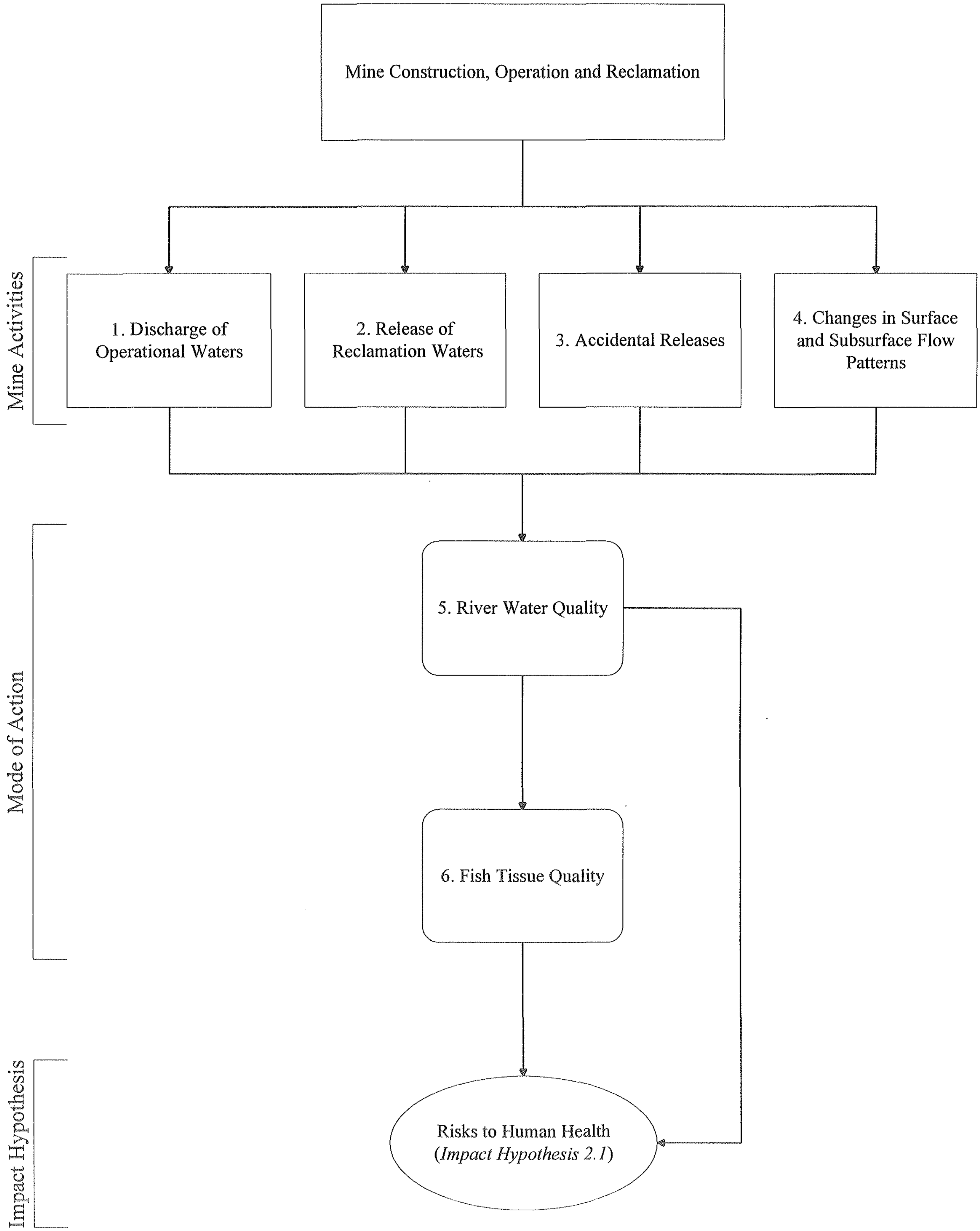
Figure D1.0-1
Linkages Among Mine Life Cycle Activities, Mode of Action and Potential Off-site Impacts on Human Health (Water Releases)



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LOCATIONS OF DISCHARGE SOURCES

Figure D1.0-2

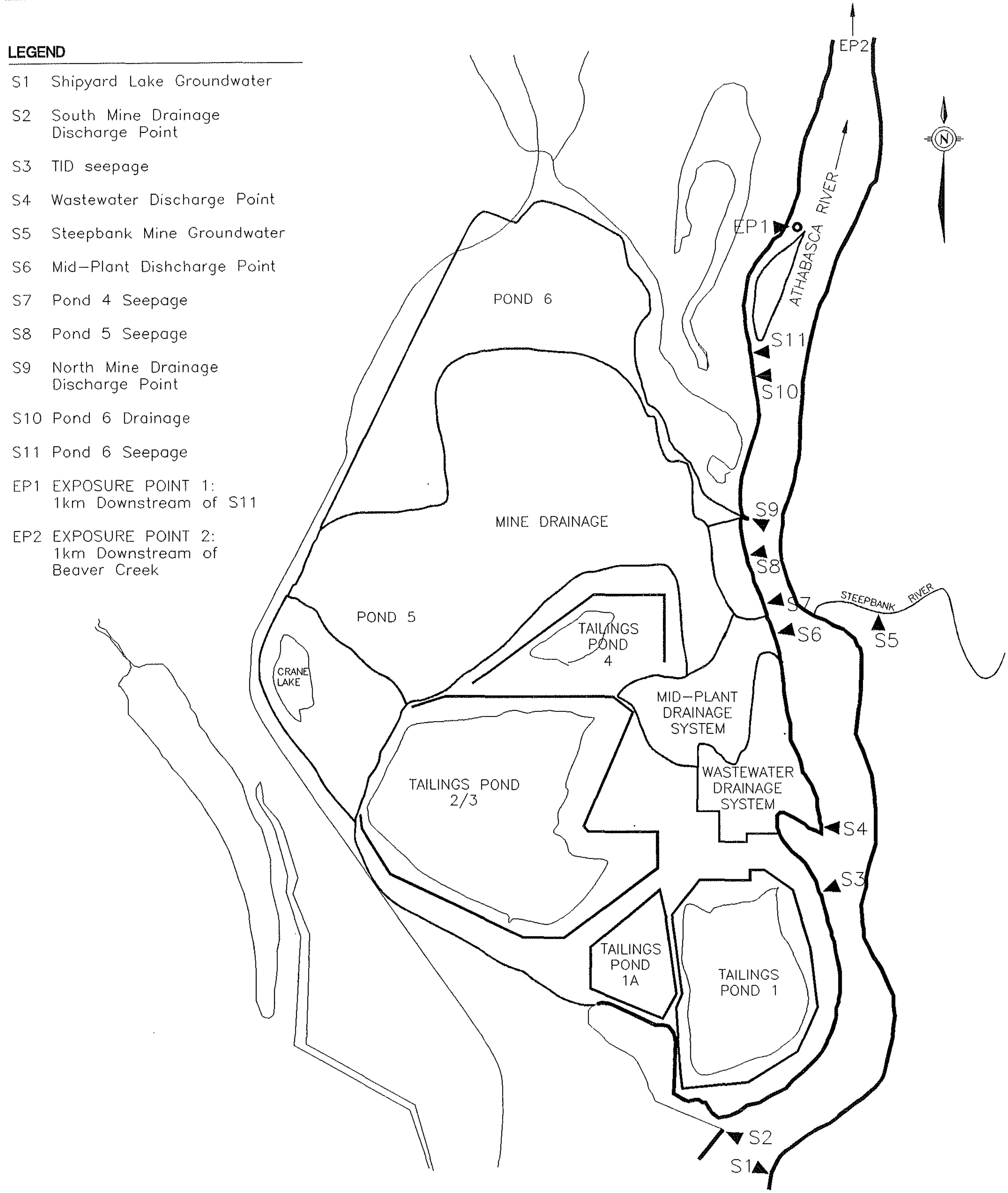

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Figure D1.0-3
Process for Chemical Screening

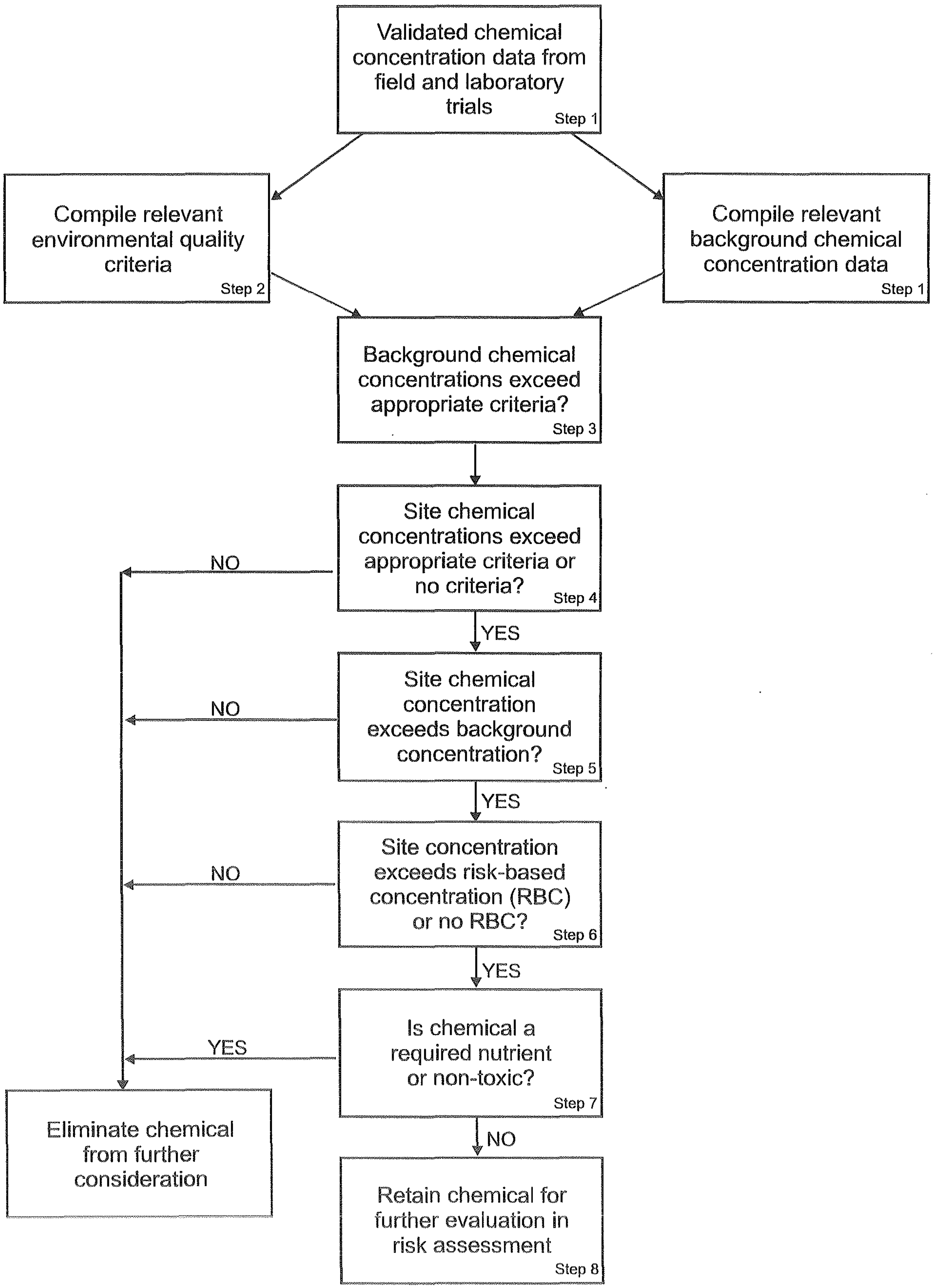

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Figure D2.0-1
Linkages Among Mine Life Cycle Activities, Mode of Action and Potential Off-site Impacts on Human Health (Air Releases)

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Figure D3.0-1
Linkages Among Mine Life Cycle Activities, Modes of Action and Potential Off-site Impacts on Human Health (Cumulative Impacts)

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Figure D4.0-1
Linkages Among Mine Reclamation, Mode of Action and Potential On-site Impacts on Human Health Associated with Reclaimed Landscape

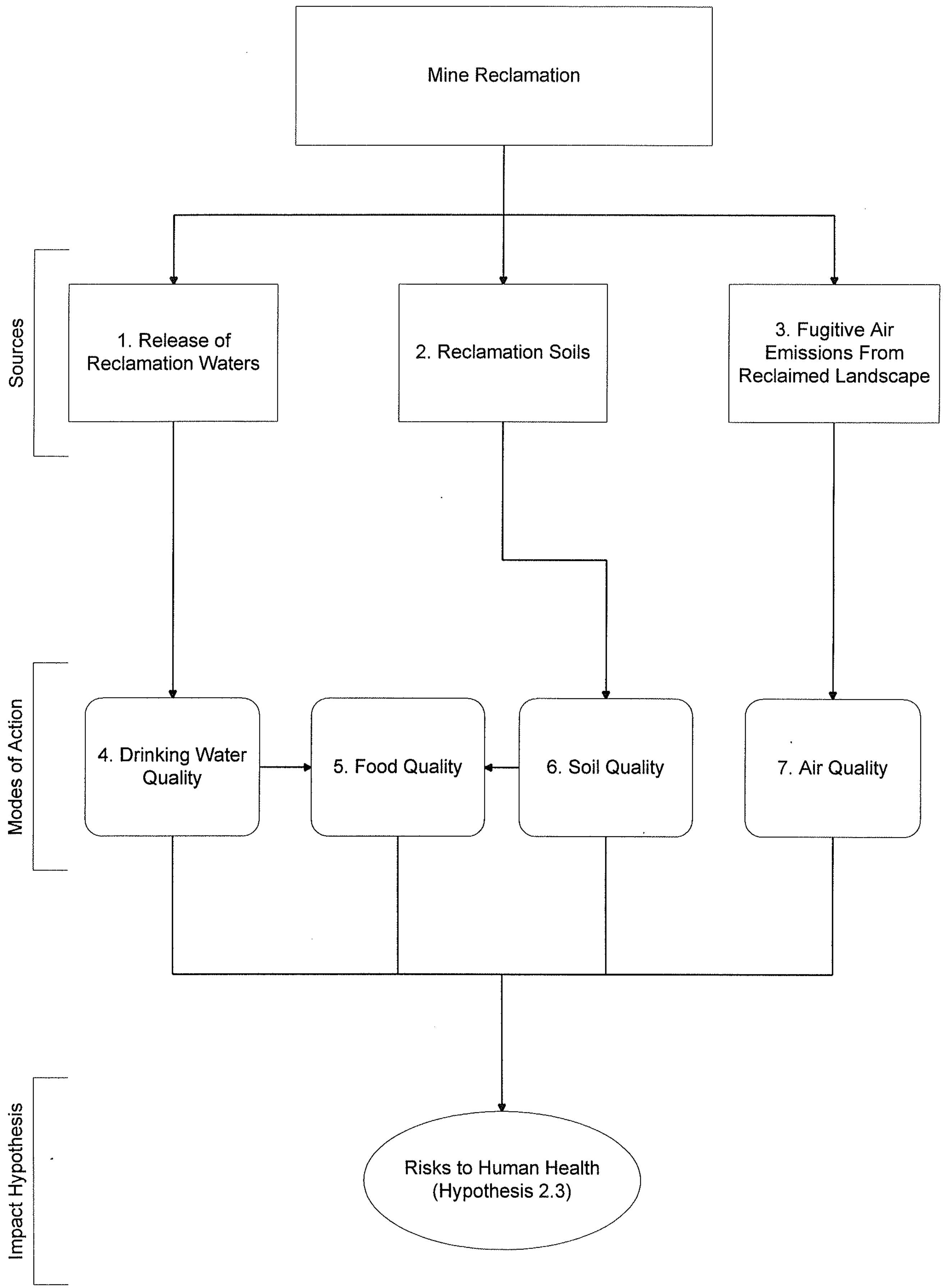

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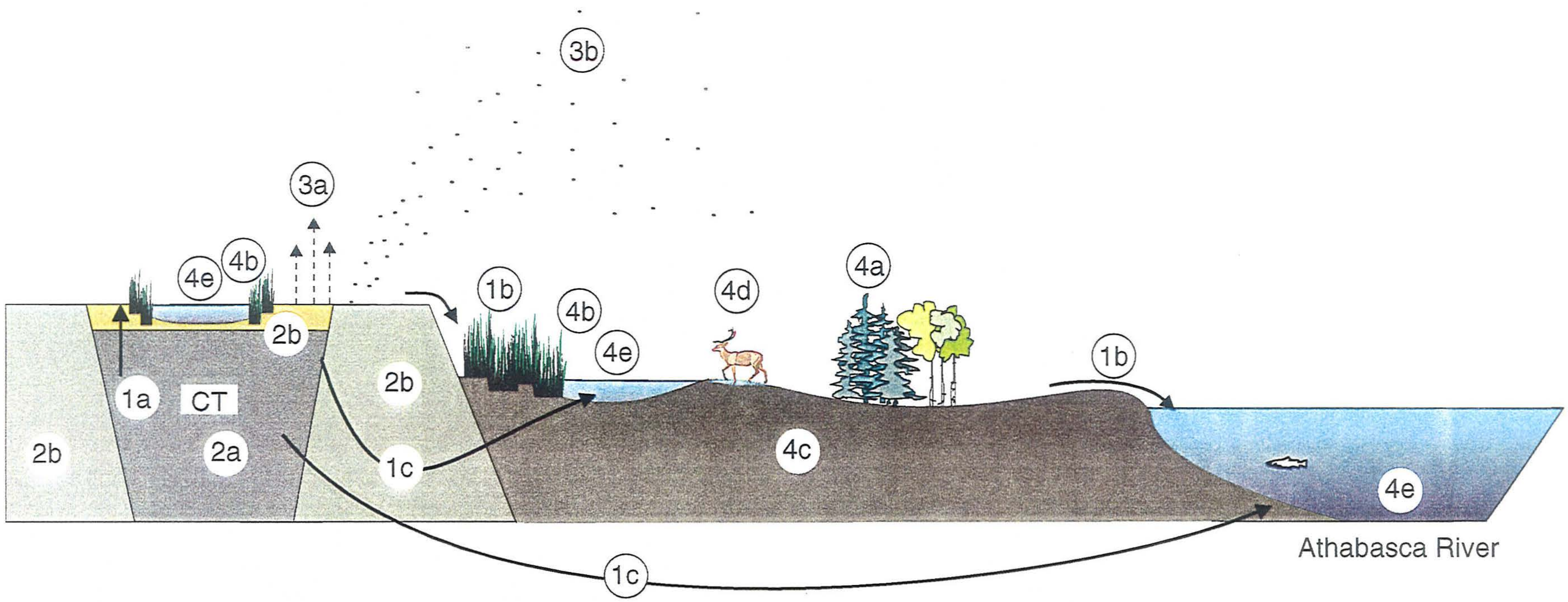
Figure D4.0-2 Conceptual Overview of Chemical Transport and Fate Pathways



1. WATER

1a. Exfiltration water
1b. Surface runoff
1c. Groundwater

2. SOILS

2a. Consolidated tails
2b. Tailings sand/overburden

3. AIR

3a. Volatilization
3b. Fugitive dust generation

4. BIOTA

4a. Terrestrial plants
4b. Wetland plants
4c. Terrestrial soil invertebrates
4d. Terrestrial vertebrates
4e. Aquatic organisms

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APPENDIX I

DATA TABLES

TABLE I-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

Chemical	NATURAL WATERS		OPERATIONAL/RECLAMATION WATERS						
	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	-

TABLE I-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]
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	-
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	-

TABLE I-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]
1,2,3-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	-
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	-

TABLE I-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]
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
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

TABLE I-1

SUMMARY OF CHEMICAL CONCENTRATIONS OF SUNCOR'S OPERATIONAL WATERS

Chemical	NATURAL WATERS: Athabasca River[1]	NATURAL WATERS: Reference Tributaries[2]	OPERATIONAL/RECLAMATION WATERS: 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]
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
Selenium	<0.0001-0.0004	<0.0002-0.0003	<0.0002-0.004	<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	<0.002-0.005	<0.002	<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	<0.5-0.007	<0.5	<0.0002-<0.1	<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 1995c; 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 I-2

SUMMARY TABLE OF CHEMICAL CONCENTRATIONS (µg/g) IN FISH

CHEMICAL	BACKGROUND			TREATMENT		
	Athabasca River Baseline[1]	Rainbow Trout[2]	Walleye[3]	Rainbow Trout[4]	Walleye[5]	Rainbow Trout[6]
	Athabasca River Water	Athabasca River Water	Athabasca River Water	10% TID Water	10% TID Water	Syncrude Pond #5
ORGANICS						
Polycyclic Aromatic Hydrocarbons						
1-Methyl-7-isopropyl	<0.04	<0.04	<0.04	<0.04	<0.04	-
Acenaphthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Acenaphthylene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0002
Anthracene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0006
Benzo(a)anthracene	-	-	-	-	-	<0.00009
Benzo(a)anthracene/chrysene	<0.02	<0.02	<0.02	<0.02	<0.02	-
Benzo(a)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Benzo(b&k)fluoranthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0008
Benzo(ghi)perylene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	-
C2 sub'd benzo(a)anthracene/ chrysene	<0.04	<0.04	<0.04	<0.04	<0.04	-
C2 sub'd benzo(b&k)fluoranthene/ benzo(a)pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	-
C2 sub'd biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	-
C2 sub'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C2 sub'd fluorene	<0.04	<0.04	<0.04	<0.04	<0.04	-
C2 sub'd naphthalene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C2 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C3 sub'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	-
C3 sub'd naphthalene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C3 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C4 sub'd dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	-
C4 sub'd naphthalene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
C4 sub'd phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01

TABLE I-2

SUMMARY TABLE OF CHEMICAL CONCENTRATIONS (µg/g) IN FISH

CHEMICAL	BACKGROUND			TREATMENT		
	Athabasca River Baseline[1]	Rainbow Trout[2]	Walleye[3]	Rainbow Trout[4]	Walleye[5]	Rainbow Trout[6]
	Athabasca River Water	Athabasca River Water	Athabasca River Water	10% TID Water	10% TID Water	Syncrude Pond #5
Chrysene	-	-	-	-	-	<0.00007
Dibenzo(a,h)anthracene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.002
Dibenzothiophene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.01
Fluoranthene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Fluorene	<0.02	<0.02	<0.02	<0.02	<0.02	0.003
Indeno(c,d-123)pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Methyl acenaphthene	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl benzo(b&k)fluoranthene/ benzo(a)pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl biphenyl	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl dibenzothiophene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
Methyl fluoranthene/pyrene	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl fluorene	<0.04	<0.04	<0.04	<0.04	<0.04	-
Methyl naphthalene	<0.02-0.03	0.03	<0.02	0.03	<0.02	0.006
Methyl phenanthrene/anthracene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.01
Naphthalene	<0.02-0.04	0.02	<0.02	0.03	<0.02	0.0051
Perylene	-	-	-	-	-	<0.0012
Phenanthrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001
Pyrene	<0.02	<0.02	<0.02	<0.02	<0.02	<0.0008
Polycyclic Aromatic Nitrogen Heterocycles						
7-Methyl quinoline	<0.02	<0.02	<0.02	<0.02	<0.02	-
Acridine	<0.02	<0.02	<0.02	<0.02	<0.02	-
C2 Alkyl subst'd carbazoles	<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	-
C3 Alkyl subst'd quinolines	<0.02	<0.02	<0.02	<0.02	<0.02	-
Carbazole	<0.02	<0.02	<0.02	<0.02	<0.02	-

TABLE I-2

SUMMARY TABLE OF CHEMICAL CONCENTRATIONS (µg/g) IN FISH

CHEMICAL	BACKGROUND			TREATMENT		
	Athabasca River Baseline[1]	Rainbow Trout[2]	Walleye[3]	Rainbow Trout[4]	Walleye[5]	Rainbow Trout[6]
	Athabasca River Water	Athabasca River Water	Athabasca River Water	10% TID Water	10% TID Water	Syncrude Pond #5
Methyl acridine	<0.02	<0.02	<0.02	<0.02	<0.02	-
Methyl carbazoles	<0.02	<0.02	<0.02	<0.02	<0.02	-
Phenanthridine	<0.02	<0.02	<0.02	<0.02	<0.02	-
Quinoline	<0.02	<0.02	<0.02	<0.02	<0.02	-
INORGANICS						
General			-	-	-	-
Calcium	246-680	2260	7090	261	7660	-
Magnesium	277-331	380	457	302	371	-
Phosphorus	2140-2960	3620	6060	2640	5820	-
Potassium	3950-5190	4840	5090	4880	4390	-
Sodium	338-409	471	635	480	748	-
Metals and Trace Elements						
Aluminum	<2-11	18	14	12	12	-
Arsenic	<0.5	<0.1	2.3	<0.1	1.1	-
Barium	<0.5	<0.5	0.9	<0.5	0.9	-
Beryllium	<0.5	<1	<1	<1	<1	-
Boron	<5	<5	<5	<5	<5	-
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	-
Chromium	<0.5	<0.5	<0.5	<0.5	<0.5	-
Cobalt	<0.5	<1	<1	<1	<1	-
Copper	<1-2	<1	<1	<1	<1	-
Iron	7-16	23	8	4	<1	-
Lead	<2	<5	<5	<5	<5	-
Manganese	<0.5-0.9	0.9	5.1	0.2	6.1	-
Mercury	-	0.04	0.45	0.03	0.44	-
Molybdenum	<1	<1	<1	<1	<1	-
Nickel	<1-2	<2	<2	<2	<2	-

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SUMMARY TABLE OF CHEMICAL CONCENTRATIONS (μg/g) IN FISH

	BACKGROUND			TREATMENT		
	Athabasca River Baseline[1]	Rainbow Trout[2]	Walleye[3]	Rainbow Trout[4]	Walleye[5]	Rainbow Trout[6]
CHEMICAL	Athabasca River Water	Athabasca River Water	Athabasca River Water	10% TID Water	10% TID Water	Syncrude Pond #5
Selenium	<0.5-0.3	0.3	0.4	<0.4	0.4	-
Silicon	4-12	<50	<50	<50	<50	-
Silver	-	<1	<1	<1	<1	-
Strontium	<0.5-0.9	2	8	<1	8	-
Thallium	<1	<1	<1	<1	<1	-
Tin	<2	<5	<5	<5	<5	-
Vanadium	<1	<1	<1	<1	<1	-
Zinc	5-6	8.9	17.2	10.3	17.5	-

[1]Athabasca River 1995 Baseline data from Golder (1996a).
Data are ranges of composite samples based on filets from 10 fish/composite, separated by gender and species (walleye, goldeye and longnose sucker; n=5-6).
[2]Data from HydroQual (1996). Fish were held for 28 days in Athabasca River water (n=1).
[3]Data from HydroQual (1996). Fish were held for 28 days in Athabasca River water (n=1).
[4]Data from HydroQual (1996). Fish were held for 28 days in 10% Tar Island Dyke Water (n=1).
[5]Data from HydroQual (1996). Fish were held for 28 days in 10% Tar Island Dyke Water (n=1).
[6]Data from Syncrude Canada Ltd., (unpublished data). Fish were held for 10 weeks in water from Syncrude Pond #5 (n=1).