Shell Canada Limited

application for the approval of

MUSKEG RIVER MINE PROJECT

Volume 3 • Environmental Impact Assessment

Biophysical and Historical Resources
Part 2: Supplements

submitted to
Alberta Energy and Utilities Board
and to
Alberta Environmental Protection

Calgary,
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SYMBOLS AND ABBREVIATIONS	
7Q10	Lowest 7-day consecutive flow that occurs, on average, once every 10 years
''	Inch
<	Less than
>	Greater than
%	Percent
°C	Temperature in degrees Celsius
°F	Temperature in degrees Fahrenheit
$k	Thousand dollars
µg/L	Micrograms per litre
$\mu g/m^3$	Micrograms per cubic metre
AAC	Annual Allowable Cut
ABDC	Aboriginal Business Development Committee
AEOSRD	Alberta Energy Oil Sands and Research Division
AEP	Alberta Environmental Protection
AEP-LFS	Alberta Environmental Protection - Land and Forest Service
AEPEA	Alberta Environmental Protection and Enhancement Act
AEUB	Alberta Energy and Utilities Board
Al-Pac	Alberta-Pacific Ltd.
AMD	Air Monitoring Directive
AOSERP	Alberta Oil Sands Environmental Research Program
AOSTRA	Alberta Oil Sands Technical Research Authority
API	American Petroleum Institute
APL	Alberta Power Limited
ARC	Alberta Research Council
asl or ASL	Above sea level
ATP	AOSTRA Taciuk Process
avg.	Average
bbl	Barrel, petroleum (42 U.S. gallons)
bpcd	Barrels per calendar day
BCM	Bank cubic metres
BCY	Bank cubic yards
BOD	Biochemical Oxygen Demand
C	Carbon

SYMBOLS AND ABBREVIATIONS	
C&R	Conservation and Reclamation
Ca	Calcium
$CaCO_3$	Calcium carbonate
CCME	Canadian Council of Ministers of the Environment
$CaSO_4$	Calcium sulphate
CANMET	Canada Centre for Mineral and Energy Technology
cd	Calendar day
CEA	Cumulative effects assessment
CEC	Cation exchange capacity
CEPA	Canadian Environmental Protection Act
ch	Calendar hour
CHWE	Clark Hot Water Extraction
CLI	Canada Land Inventory
cm	Centimetre
cm^2	Square centimetres
cm/s	Centimetres per second
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COH	Co-efficient of haze
Conif.	Coniferous
CONRAD	Canadian Oil Sands Network for Research and Development
Consortium	Fine Tailings Fundamentals Consortium
CPUE	Catch per unit of effort
CSA	Canadian Standards Association
CSEM	Continuous Stack Emissions Monitor
CT	Consolidated Tailings
CWQG	Canadian Water Quality Guidelines
d	Day
DBH	Diametre at breast height
Decid.	Deciduous
DL	Detection limit
DEM	Digital elevation model
DO	Dissolved oxygen
DRU	Diluent Recovery Unit
EC	Effective Concentration

SYMBOLS AND ABBREVIATIONS	
e.g.	For example
EIA	Environmental Impact Assessment
ELC	Ecological Land Classification
elev	Elevation
EPA	Environmental Protection Agency (U.S.)
EPL	End Pit Lake
ER	Exposure ratio
FEM	Finite Element Modelling
FGD	Flue Gas Desulphurization
FMA	Forest Management Agreement
ft.	Feet
$ft.^3$	Cubic feet
g	Grams
g/cc	Grams per cubic centimetre
GC/FID	Gas Chromatography/Flare Ionization Detection
GC/MS	Gas Chromatography/Mass Spectrometry
GDP	Gross Domestic Product
GIS	Geographic Information System
GJ	Gigajoules
GLC	Ground Level Concentration
Golder	Golder Associates Ltd.
h	Hour
ha	Hectares
HQ	Hazard quotient
HSI	Habitat suitability index
H_2S	Hydrogen sulphide
HU	Habitat unit
ibid.	In the same place
i.e.	That is
IC	Inhibiting concentration
ICP	Inductively coupled argon plasma atomic emission spectrometric analysis
IR	Infrared spectrophotometric analysis
IRIS	Integrated Risk Information System
IRP	Integrated Resource Plan
k or K	Thousand

SYMBOLS AND ABBREVIATIONS	
kg	Kilogram
kg/d	Kilograms per day
kg/ha	Kilograms per hectare
kg/h	Kilograms per hour
KIRs	Key Indicator Resources
km	Kilometre
km^2	Square kilometres
km^3	Thousand cubic metres
KV	Kilovolt
L or l	Litre
LC/MS	Liquid Chromatography/Mass Spectrometry
LGHR	Low grade heat recovery
lb/hr	Pounds per hour
LC	Lethal concentration
LOAEL	Lowest observed adverse effect level
LOEL	Lowest observed effect level
LSA	Local Study Area
m	Metre
M	Million
m/s	Metres per second
m^2	Square metres
m^3	Cubic metres
m^3/ha	Cubic metres per hectare
m^3/cd	Cubic metres per calendar day
m^3/d	Cubic metres per day
m^3/hr	Cubic metres per hour
m^3/s	Cubic metres per second
Mm^3	Million cubic metres
meq	Milliequivalents
MFT	Mature Fine Tails
mg	Milligrams
mg/kg/d	Milligrams per kilogram body weight per day
mg/L	Milligrams per litre
MJ	Megajoule
MLA	Member of the Legislative Assembly
mm	Millimetre
Mobil	Mobil Oil Canada
MP	Member of Parliament

SYMBOLS AND ABBREVIATIONS	
mS/cm	millisiemens per centimetre
MVA	Megavolt amperes
MW	Megawatt
N	Nitrogen
N/A or n/a	Not applicable
NAQUADAT	Alberta Environmental Historical Water Database
n.d.	No date
N.D.	No data
No.	Number
NOAEL	No observed adverse effect level
NOEL	No Observable Effect Level
NO_x	Oxides of nitrogen
NPRI	National Pollutant Release Inventory
NRBS	Northern River Basin Study
O & G	Oil and Grease
OSEC	Oil Sands Environmental Coalition
OSLO	Other Six Lease Owners
OSWRTWG	Oil Sands Water Release Technical Working Group
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbons
PANH	Polycyclic Aromatic nitrogen heterocycles
PASH	Polycyclic aromatic sulphur heterocycles
PM_{10}	Particulate matter $\leq$ 10 microns in diameter
$PM_{2.5}$	Particulate matter $\leq$ 2.5 microns in diameter
PMF	Probable maximum flood
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
Q	Quarter (i.e., 3 months of a year)
QA/QC	Quality Assurance/Quality Control
RSA	Regional Study Area
RAQCC	Regional Air Quality Coordinating Committee
RfD	Reference dose
RsD	Risk Specific dose

SYMBOLS AND ABBREVIATIONS	
RRTAC	Reclamation Research Technical Advisory Committee
s	Second
S	Sulphur
SAGD	Steam Assisted Gravity Drainage
SAR	Sodium absorption ratio
scf/d	Standard cubic feet per day
SCO	Synthetic crude oil
SEC	Supplementary Emission Control
SFR	Sand to fines ratio
SLC	Screening level criteria
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SO_4	Sulphate
spp.	Species
Suncor	Suncor Energy Inc., Oil Sands
Syncrude	Syncrude Canada Ltd.
t	Tonne
t/cd	Tonnes per calendar day
t/d	Tonnes per day
TDS	Total dissolved solids
THC	Total hydrocarbons
TID	Tar Island Dyke
TIE	Toxicity identification evaluation
TKN	Total Kjeldahl Nitrogen
TOC	Total organic carbon
TofR	Terms of Reference
Ton	2000 pounds (Imperial)
Tonne	2205 pounds (Metric)
t/h	Tonnes per hour
TRV	Toxicity reference value
TSS	Total suspended solids
TV/BIP	Ratio of total volume removed to total volume of bitumen in place
Twp	Township
$\mu g/m^3$	microgram per cubic metre
$\mu g/L$	microgram per litre
$\mu g/kg/d$	microgram per kilogram body weight per day
UTF	Underground test facility

SYMBOLS AND ABBREVIATIONS	
USEPA	U.S. Environmental Protection Agency
USgpm	U.S. gallons per minutes
VOC	Volatile organic compound
Vol.	Volume
vs.	Versus
wt%	Weight percentage
y	Year

Abiotic	Non-living factors that influence an ecosystem, such as climate, geology and soil characteristics.
Activity Area	A limited portion of a site in which a specialized cultural function was carried out, such as hide scraping, tool manufacture, food preparation and other activities.
Adverse Effect	An undesirable or harmful effect to an organism (human, animal or plant), indicated by some result such as mortality, growth inhibition, reproductive abnormalities, altered food consumption, altered body and organ weights, altered enzyme concentrations, visible pathological changes or carcinogenic effects.
Age-to-maturity	Most often refers to the age at which more than 50% of the individuals of a particular sex within a popuation reach sexual maturity. Age-to-maturity of individuals within the same population can vary considerably from the population median value. In fish species, males often reach sexual maturity at a younger age than female.
Airshed	Describes the geographic area requiring unified management for achieving air pollution control.
Alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.
Alluvium	Sediment deposited in land environments by streams.
Ambient	The conditions surrounding an organism or area.
AOSERP	Alberta Oil Sands Environmental Research Program.
Aquifer	A body of rock or soil that contains sufficient amounts of saturated permeable material to yield economic quantities of water to wells or springs.
Archaeology	The scientific discipline responsible for studying the unwritten portion of man's historic and prehistoric past.
Armouring	Channel erosion protection by covering with protection material.
Artifact	Any portable object modified or manufactured by man.
Aspect	Compass orientation of a slope as an inclined element of the ground surface.
ASWQO	Alberta Surface Water Quality Objectives. Numerical concentrations or narrative statements established to support and protect the designated uses of water. These are minimum levels of quality, developed for Alberta watersheds, below which no waterbody is permitted to deteriorate. These objectives were established as minimum levels that would allow for the most sensitive use. These concentrations represent a goal to be achieved or surpassed.
Available Drawdown	The vertical distance that the equipotential surface of an aquifer can be lowered; in confined aquifers, this is to the top of the aquifer; in unconfined aquifers, this is to the bottom of the aquifer.

Background	An area not influenced by chemicals released from the site under evaluation.
Background Concentration (environmental)	The concentration of a chemical in a defined control area during a fixed period before, during or after data-gathering.
Backwater	Discrete, localized area exhibiting reverse flow direction and, generally lower stream velocity than main current; substrate similar to adjacent channel with more fines.
Baseline	A surveyed condition that serves as a reference point on which later surveys are coordinated or correlated.
Beaver River Sandstone	A light gray, medium to fine-grained quartz sandstone cemented in a silica matrix.
Bedrock	The body of rock that underlies the gravel, soil or other superficial material.
Benthic Invertebrates	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the river. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the open water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.
Bile	An alkaline secretion of the vertebrate liver. Bile, which is temporarily stored in the gall bladder, is composed of organic salts, excretion products and bile pigments. It primarily functions to emulsify fats in the small intestine.
Bioaccumulation	A general term meaning that an organism stores within its body a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate salt 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.
Biodiversity	The variety of organisms and ecosystems that comprise both the communities of organisms within particular habitats and the physical conditions under which they live.
Biological Indicators	Any biological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.
Biomarker	Biomarker refers to a chemical, physiological or pathological measurement of exposure or effect in an individual organism from the laboratory or the field. Examples include: contaminants in liver enzymes, bile and sex steroids.

Biome	A major community of plants and animals such as the boreal forest or tundra biome.
Biotic	The living organisms in an ecosystem.
Bitumen	A highly viscous, tarry, black hydrocarbon material having an API gravity of about 9° (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80 to 85% of the elemental composition of bitumen, hydrogen - 10%, sulphur - 5%, and nitrogen, oxygen and trace elements the remainder.
BOD	The biochemical oxygen demand (BOD) determination is an imperical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters.
Bottom Sediments	Substrates that lie at the bottom of a body of water. For example, soft mud, silt, sand, gravel, rock and organic litter, that make up a river bottom.
Bottom-feeding Fish	Fish that feed on the substrates and/or organisms associated with the river bottom.
Cancer	A disease characterized by the rapid and uncontrolled growth of aberrant cells into malignant tumours.
Canopy	An overhanging cover, shelter or shade; the tallest layer of vegetation in an area.
Carcinogen	An agent that is reactive or toxic enough to act directly to cause cancer.
Centre Reject	A non bituminous baring material found within a central zone of the oil sand ore body.
Chert	A fine-grained siliceous rock. Impure variety of chalcedony that is generally light-coloured.
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 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.
Chronic Toxicity Unit (TU_c)	Measurement of long duration toxicity that produces an adverse effect on organisms.
Climax	The culminating stage in plant succession for a given site where the vegetation has reached a stable condition.
Cline	A gradual change in a feature across the distributional range of a species or population.
Closure	The point after shutdown of operations when regulatory certification is received and the area is returned to the Crown.
Community	Pertaining to plant or animal species living in close association or interacting as a unit.
Composite Tailings	A non-segregating mixture made by Syncrude Canada Ltd. of oil sands extraction tailings that consolidates relatively quickly in deposits. Composed of sand tailings, mature fine tailings and a chemical stabilizer (e.g., $CaSO_4$).

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 the populations potentially at risk along with the relevant exposure pathways and scenarios.
Condition Factor	A measure of the relative "fitness" of an individual or population of fishes by examining the mathematical relationship between length and weight. The values calculated show the relationship between growth in length relative to growth in weight. In populations where increases in length are matched by increases in weight, the growth is said to be isometric. Allometric growth, the most common situation in wild populations, occurs when increases in either length or weight are disproportionate.
Conductivity	A measure of a waterbody's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides the limnologist with an estimation of the total concentration of dissolved ionic matter in the water. It allows for a quick check of the alteration of total water quality due to the addition of pollutants to the water.
Confined Aquifer	An aquifer in which the potentiometric surface is above the top of the aquifer.
Conifers	White and black spruce, balsam fir, jack pine and tamarack.
Conservative Approach	Approach taken to incorporate protective assumptions to ensure that risks will not be underestimated.
Consolidated Tailings (CT)	Consolidated Tailings (CT) is a non-segregating mixture of oil sands extraction tailings that consolidates relatively quickly in deposits. Consolidated tailings are prepared by combining mature fine tails with thickened (cycloned) fresh sand tailings. This mixture is chemically stabilized using gypsum ($CaSO_4$) to prevent segregation of the fine and coarse mineral solids.
Consolidated Tailings Release Water	Water expelled from Consolidated Tailings mixtures during consolidation.
Consolidation	The gradual reduction in volume of a soil or semi-solid mass.
Contaminant Body Burdens	The total concentration of a contaminant found in either whole-body or individual tissue samples.
Contaminants	A general term referring to any chemical compound added to a receiving environment in excess of natural concentrations. The term includes chemicals or effects not generally regarded as "toxic," such as nutrients, colour and salts.
Control	A treatment in a toxicity test that duplicates all the conditions of exposure treatments but contains no test material. The control is used to determine basic test conditions in the absence of toxicity (e.g., health of test organisms, quality of dilution water).
Crop Tree Regeneration	The renewal of a forest or stand of trees by natural or artificial means, usually white spruce, jack pine or aspen.
Culture	The sum of man's non-biological behavioural traits: learned, patterned and adaptive.

CWQG	Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.
Darcy's Law	A law describing the rate of flow of water through porous media. (Named for Henry Darcy of Paris who formulated it in 1856 from extensive work on the flow of water through sand filter beds.)
Depressurization	The process of reducing the pressure in an aquifer, by withdrawing water from it.
DEM (Digital Elevation Model)	A three-dimensional grid representing the height of a landscape above a given datum.
Dendritic Drainage Pattern	A drainage pattern characterized by irregular branching in all directions with the tributaries joining the main stream at all angles.
Deposit	Material left in a new position by a natural transporting agent such as water, wind, ice or gravity, or by the activity of man.
Depuration	To free from impurities; to cleanse.
Detection Limit (DL)	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Deterministic	Risk approach using a single number from each parameter set in the risk calculation and producing a single value of risk.
Detoxification	To decrease the toxicity of a compound. Bacteria decrease the toxicity of resin and fatty acids in mill effluent by metabolizing or breaking down these compounds; enzymes like the EROD or P4501A proteins begin the process of breaking down and metabolizing many "oily" compounds by adding an oxygen atom.
Development Area	Any area altered to an unnatural state. This represents all land and water areas included within activities associated with development of the oil sands leases.
Diameter at breast height (DBH)	The diameter of a tree 1.5 m above the ground on the uphill side of the tree.
Discharge	In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).
Disclimax	A type of climax community that is maintained by either continuous or intermittent disturbance to a severity that the natural climax vegetation is altered.
Disturbance (Historic)	A cultural deposit is said to be disturbed when the original sequence of deposition has been altered. Examples of agents of disturbance include erosion, plant or animal activity, cultivation and excavations.
Disturbance (Terrestrial)	A force that causes significant change in structure and/or composition of a habitat.
Diversity	The variety, distribution and abundance of different plant and animal communities and species within an area.

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.
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 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.
Drainage Basin	The total area that contributes water to a stream.
Ecological Land Classification	A means of classifying landscapes by integrating landforms, soils and vegetation components in a hierarchical manner.
Ecoregion	Ecological regions that have broad similarities with respect to soil, terrain and dominant vegetation.
Ecosection	Clearly recognizable landforms such as river valleys and wetlands, at a broad level of generalization.
Ecosite	Subdivisions of the ecosection described and analyzed in greater detail (e.g., subdivisions of the river valley). The focus at this level is on specific vegetation associations (e.g., wetlands shrub) and the particular soil, drainage and site conditions that support it.
Ecosystem	An integrated and stable association of living and nonliving resources functioning within a defined physical location.
Edaphic	Referring to the soil. The influence of the soil on plant growth is referred to as an edaphic factor.
Edge	Where plant communities meet.
Effects Assessment	The process of determining the amount (concentration or dose) of a chemical to which a receptor may be exposed without the development of adverse effects.
Effluent	Stream of water discharging from a source.
Environmental Impact Assessment	A review of the effects that a proposed development will have on the local and regional environment.
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.
Ephemeral	A phenomenon or feature that last only a short time (i.e., an ephemeral stream is only present for short periods during the year).
ER (Exposure Ratio)	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.

EROD	Ethoxyresorufin-O-deethylase (EROD) are enzymes that can increase in concentration and activity following exposure of some organisms to chemicals such as polycyclic aromatic hydrocarbons. EROD measurement indirectly measures the presence of catalytical proteins that remove a CH_3CH_2-group from the substrate ethoxyresorufin.
Escarpment	A cliff or steep slope at the edge of an upland area. The steep face of a river valley.
Exposure	The contact reaction between a chemical and a biological system, or organism.
Exposure Assessment	The process of estimating the amount (concentration or dose) of a chemical that is taken up by a receptor without the development of adverse effects.
Exposure Concentration	The concentration of a chemical in its transport or carrier medium at the point of contact.
Exposure Limit or Toxicity Reference Value	For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical that a specified receptor can be exposed to, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed to, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as a toxicity reference value.
Exposure Pathway or Route	The route by which a receptor comes into contact with a chemical or physical 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) or Hazard Quotient (HQ)	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. Also referred to as hazard quotient (HQ).
Exposure Scenario	A set of facts, assumptions and inferences about how exposure takes place, that helps the risk assessor evaluate, estimate and quantify 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.
Fauna	An association of animals living in a particular place or at a particular time.
Fecundity	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Filter-Feeders	Organisms that feed by straining small organisms or organic particles from the water column.

Filterable Residue	Materials in water that pass through a standard-size filter (often 0.45 mm). This is a measure of the "total dissolved solids" (TDS), i.e., chemicals that are dissolved in the water or that are in a particulate form smaller than the filter size. These chemicals are usually salts, such as sodium ions and potassium ions.
Fine Tailings	A suspension of fine silts, clays, residual bitumen and water that forms in the course of bitumen extraction from oil sands using the hot water extraction process. This material segregates from coarse sand tailings during placement in tailings ponds and accumulates in a layer, referred to as fine tailings, that dewaters very slowly. The top of the fine tailings deposit is typically about 85% water, 13% fine minerals and 2% bitumen by weight.
Fines	Silt and clay particles.
Fish Health Parameters	Parameters used to indicate the health of an individual fish. May include, for example, short-term response indicators such as changes in liver mixed function oxidase activity and the levels of plasma glucose, protein and lactic acid. Longer-term indicators include internal and external examination of exposed fish, changes in organ characteristics, hematocrit and hemoglobin levels. May also include challenge tests such as disease resistance and swimming stamina.
Fisheries Act	Federal legislation that protects fish habitat from being altered, disrupted or destroyed by chemical, physical or biological means. Destruction of the habitat could potentially undermine the economic, employment and other benefits that flow from Canada's fisheries resources (DFO 1986).
Floodplain	Land near rivers and lakes that may be inundated during seasonally high water levels (i.e., floods).
Flue Gas Desulphurization (FGD)	A process involving removal of a substantial portion of sulphur dioxide from the combustion gas (flue gas) formed from burning petroleum coke. Desulphurization is accomplished by contacting the combustion gases with a solution of limestone. Gypsum ($CaSO_4$) is formed as a byproduct of this process.
Fluvial	Relating to a stream or river.
Food Chain Transfer	A process by which materials accumulate in the tissues of lower trophic level organisms and are passed on to higher trophic level organisms by dietary uptake.
Forage Area	The area used by an organism for hunting or gathering food.
Forage Fish	Small fish that provide food for larger fish (e.g., longnose sucker, fathead minnow)
Forb	Broadleaved herb, as distinguished from grasses.
Forest	A collection of stands of trees that occur in similar space and time.
Forest Fragmentation	The change in the forest landscape, from extensive and continuous forests.
Forest Landscape	Forested or formerly forested land not currently developed for non-forest use.
Forest Succession	The orderly process of change in a forest as one plant community or stand condition is replaced by another, evolving toward the climax type of vegetation.

Fragmentation	The process of reducing size and connectivity of stands of trees that compose a forest.
Froth	Air-entrained bitumen with a froth-like appearance that is the product of the primary extraction step in the hot water extraction process.
Fugitive Emissions	Contaminants emitted from any source except those from stacks and vents. Typical sources include gaseous leakages from valves, flanges, drains, volatilization from ponds and lagoons, and open doors and windows. Typical particulate sources include bulk storage areas, open conveyors, construction areas or plant roads.
Geomorphic	Pertaining to natural evolution of surface soils and landscape over long periods.
Geomorphical Processes	The origin and distribution of landforms, with the emphasis on the nature of erosional processes.
Geomorphology	That branch of science that deals with the form of the earth, the general configurations of its surface, and the changes that take place in the evolution of landforms.
GIS	Geographic Information System. Pertains to a type of computer software that is designed to develop, manage, analyze and display spatially referenced data.
Glacial Till	Unsorted and unstratified glacial drift, generally unconsolidated, deposited directly by a glacier without subsequent reworking by water from the glacier. Consisting of a heterogeneous mixture of clay, silt, sand, gravel and boulders (i.e., drift) varying widely in size and shape.
Glaciolacustrine	Relating to the lakes that formed at the edge of glaciers as the glaciers receded. Glaciolacustrine sediments are commonly laminar deposits of fine sand, silt and clay.
Golder	Golder Associates Ltd.
Gonads	Organs responsible for producing haploid reproductive cells in multicellular cells in multicellular animals. In the male, these are the testes and in the female, the ovaries.
Groundtruth	Conductive site visits to confirm accuracy of remotely sensed information.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Groundwater Level	The level below which the rock and subsoil, to unknown depths, are saturated.
Groundwater Regime	Water below the land surface in a zone of saturation.
Groundwater Velocity	The speed at which groundwater advances through the ground. In this document, the term refers to the average linear velocity of the groundwater.
GSI	Gonad-Somatic Index. The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total gonad weight by the total body weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
Guild	A set of coexisiting species that share a common resource.

Habitat	The place where an animal or plant naturally or normally lives and grows, for example, a stream habitat or a forest habitat.
Hazard	A condition with the potential for causing an undesirable consequence.
Head	The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. It is used in various compound terms such as pressure head, velocity head and loss of head.
Herb	Tender plant, lacking woody stems, usually small or low; it may be annual or perennial, broadleaf (forb) or graminoid (grass).
Heterogeneity	Variation in the environment over space and time.
Histology/ Histological	The microscopic study of tissues.
Historical Resources Impact Assessment	A review of the effects that a proposed development will have on the local and regional historic and prehistoric heritage of an area.
Historical/Heritage Resources	Works of nature or of man, valued for their palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific, or aesthetic interest.
Hydraulic Conductivity	The permeability of soil or rock to water.
Hydraulic Gradient	A measure of the force of moving groundwater through soil or rock. It is measured as the rate of change in total head per unit distance of flow in a given direction. Hydraulic gradient is commonly shown as being dimensionless, since its units are m/m.
Hydraulic Head	The elevation, with respect to a specified reference level, at which water stands in a piezometer connected to the point in question in the soil. Its definition can be extended to soil above the water table if the piezometer is replaced by a tensiometer. The hydraulic head in systems under atmospheric pressure may be identified with a potential expressed in terms of the height of a water column. More specifically, it can be identified with the sum of gravitational and capillary potentials, and may be termed the hydraulic potential.
Hydraulic Structure	Any structure designed to handle water in any way. This includes retention, conveyance, control, regulation and dissipation of the energy of water.
Hydrogeology	The study of the factors that deal with subsurface water (groundwater), and the related geologic aspects of surface water.
ICP (Metals)	Inductively Coupled Plasma (Atomic Emission Spectroscopy). This analytical method is a U.S. EPAdesignated method (Method 6010). The method determines elements within samples of groundwater, aqueous samples, leachates, industrial wastes, soils, sludges, sediments and other solid wastes. Samples require chemical digestion before analysis.

Induction	Response to a biologically active compound — involves new or increased gene expression resulting in enhanced synthesis of a protein. Such induction is commonly determined by measuring increases in protein levels and/or increases in the corresponding enzyme activity. For example, induction of EROD would be determined by measuring increases in cytochrome P4501A protein levels and/or increases in EROD activity.
Inorganics	Pertaining to a compound that contains no carbon.
Integrated Resource Management	A coordinated approach to land and resource management, which encourages multiple-use practices.
Interspersion	The percentage of map units containing categories different from the map unit surrounding it.
Isolated Find	The occurrence of a single artifact with no associated artifacts or features.
KIRs	Key indicator resources are the environmental attributes or components identified as a result of a social scoping exercise as having legal, scientific, cultural, economic or aesthetic value.
Landform	General term for the configuration of the ground surface as a factor in soil formation; it includes slope steepness and aspect as well as relief. Also, configurations of land surface taking distinctive forms and produced by natural processes (e.g., hill, valley, plateau).
LANDSAT	A specific satellite or series of satellites used for earth resource remote sensing. Satellite data can be converted to visual images for resource analysis and planning.
Landscape	A heterogeneous land area with interacting ecosystems.
Landscape Diversity	The size, shape and connectivity of different ecosystems across a large area.
Leaching	The removal, by water, of soluble matter from regolith or bedrock.
Lean Oil Sands	Oil bearing sands, which do not have a high enough saturation of oil to make extraction of them economically feasible.
Lesions	Pathological change in a body tissue.
Lethal	Causing death by direct action.
Lipid	One of a large variety of organic fats or fat-like compounds, including waxes, steroids, phospholipids and carotenes. Refers to substances that can be extracted from living matter using hydrocarbon solvents. They serve several functions in the body, such as energy storage and transport, cell membrane structure and chemical messengers.
Littoral Zone	The zone in a lake that is closest to the shore.
Loading Rates	The amount of deposition, determined by technical analysis, above which there is a specific deleterious ecological effect on a receptor.
LOAEL	Lowest Observed Adverse Effect Level. In toxicity testing it is the lowest concentration at which adverse effects on the measurement end point are observed.
LOEC	Lowest Observed Effect Concentration. The lowest concentration in a medium that causes an effect that is a statistically significant difference in effect compared to controls.

LOEL	Lowest Observed Effect Level. In toxicity testing it is the lowest concentration at which effects on the measurement end point are observed.
LSI	Liver Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight.
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.
Mature Fine Tailings (MFT)	These are fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.
Mature Forest	A forest greater than rotation age with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; some with broken tops and other decay; numerous large snags and accumulations of downed woody debris.
Mature Stand	A stand of trees for which the annual net rate of growth has peaked.
Media	The physical form of the environmental sample under study (e.g., soil, water, air).
Mesic	Pertaining to, or adapted to an area that has an intermediate supply of water; neither wet not dry.
Metabolism	Metabolism is the total of all enzymatic reactions occurring in the cell; a highly coordinated activity of interrelated enzyme systems exchanging matter and energy between the cell and the environment. Metabolism involves both the synthesis and breakdown (catabolism) of individual compounds.
Metabolites	Organisms alter or change compounds in various ways, such as removing parts of the original or parent compound, or in other cases adding new parts. Then, the parent compound has been metabolized and the newly converted compound is called a metabolite.
MFO	Mixed Function Oxidase. A term for reactions catalyzed by the Cytochrome P450 family of enzymes, occurring primarily in the liver. These reactions transform organic chemicals, often altering toxicity of the chemicals.
Microclimate	The temperature, precipitation and wind velocity in a restricted or localized area, site or habitat.
Microtox^{c}	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Multilayered Canopy	Forest stands with two or more distinct tree layers in the canopy; also called multistoried stands.
NOAEL	No observed adverse effect level. No observed effect level. In toxicity testing, it is the highest concentration at which no adverse effects on the measurement end point are observed.

Node	Location along a river channel, lake inlet or lake outlet where flows, sediment yield and water quality have been quantified.
NOEC	No observed adverse effect concentration. The highest concentration in a medium that does not cause a statistically significant difference in effect as compared to controls.
NOEL	No observed effect level. In toxicity testing, it is the highest concentration at which no effects on the measurement end point are observed.
Non-Filterable Residue	Material in a water sample that does not pass through a standard size filter (often 0.45 mm). This is considered to represent "total suspended solids" (TSS), i.e., particulate matter suspended in the water column.
Noncarcinogen	A chemical that does not cause cancer and has a threshold concentration, below which adverse effects are unlikely.
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine-grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44mm) and a fines (<44mm) fraction, consisting of silts and clays.
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCO_3$).
Overburden	The soil, sand, silt or clay that overlies bedrock. In mining terms, this includes all material that has to be removed to expose the ore.
Overstory	Those trees that form the upper canopy in a multilayered forest.
Overwintering Habitat	Habitat used during the winter as a refuge and for feeding.
PAH(s)	Polycyclic Aromatic Hydrocarbon. A chemical byproduct of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.
Paleosol	A paleosol is a soil that was formed in the past. Paleosols are usually buried beneath a layer of sediments and are thus no longer being actively created by soil formation processes like organic decay.
PANH	Polycyclic Aromatic Nitrogen Heterocycle. See PAH.
PASH	Polycyclic Aromatic Sulphur Heterocycle.
Patch	This term is used to recognize that most ecosystems are not homogeneous, but rather exist as a group of patches or ecological islands that are recognizably different from the parts of the ecosystem that surround them but nevertheless interact with them.
Pathology	The science that deals with the cause and nature of disease or diseased tissues.

Performance Assessment	Prediction of the future performance of a reclaimed lease to allow identification of potential adverse effects with respect to geotechnical, geomorphic and ecosystem sustainability.
Permit Holder	The director of an Historical Resource Impact Assessment. Responsible for the satisfactory completion of all field and laboratory work and author of the technical report.
Physiological	Related to function in cells, organs or entire organisms, in accordance with natural processes of life.
Pictograph	Aboriginally painted designs on natural rock surfaces. Red ochre is the most frequently used pigment.
Piezometer	A pipe in the ground in which the elevation of water level can be measured.
Piezometric Surface	If water level elevations in wells completed in an aquifer are plotted on a map and contoured, the resulting surface described by the contours is known as a potentiometric or piezometric surface.
Plant Community	An association of plants of various species found growing together.
PM_{10}	Particulate matter in air that is ≤ 10 microns in diameter and represents the proportion of suspended particulates that is small enough to be inhaled into the lungs.
$PM_{2.5}$	Particulate matter in air that is ≤ 2.5 microns in diameter and can be inhaled into the lungs.
Polishing Pond	Pond where final sedimentation takes place before discharge.
Population	A collection of individuals of the same species that potentially interbreed.
Porewater	Water between the grains of a soil or rock.
Problem Formulation	The initial step in a risk assessment that focuses the assessment on the chemicals, receptors and exposure pathways of greatest concern.
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.
QA/QC Plan	Quality Assurance/Quality Control Plan.
Rearing Habitat	Habitat used by young fish for feeding and/or as a refuge from predators.
Receptor	The person or organism subjected to exposure to chemicals or physical agents.
Reclamation	The restoration of disturbed or waste land to a state of useful capability. Reclamation is the initiation of the process that leads to a sustainable landscape (see definition), including the construction of stable landforms, drainage systems, wetlands, soil reconstruction, addition of nutrients and revegetation. This provides the basis for natural succession to mature ecosystems suitable for a variety of end uses.
Reclamation Unit	A unique combination of reclamation conditions, namely surface shape, sub-base material, cover material and initial vegetation.

Regeneration	The natural or artificial process of establishing young trees.
Rejects	Hard clusters of clays or lean oil sands that do not pass sizing screens in the extraction process and are rejected. Rejects contain residual bitumen and account for a portion of extraction recovery loss.
Relative Abundance	The proportional representation of a species in a sample or a community.
Remote Sensing	Measurement of some property of an object or surface by means other than direct contact; usually refers to the gathering of scientific information about the earth's surface from great heights and over broad areas, using instruments mounted on aircraft or satellites.
Replicate	Duplicate analyses of an individual sample. Replicate analyses are used for measuring precision in quality control.
RfD (Reference Dose)	The maximum recommended daily exposure for a non-carcinogenic chemical exhibiting a threshold (highly nonlinear) dose-response based on the NOAEL determined for the chemical from human and/or animals studies and the use of an appropriate uncertainty factor.
Riffle Habitat	Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.
Riparian Area	A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affect it.
Risk	The likelihood or probability, that the toxic effects associated with a chemical or physical agent will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect at a given time and the total number of individuals exposed to the factor. Risk is expressed as a fraction without units and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.
Risk-Based Concentration (RBC)	Concentration in environmental media below which health risks are not expected to occur.
Risk Analysis	Quantification of predictions of magnitudes and probabilities of potential impacts on the health of people, wildlife and/or aquatic biota that might arise from exposure to chemicals originating from a study area.
Risk Assessment	Process that evaluates the probability of adverse effects that may occur, or are occurring on target organism(s) as a result of exposure to one or more stressors.
Risk Characterization	The process of evaluating the potential risk to a receptor based on comparison of the estimated exposure to the toxicity reference value.
Risk Management	The managerial, decision-making and active hazard control process used to deal with those environmental agents for which risk evaluation has indicated the risk is too high.
Robust Landscape	Landscape with either an capability to self-correct after extreme events or one with hazard triggers reducing with time.

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 q_1^*, 1×10^{-6}.
Run Habitat	Areas of swiftly flowing water, without surface waves, that approximate uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Run-on	Essentially the same as runoff, but referring to water that flows onto a property, or any piece of land of interest. Includes only those waters that have not been in contact with exposed oil sands, or with oil sands operational areas.
Saturation Percentage	Percent water content where the soil is completely saturated with water.
Scale	Level of spatial resolution.
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.
Secondary Extraction	In this step, bitumen froth from the primary extraction step is diluted with light hydrocarbon and water and fine solids are removed by centrifuges in stages.
Sediment Sampling	A field procedure relating to a method for determining the configuration of sediments.
Sedimentation	The process of subsidence and deposition of suspended matter carried by water, wastewater or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.
Shell	Shell Canada Limited
Silviculture	The science and practice of controlling the establishment, composition and growth of the vegetation in forest stands. It includes the control or production of stand structures such as snags and down logs, in addition to live vegetation.
Site [Human Health]	The area determined to be significantly impacted after the iterative evaluations of the risk assessment. Can also be applied to political or legal boundaries.
Site [Historic]	Any location with detectable evidence of past human activity.
Slumps	Small shallow slope failure involving relocation of surficial soil on a slope without risk to the overall stability the facility.
Snag	Any standing dead, or partially dead tree.
Snye	Discrete section on non-flowing water connected to a flowing channel only at its downstream end, generally formed in a side channel or behind a peninsula (bar).

Sodium Adsorption Ratio (SAR)	Concentrations of sodium, calcium and magnesium ions in a solution.
Soil Structure	The combination or arrangement of primary soil particles into secondary particles, units or peds.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
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.
Species Composition	A term that refers to the species found in the sampling area.
Species Distribution	Where the various species in an ecosystem are found at any given time. Species distribution varies with season.
Species Diversity	A description of a biological community that includes both the number of different species and their relative abundances. Provides a measure of the variation in number of species in a region. This variation depends partly on the variety of habitats and the variety of resources within habitats and, in part, on the degree of specialization to particular habitats and resources.
Species Richness	The number of different species occupying a given area.
Sport/Game Fish	Large fish caught for food or sport (e.g., northern pike, Arctic grayling).
Stand	An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement and condition so that it is distinguishable from trees in adjoining areas.
Stand Age	The number of years since a stand experienced a stand-replacing disturbance event (e.g., fire, logging).
Stand Density	The number and size of trees on a forest site.
Standard Deviation (Sd)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
Stratigraphy	The succession and age of strata of rock and unconsolidated material. Also concerns the form, distribution, lithologic composition, fossil content and other properties of the strata.
Strip Mining	Mining method in which overburden is first removed from a seam of coal, or a sedimentary ore such as oil sands, allowing the coal or ore to be removed.
Structure (Stand Structure)	The various horizontal and vertical physical elements of the forest. The physical appearance of canopy and subcanopy trees and snags, shrub and herbaceous strata and downed woody material.
Subchronic toxicity	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.
Succession	A series of dynamic changes by which one group of organisms succeeds another through stages leading to a climax community.

Successional Stage	A stage or recognizable condition of a forest community that occurs during its development from bare ground to climax.
Suncor	Suncor Energy Inc., Oil Sands
Surficial Aquifer	A surficial deposit containing water considered an aquifer.
Surficial Deposit	A geologic deposit (clay, silt or sand) that has been placed above bedrock. (See also "Overburden")
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Sustainable Landscape	Capability of landscape (including landforms, drainage, waterbodies and vegetation) to survive extreme events and natural cycles of change, without causing accelerated erosion and environmental impacts much more severe than that of the natural environment.
Syncrude	Syncrude Canada Ltd.
Tailings	A byproduct of oil sands extraction composed of water, sands and clays, with minor amounts of residual bitumen.
Tailings Ponds	Man-made impoundment structures required to contain tailings. Tailings ponds are enclosed by dykes made with tailings sand and/or overburden materials to stringent geotechnical standards.
TDS	Total dissolved solids. See filterable residue.
Thalweg	The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.
TID	Tar Island Dyke
Till	Sediments laid down by glaciers.
TOC	Total Organic Carbon. TOC is composed of both dissolved and particulate forms. TOC is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). TOC has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample.
Toxic	A substance, dose or concentration that is harmful to a living organism.
Toxic Threshold	Almost all compounds (except genotoxic carcinogens) 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. Genotoxic carcinogens exhibit some toxic potential at any level.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

Toxicity Reference Value (TRV)	For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical to which a specified receptor can be exposed, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as exposure limit.
TSP	Total suspended particulates. A measure of the total amount of suspended particulate matter in air.
TSS	Total suspended solids. See non-filterable residue.
U.S. EPA	U.S. Environmental Protection Agency.
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 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). The exposure limit (or toxicity reference value) equals the NOAEL divided by the uncertainty factor.
Unconfined Aquifer	An aquifer in which the water level is below the top of the aquifer.
Understory	Those trees or other vegetation in a forest stand below the main canopy level.
Upgraded Crude Oil	Often referred to as synthetic oil, upgraded crude oil is bitumen that has undergone alteration to improve its hydrogen-carbon balance to a lighter specific gravity product. Upgraded crude oil products may include: • Oil Sands A, a blend of low sulphur (hydrotreated) naphtha, kerosene and gas oil; • Oil Sands Diesel, hydrotreated kerosene; • Oil Sands E, a sour (higher sulphur) blend of coker distillate; and • Oil Sands Virgin, an uncracked vacuum tower product.
Uptake	The process by which a chemical crosses an absorption barrier and is absorbed into the body.
Vegetation Community	See plant community.
Waste Area	The area where overburden materials are placed that are surplus to the need of the mine. Also referred to as a "waste dump or stockpile."
Water Equivalent	As relating to snow; the depth of water that would result from melting.
Water Table	The shallowest saturated ground below ground level — technically, that surface of a body of unconfined groundwater in which the pressure is equal to atmospheric pressure.

Watershed	The entire surface drainage area that contributes water to a lake or river.
Wetlands	Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskegs, potholes, swales, glades, slashes and overflow land of river valleys.
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.
WSC	Water Survey of Canada
Xeric	Referring to habitats in which plant production is limited by availability of water.
YOY	Young of the year. Fish at age 0, within the first year after hatching.

APPENDIX IV

Hydrogeology Impact Analysis, Detailed Calculations

IV HYDROGEOLOGY IMPACT ANALYSIS, DETAILED CALCULATIONS

IV.1 Introduction

Potential hydrogeologic impacts from the proposed development that have been considered in the environmental impact assessment include:

- impacts on groundwater resources;
- changes in groundwater regimes that interact with surface waters in terms of quantity of flow; and
- effects on groundwater quality, particularly those that are subsequently transmitted to receiving surface waters.

These potential impacts from the Muskeg River Mine Project are discussed in detail in the body of the EIA report, in Sections IV3 and F3. The hydrogeologic setting and baseline information are included in section D3 of the EIA report.

The appendix includes details of specific groundwater discharge and seepage calculations that provided the data in Sections IV3 and F3 of the EIA report. Technical review and data analysis is included as part of the discussion in Sections IV3 and F3.

IV.2 Geologic Framework

The geologic framework of the Muskeg River Mine Project area is the starting point for many of the hydrogeologic analyses conducted for the Environmental Impact Assessment. Site geology was characterized by Shell Canada Limited, and provided to Komex in the form of geologic structure and isopach maps.

The distribution and characteristics of overburden material in the Muskeg River Mine Project area were estimated primarily from two maps:

- The thickness of surficial sand (Figure IV3-1) was used to estimate both the thickness of overburden material that would contribute to overburden dewatering and to assess seepage from backfilled mine pits and from the tailings settling pond.

- The Bedrock Topography map (Figure IV3-2) together with surface topography, provided an estimate of the total overburden thickness.

Structure and isopach maps for the Basal Aquifer (Figures IV3-3 and IV3-4, respectively) were used to generate cross-section models. The Basal Aquifer isopach map (Figure IV3-4) was used to estimate Basal Aquifer thickness in the mine area, for use in calculating transmissivity for Basal Aquifer depressurization. In many of the cross-section models, lean oil sands are present beneath the mine pit floor; the thickness of lean oil sands was incorporated into the models based on the isopach map (Figure IV3-5).

IV.3 Location of Model Cross-Sections

Eleven vertical cross-sections were developed for finite element modelling of the various pits within the Project area. The cross-section locations are shown in Figure IV3-6. In addition, one regional cross-section was developed for the external tailings setling pond structure, extending from the Athabasca River, across the tailings settling pond, to the Muskeg River. The location of this cross-section (7R) is shown in Figure IV3-6.

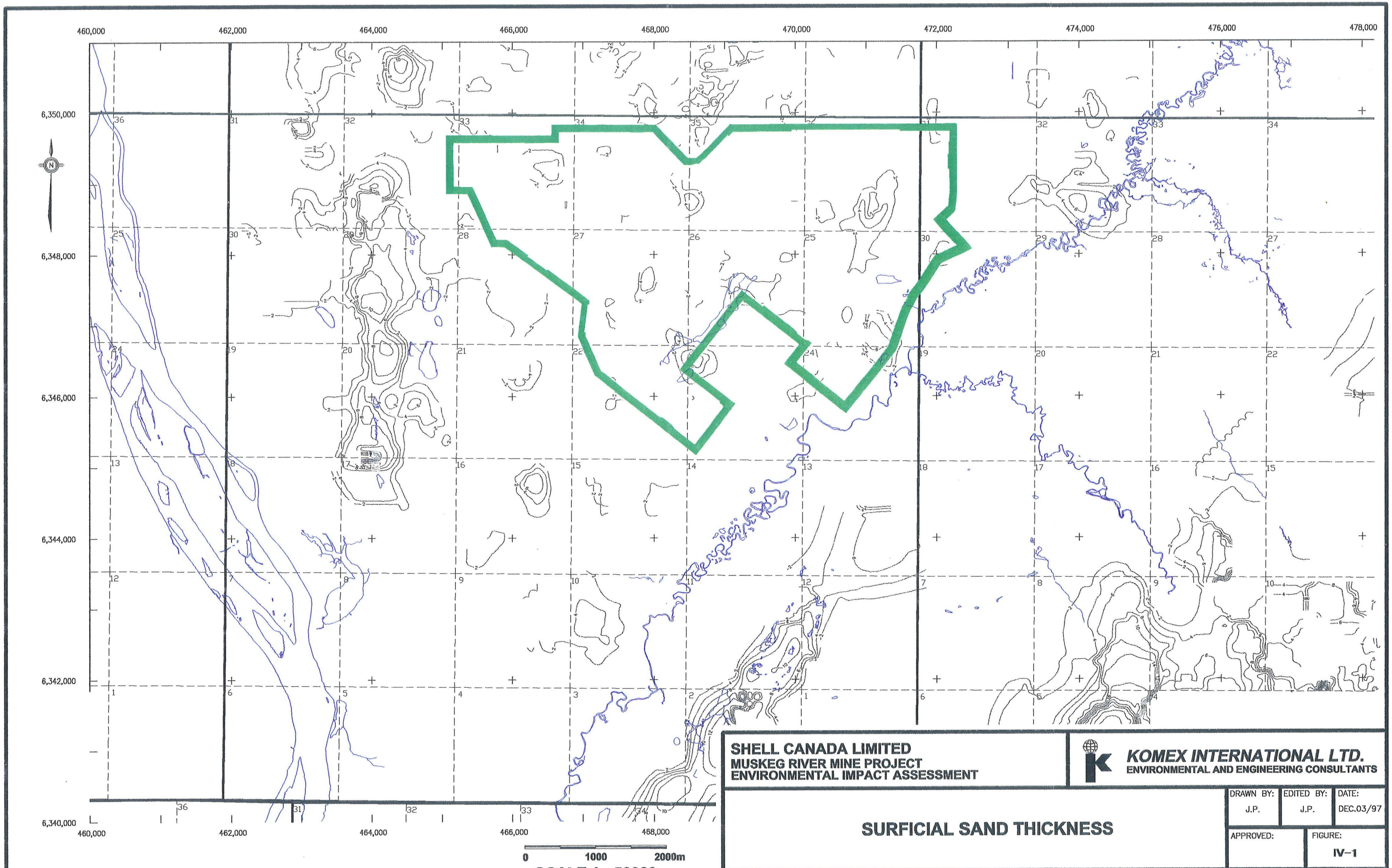
IV.4 OVERBURDEN DEWATERING CALCULATIONS

IV.4.1 Approach

The dewatering of surficial overburden is expected to be done by means of a series of ditches, collecting groundwater for discharge to the surface water management system. Most of the overburden that is dewatered is ultimately mined. Therefore, the groundwater collected by the dewatering system represents a finite volume. The volume of groundwater removed includes the amount released from storage in the overburden plus any natural recharge that may occur from precipitation during the dewatering period.

Six assumptions underlie the overburden dewatering calculations:

1. Groundwater collected from overburden dewatering and drainage is discharged to receiving streams.
2. Loss of baseflow to surface streams due to overburden dewatering is not calculated separately.
3. Groundwater inflow is calculated only for sand or sand and gravel deposits. Inflow from till or lacustrine sediments is assumed to be negligible.
4. Groundwater collected from overburden drainage has three components:
   (1) porewater that drains from overburden according to the specific yield of the aquifer material;
   (2) groundwater recharge from direct precipitation on the area being dewatered; and



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SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

SURFICIAL SAND THICKNESS

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J.P.	J.P.	DEC.03/97

APPROVED:

FIGURE: IV-1

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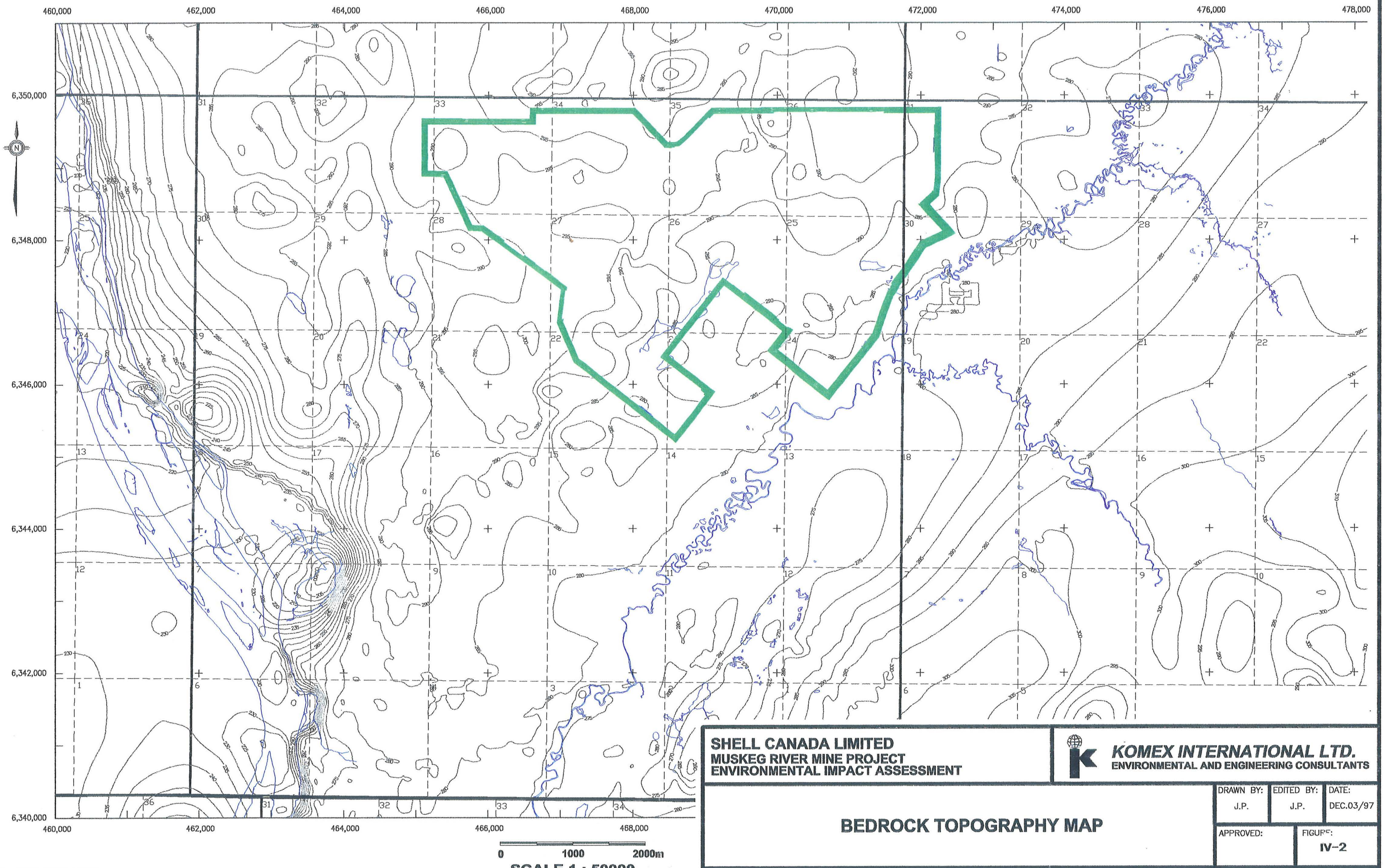

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ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LTD.
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BEDROCK TOPOGRAPHY MAP

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J.P.	J.P.	DEC.03/97

APPROVED:	FIGURE:
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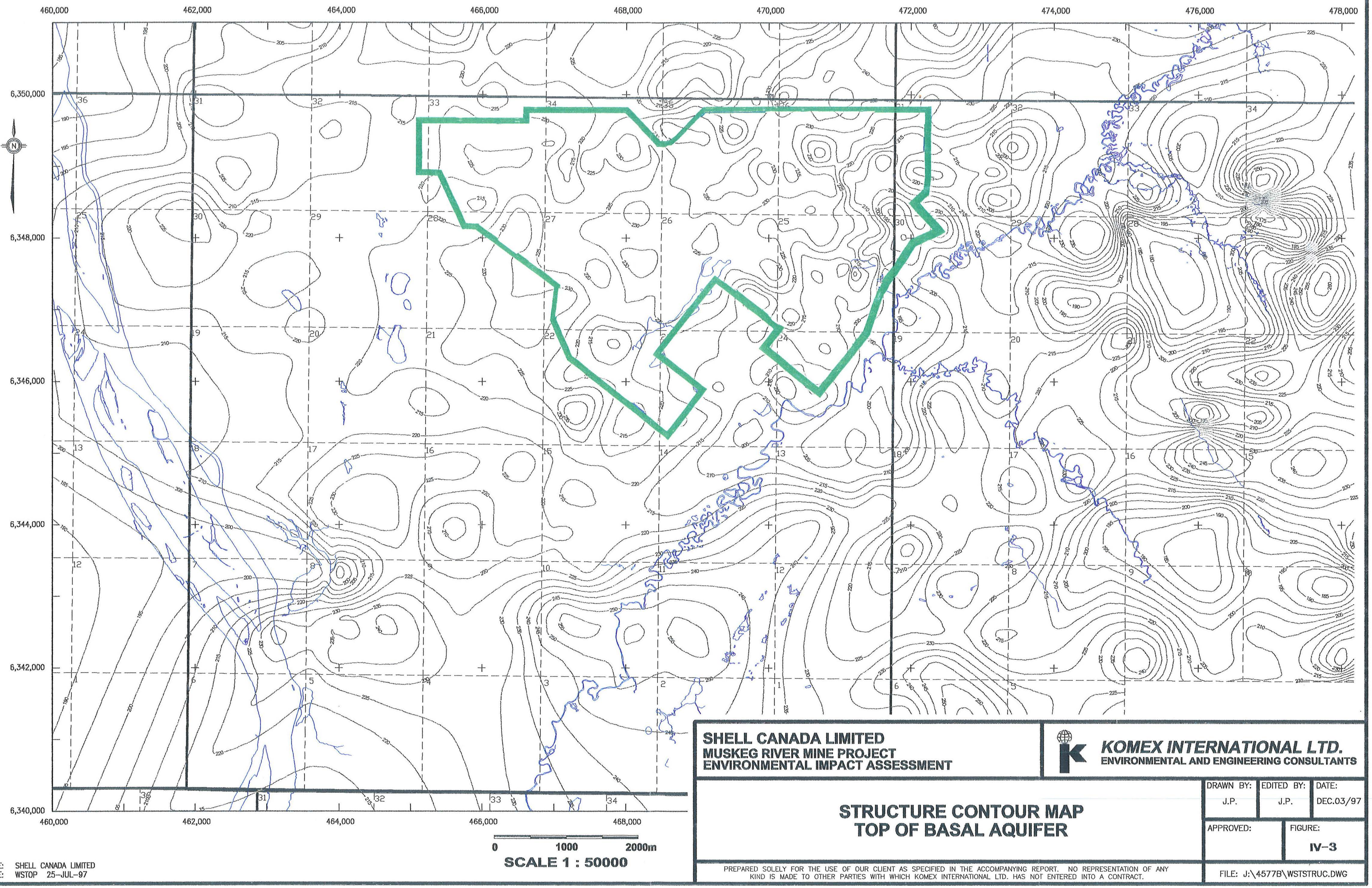

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ENVIRONMENTAL IMPACT ASSESSMENT

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STRUCTURE CONTOUR MAP
TOP OF BASAL AQUIFER

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J.P.	J.P.	DEC.03/97

APPROVED:	FIGURE:
	IV-3

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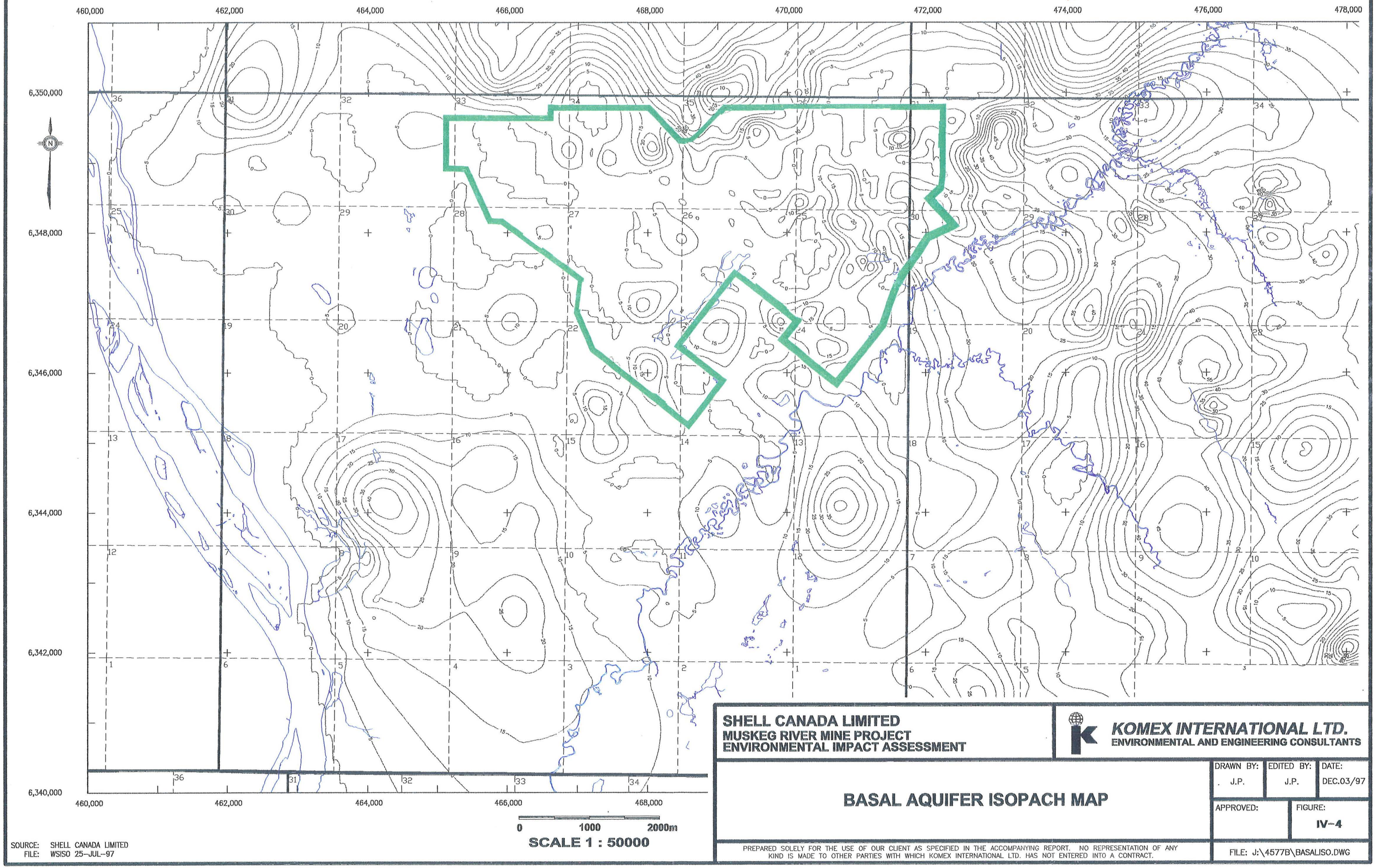

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BASAL AQUIFER ISOPACH MAP

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	DEC.03/97

APPROVED:

FIGURE: IV-4

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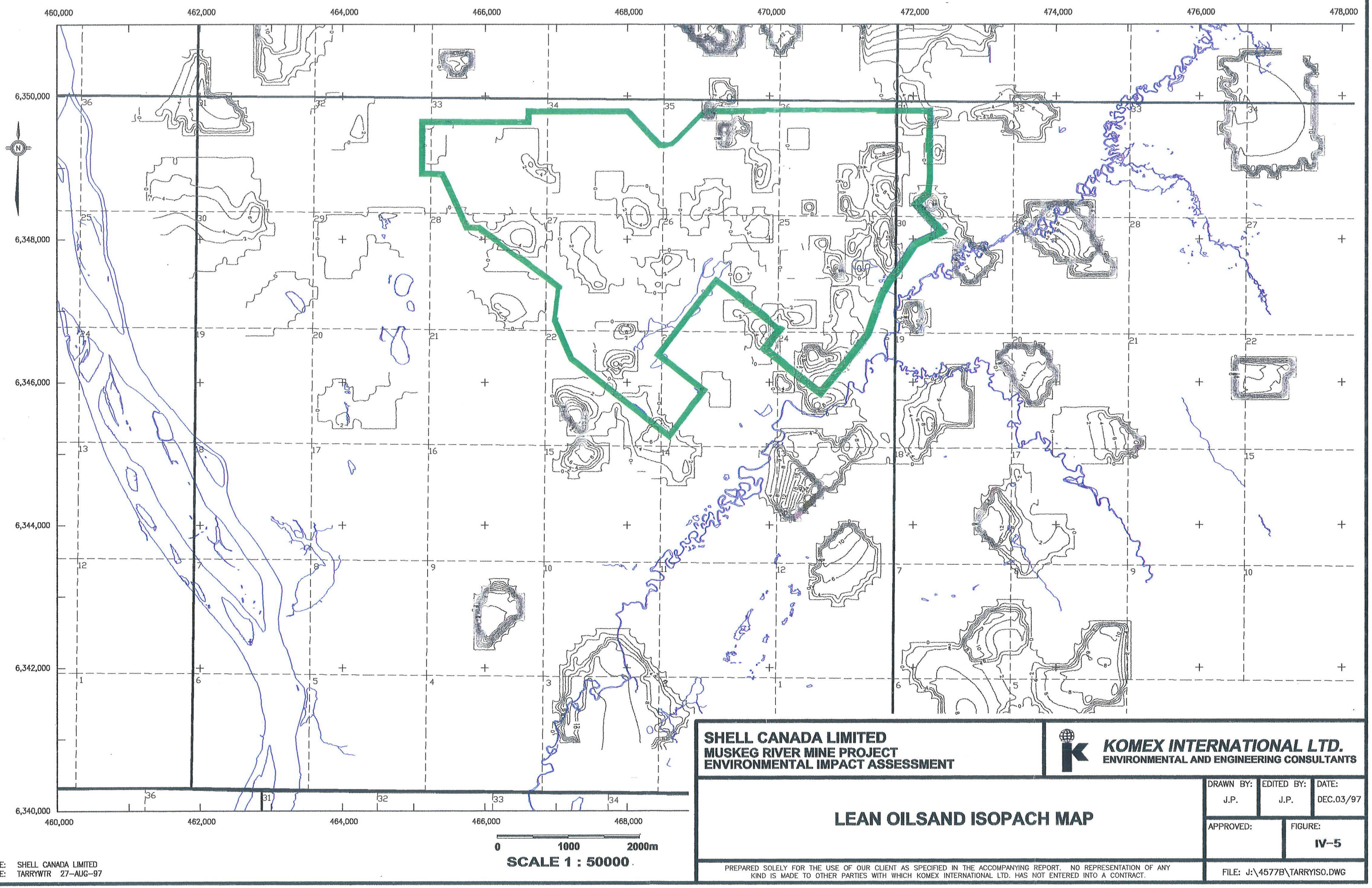

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LEAN OILSAND ISOPACH MAP

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	DEC.03/97

APPROVED:

FIGURE: IV-5

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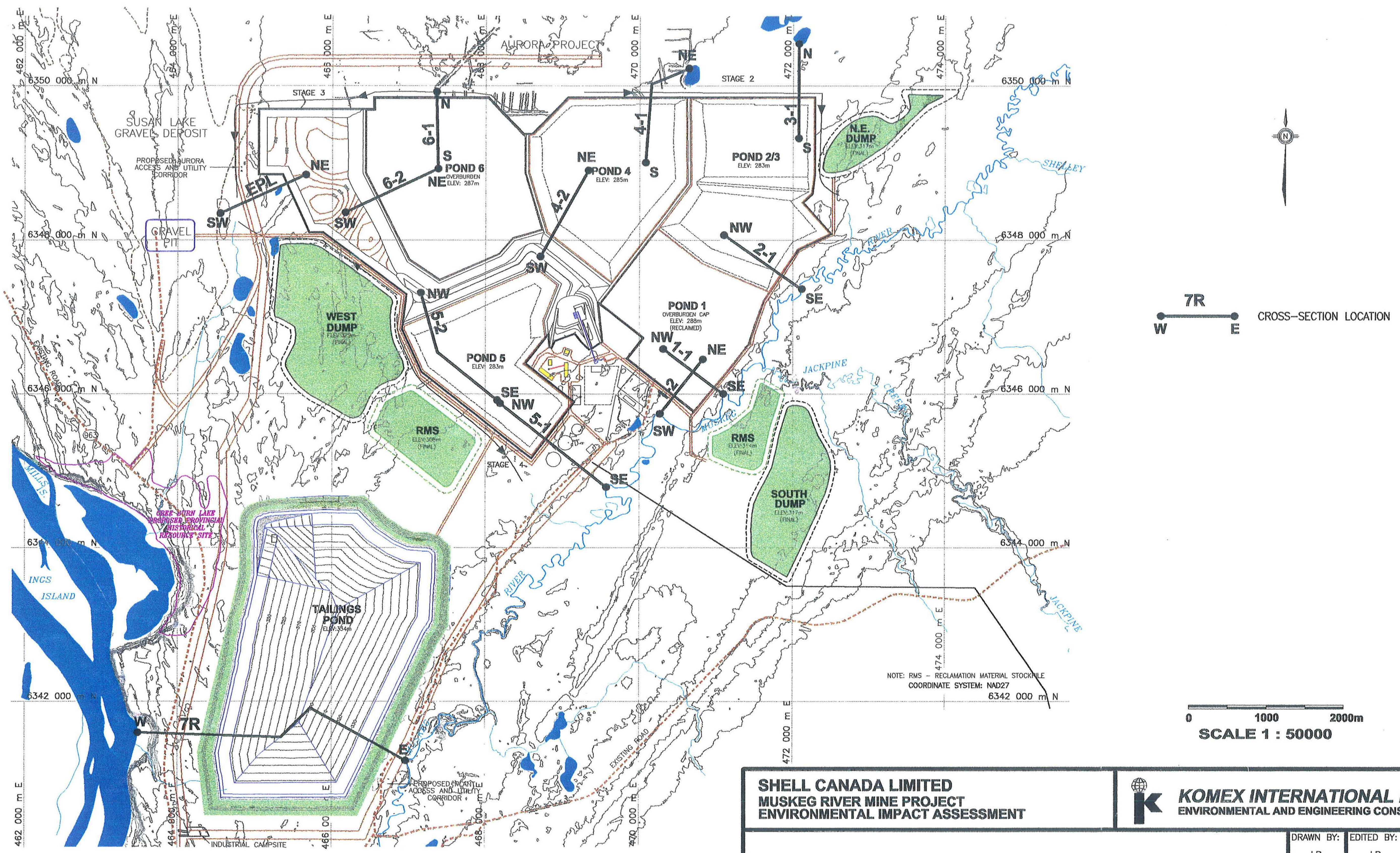

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LOCATION OF MINE PITS AND MODEL CROSS-SECTIONS

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	DEC.03/97
APPROVED:		FIGURE: IV-6

FILE: J:\4577B\PIT-LOC.DWG

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FILE: PIT2022 5-NOV-97 FINAL EIA

(3) inflow from around the perimeter of the dewatering area.

5. Overburden storage areas, plant sites and sand disposal areas are built on cleared land where the muskeg is drained, but no overburden dewatering is required.
6. Overburden dewatering for each 1-year mine block takes place over a period of two years, and flow rates are reported as the average over that period.

Two approaches were used to estimate the dewatering of surficial overburden deposits: a water balance approach, and an analytical solution for unconfined groundwater flow. These approaches are discussed below.

The water balance approach is based on the assumption that the maximum amount of groundwater that can be recovered from the overburden is limited to the amount of groundwater recharge that occurs, plus any groundwater released from storage. This method neglects inflows from the perimeter of the dewatering area, and therefore will underestimate total dewatering discharge.

The first (recharge) component of the water balance can be represented as:

$$Q_r = q_r \bullet A \quad (1)$$

where Q_r is the total overburden discharge that can be obtained from groundwater recharge q_r over the surface area A of dewatering. The water balance discharge calculations are influenced by the natural groundwater recharge rate; two values of recharge (low recharge of 50 mm/y, and high recharge of 69 mm/yr; Alsands 1981) are used to calculate a range of discharge that reflects variation in this parameter. The second (storage) component of the water balance can be represented as:

$$Q_s = A \bullet D \bullet S_y \quad (2)$$

where Q_s is the total discharge obtained from the release of overburden porewater from storage, D is the thickness of the overburden and Sy is the specific yield of the overburden. The total discharge (Q_t) from both components of the water balance is:

$$Q_t = Q_r + Q_s \quad (3)$$

The analytical approach is based on dewatering equations for a trench in unconfined aquifers (Driscoll 1987). The dewatering equation allows calculation of the discharge per unit length of ditch, based on the hydraulic properties and water levels in the area to be dewatered.

The dewatering equation for flow from an unconfined aquifer to one side of a dewatering ditch of unit length is given as:

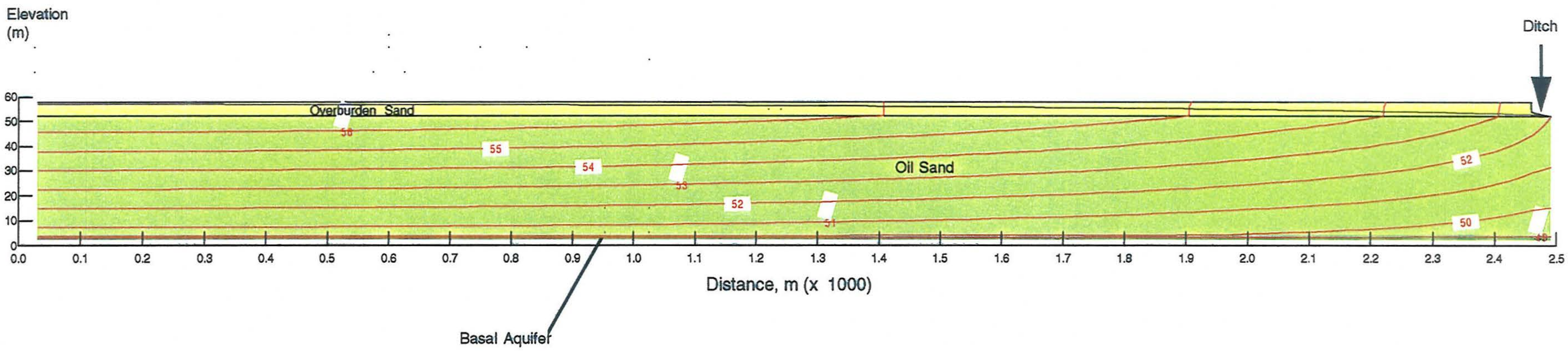
$$Q = \frac{K(H^2 - h^2)}{2L_o} \qquad (4)$$

where Q is the discharge per unit length of ditch, K is hydraulic conductivity of the overburden, H is the saturated thickness of the overburden before dewatering, h is the height of water in the ditch and L_o is distance to the point of zero drawdown in the overburden.

To obtain an estimate of L_o, a schematic cross-section of a single drainage ditch was analyzed using a two-dimensional, finite element groundwater flow model. The program used was SEEP/W, version 3.02 by Geo-slope International of Calgary, Alberta. The finite element model was used to evaluate drawdown versus distance from a ditch for a range of hydraulic conductivity values and natural groundwater recharge rates. The model was constructed to simulate one side of a single ditch, 46 m deep and 430 m wide, excavated to the base of overburden sand 46 m thick. The overall cross-section was 2.5 km long, with a single constant head node in the centre of the ditch representing the drainage elevation of the ditch. The vertical dimension of the cross-section included oil sands 48 m thick overlying a 2 m thickness of Basal Aquifer in which a constant head was specified at an elevation 10 m below ground surface. An example of the single-ditch simulation is shown in Figure IV3-7

The model calculations showed, for reasonable combinations of recharge and hydraulic conductivity, that the distance to insignificant drawdown ranged from 1,000 to 2,000 m from the ditch.

The finite element model was also used to estimate an appropriate ditch spacing. For a single ditch as described above, at a distance of 100 m from the ditch, 0.1 to 0.4 m of overburden would remain saturated. For multiple ditches spaced 200 m part, the additive effect of drawdown from adjacent ditches should be adequate to dewater nearly the full thickness of overburden material.



NOTES

🟥 Contours are hydraulic head, arbitrary datum

🟦 Groundwater surface

Vertical Exaggeration 4x

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OVERBURDEN DEWATERING
SINGLE GENERIC DITCH, VERTICAL CROSS-SECTION
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-7

At a ditch spacing of 200 m, then the equivalent of five ditches each 1 km in length would be required to dewater 1 km^2 of overburden, for a total length of 5,000 m of ditch per km^2. Calculating the total dewatering discharge for 1 km^2, includes two steps:

1. The discharge (Q) per unit length of ditch from the Driscoll equation, (4) is doubled to reflect flow toboth sides of the ditch.

2. The above discharge per unit length of ditch is multiplied by 500 m the total length of ditch per 1 km^2.

The analytical calculation is affected by the hydraulic conductivity (K) of the overburden, so discharge values were calculated reflecting high K (1x 10^{-3} m/s) and low K (5x10^{-4} m/s) overburden materials. The high K case represents the K value measured by Golder Associates (1997) in eight pumping tests of test pits in surficial material as part of the test ditching and dewatering program at Syncrude's Aurora Mine. This comprehensive set of measurements was taken to be the most reliable measure of surficial sand K. Although a wider range of K values has been reported Alsands 1981 estimated a range from 10^{-6} to 10^{-3} m/s), for the present study a value of 5x10^{-4} m/s was selected to represent a low value of K.

The Driscoll equation is intended to calculate steady-state drainage, however for the present situation, the overburden is gradually dewatered over a period of two years to zero saturated thickness. This condition was approximated in the following manner. In the first year of dewatering, the average saturated thickness was assumed to be 75% of the maximum saturated thickness, assuming the groundwater surface declines linearly from 100% to 50% of the maximum saturated thickness in the first year. In the second year, the average saturated thickness was assumed to be 25% of the maximum saturated thickness, assuming the groundwater surface declines from 50% to 0% of the maximum saturated thickness in the second year.

IV.4.2 Overburden Dewatering Results

The calculated discharge rates of groundwater that will be collected by the overburden dewatering ditches are given in Table IV3-1. The 4 m thickness of overburden sand is likely to be the most representative case. In this case, the water balance results show overburden discharge rates at the start of dewatering to be 38 to 40 m^3/r, reaching a maximum of 109 to 114 m^3/hr in 2011 to 2014. The analytical method shows higher discharge rates for the 4 m thickness of sand, ranging from 72 to 145 m^3/h at the start of dewatering, and reaching a maximum of 116 to 232 m^3/h in 2011 to 2014. Over the entire period of dewatering, for a 4 m thickness of overburden, the average dewatering rate from the water balance approach is 78 to 82 m^3/h; from the analytical solution method, the average rate ranges from 83 to 166 m^3/h.

The distance to which overburden dewatering ditches are expected to affect groundwater levels is illustrated in Figure IV3-8. This figure shows the height of groundwater in the overburden as a function of distance from a single, generic ditch. The case illustrated is for a hydraulic conductivity of 5 x 10^{-4} m/s (i.e., a low K case) and for high and low groundwater recharge conditions (50 and 69 mm/y, respectively; Alsands 1981), as calculated using the SEEP/W model for a generic ditch. Figure IV3-8 shows that the influence of the ditch extends for a distance of about 1,000 m (low recharge case) to 2,000 m (high recharge case) from the ditch.

IV.5 Basal Aquifer Depressurization Calculations

The natural groundwater level in the Basal Aquifer in the area of the mine is 270 to 280 m above sea level (asl), which is substantially above the elevation of the base of the mine pit, at 200 to 230 m asl. To have a stable pit walls and floor, the Basal Aquifer must be depressurized before mining. Depressurization of the Basal Aquifer entails pumping the aquifer to lower the groundwater surface below the base of the mine pit.

The average, minimum and maximum thickness values for the Basal Aquifer in each 5-year mine block were estimated from the isopach map (Figure IV3-4), and summarized with other basic structural data for the mine blocks in Table IV3-2. Transmissivity (*T*) is the product of thickness and hydraulic conductivity. The product of the average, minimum and maximum thickness values and the geometric mean hydraulic conductivity of 5x10^{-5} m/s (Komex 1997) was used to estimate *T* for each of the 5-year mine blocks. Where noticeable differences in Basal Aquifer thickness were present within one mine block, the proportion of each block with corresponding thickness of Basal Aquifer was estimated separately, as shown in the "Mine Block" column of Table E3, IV-2.

The Basal Aquifer drawdown required in each 5-year mine block was estimated by NorWest Mine Services from the difference between the piezometric surface elevation in the Basal Aquifer (Komex 1997) and the pit floor elevation in the mine plan (Table IV3-2, IV3-3).

The ranges of Basal Aquifer transmissivity and required drawdowns for each 5-year mine block are shown in Table IV3-3.

The estimated value of storativity (*S*) of the Basal Aquifer used in the depressurization calculations was 1.7x10^{-4}. This value is within the range of storativity values from pumping tests quoted by Komex (1997) as typical for the Basal Aquifer.

To calculate the groundwater discharge rates that will accompany depressurization of the Basal Aquifer, simple, well-established analytical methods were used. The first component of this analysis, called the "Equivalent Well Approach" (Driscoll 1987), assumes that an individual mine pit will act as a very large-diameter, imaginary well. This method

Table IV3-1 Overburden Dewatering Discharge

Table IV3-1 Overburden Dewatering Discharge

Year	Method 1 Calculation: RESULTS Overburden Dewatering, Water Balance Results Total Discharge (m^3/hr)						Method 2 Calculation: RESULTS Overburden Dewatering, Analytical Solution Results Total Discharge (m^3/hr)					
	Saturated Thickness =2m		Saturated Thickness =4m		Saturated Thickness =6m		Saturated Thickness =2m		Saturated Thickness =4m		Saturated Thickness =6m	
	Low Recharge	High Recharge	Low Recharge	High Recharge	Low Recharge	High Recharge	low K	High K	low K	High K	low K	High K
1999												
2000	21	23	38	40	54	56	18	36	72	145	163	325
2001	43	47	75	79	108	112	20	40	80	161	181	361
2002	43	47	75	79	108	112	20	40	80	161	181	361
2003	43	47	75	79	108	112	20	40	80	161	181	361
2004	43	47	75	79	108	112	20	40	80	161	181	361
2005	44	48	77	81	111	115	21	42	84	169	190	379
2006	45	49	80	84	114	118	21	42	85	169	191	381
2007	45	49	80	84	114	118	21	42	85	169	191	381
2008	45	49	80	84	114	118	21	42	85	169	191	381
2009	45	49	80	84	114	118	21	42	85	169	191	381
2010	53	58	94	99	135	140	28	56	113	226	254	508
2011	62	67	109	114	156	162	29	58	116	232	261	522
2012	62	67	109	114	156	162	29	58	116	232	261	522
2013	62	67	109	114	156	162	29	58	116	232	261	522
2014	62	67	109	114	156	162	29	58	116	232	261	522
2015	56	61	99	104	141	146	24	48	96	193	217	434
2016	50	55	89	93	127	131	24	47	94	189	212	424
2017	50	55	89	93	127	131	24	47	94	189	212	424
2018	50	55	89	93	127	131	24	47	94	189	212	424
2019	50	55	89	93	127	131	24	47	94	189	212	424
2020	30	32	52	55	75	78	6	13	25	50	57	113
2021	9	10	16	17	23	24	4	9	17	35	39	79
2022	5	5	8	9	12	12	0	1	2	3	4	8
Mean, 2000 2022	**44**	**48**	**78**	**82**	**112**	**116**	**21**	**42**	**83**	**166**	**187**	**374**

Table IV3-2 Basic Data Used in Basal Aquifer Depressurizaton Calculations

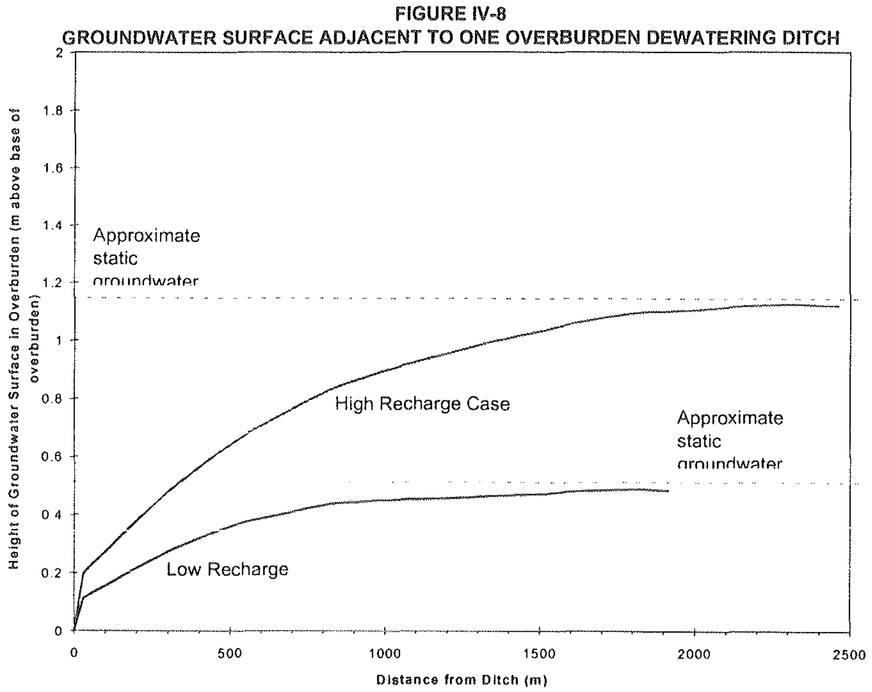
Table IV-2 Basic Data Used in Basal Aquifer Depressurization Calculations

Mine Block	Pit Area (m^2)	R_w (m)	Basal Aquifer Thickness (m)			Elevation of Pit Floor (masl)			Basal Aquifer Piezometric Surface Elevation (masl)		
			Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
2002 - 2006	4461953	1192	10	2.5	20	215	202	230	275	272	278
2007 - 2011	4707449	1224	8	2.5	20	227	202	236	277	275	282
2012 - 2016 N$^1/_3$	2146775.3	827	15	5	30	228	212	234	274	272	277
2012 - 2016 S$^2/_3$	4293550.7	1169	5	2.5	10	226	224	232	277	277	277
2017 - 2021 N$^2/_3$	3493418	1055	2.5	0.5	5	222	210	224	269	269	269
2017 - 2021 S$^1/_3$	1746709	746	8	2.5	20	226	216	232	265	265	265
2022 - 2023	387696	351	2.5	0.5	5	219	218	220	265	265	265

Table IV3-3 Basal Aquifer Depressurization, Hydraulic Data and Steady State Discharge

Mine Block	Basal Aquifer Transmissivity (m^2/d)			Drawdown Required (m)			Radius of Influence (km)			Steady State Discharge Rate (Q) m^3/hr, Thiem Method		
	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
2002 - 2006	43.2	10.8	86.4	60	42	76	45.5	23	65	186	40	430
2007 - 2011	34.56	10.8	86.4	50	39	80	41	23	65	129	38	456
2012 - 2016 $N^{1}/_{3}$	64.8	21.6	129.6	46	38	65	56	32.6	80	185	58	482
2012 - 2016 $S^{2}/_{3}$	21.6	10.8	43.2	51	45	53	32.6	23	45.5	87	43	164
2017 - 2021 $N^{1}/_{3}$	10.8	2.16	21.6	47	45	59	23	9.8	32.6	43	11	97
2017 - 2021 $S^{2}/_{3}$	34.56	10.8	86.4	39	33	49	41	23	65	88	27	248
2022 - 2023	10.8	2.16	21.6	46	45	47	23	9.8	32.6	31	8	59
Average	**31**	**10**	**68**	**48**	**41**	**61**	**37**	**23**	**55**	**107**	**32**	**276**

Figure IV3-8 Basal Aquifer Depressurization, Transient Discharge



assumes that the irregular area A of each mine pit can be approximated by a fully penetrating cylindrical well with radius r_w, such that:

$$r_w = \sqrt{\frac{A}{\pi}}$$

(5)

The area of each 5-year mine block, and corresponding equivalent well radius is given in Table IV3-2.

IV.5.1 Steady-State Discharge

Given the transmissivity of the Basal Aquifer, the drawdown required for depressurization, and the storativity of the Basal Aquifer, steady-state discharge for the "equivalent well" was calculated using the analytical equations of Thiem (1906):

$$Q = \frac{2\pi \ T s_w}{\ln\left(\frac{R}{r_w}\right)}$$

(6)

where Q is the total transmissivity of the Basal Aquifer, the drawdown required for depressurization and the storativity of the Basal steady-state discharge from the mine block with equivalent well radius r_w; R is the radius of influence of the equivalent well; and s_w is the drawdown required in the mine block.

The following assumptions underlie this analytical solution:

- the Basal Aquifer is confined, and non-leaky;
- the aquifer is of uniform thickness and of infinite areal extent;
- the aquifer is homogeneous and isotropic;
- before pumping, the piezometric surface in the aquifer is horizontal;
- the discharge rate from the aquifer is constant; and
- the equivalent well penetrates the full thickness of the aquifer, so flow to the well is only horizontal.

To estimate the radius of influence of the equivalent well, the Jacob method (Cooper and Jacob 1946) was used:

$$s = \frac{2.303Q}{4\pi T} \log \frac{2.25Tt}{R^2 S}$$

(7)

where t is the time since the start of pumping. A time of 10 years was selected for estimating the radius of influence. The value of R corresponding to $s = 0$ was estimated using equation *7*. Since Q is the same in both equations *6* and *7*, an estimated Q was used in equation *7* to calculate R, then a revised Q was calculated using equation *6*. The revised Q was then used to iterate through equation *7* and checked again with equation *6*. However, the radius of influence in equation *6* was not very sensitive to the value of Q, so in all cases only one iteration was performed.

The variation in transmissivity and drawdown was incorporated into the calculations to give the greatest range in steady-state discharge rates. The maximum T and s_w were used in the calculation of maximum Q; similarly average T and s_w were used for average Q; and minimum T and s_w used for minimum Q.

IV.5.2 Transient Discharge

Initial discharge is typically higher at the beginning of depressurization, declining over time to the steady-state discharge rate. Consequently, the time-varying (transient) discharge rate was calculated using the Jacob-Lohman analytical method (Jacob and Lohman 1962). This approach applies to a confined aquifer in which the drawdown is constant, and the discharge varies with time, such that:

$$Q = \frac{4\pi T s_w}{2.30 \log\left(2.25Tt \middle/ r_w^2 \right)}$$

(8)

This calculation also used the equivalent well approach to estimate r_w as described above. The simplifying assumptions associated with this method include all of those listed for the Thiem method (except assumption 5), plus the following:

- water is released from storage instantaneously with the decline in head in the aquifer; and
- storage in the well can be neglected.

Table IV-4a Basal Aquifer Depressurization, Transient Discharge Calculated by the Jacob-Lohman Method

	Transient Basal Aquifer Discharge Rate (Q) m^3/hr, Jacob-Lohman Method								
Mine Block	**Average T, Average Drawdown**			**Minimum T, Minimum Drawdown**			**Maximum T, Maximum Drawdown**		
	Year 1	**Year 2**	**Years 3-5**	**Year 1**	**Year 2**	**Years 3-5**	**Year 1**	**Year 2**	**Years 3-5**
2002 - 2006	326	250	216	87	59	49	707	562	493
2007 - 2011	233	176	151	82	55	46	752	596	523
2012 - 2016 N$^1/_3$	294	238	211	102	79	68	733	608	544
2012 - 2016 S$^2/_3$	165	121	103	91	62	52	286	219	190
2012 - 2016 Total	**459**	**359**	**313**	**194**	**141**	**120**	**1018**	**827**	**734**
2017 - 2021 N$^2/_3$	89	62	52	37	19	14	180	134	115
2017 - 2021 S$^1/_3$	144	115	101	75	56	48	257	211	189
2017 - 2021 Total	**233**	**177**	**153**	**112**	**74**	**62**	**437**	**345**	**303**
2022 - 2023	50	40	35	14	10	9	90	74	66
Average	**221**	**171**	**148**	**88**	**62**	**52**	**495**	**397**	**351**

Table IV-4b
Basal Aquifer Depressurization, Transient Discharge Calculated by the Jacob-Lohman Method

	Basal Aquifer Discharge (m^3/hr)		
Year	**Mean(a)**	**Minimum(b)**	**Maximum(c)**
2002	326	87	707
2003	250	59	562
2004	216	49	493
2005	216	49	493
2006	216	49	493
2007	233	82	752
2008	176	55	596
2009	151	46	523
2010	151	46	523
2011	151	46	523
2012	459	194	1018
2013	359	141	827
2014	313	120	734
2015	313	120	734
2016	313	120	734
2017	233	112	437
2018	177	74	345
2019	153	62	303
2020	153	62	303
2021	153	62	303
2022-23	90	24	164
Average	**218**	**75**	**526**

NOTES: (a) Mean hydraulic conductivity, average transmissivity average drawdown;
(b) Mean hydraulic conductivity, minimum transmissivity minimum drawdown;
(c) Mean hydraulic conductivity, maximum transmissivity maximum drawdown;

The Jacob-Lohman method was used to calculate the average discharge rate in the first year and second year of depressurization, and also the average for years 3 to 5.

The variation in transmissivity and drawdown was incorporated in the calculations to gives minimum, average and maximum *Q* values in the same manner as the steady-state calculations, described above. The values of K and *S* used were the same as in the Thiem method.

This approach was applied to each 5-year mine block, as for the Thiem method.

IV.5.3 Results

The drawdown required in the mine ranges from 39 and 80 m, with an average drawdown of 48 m. The steady-state discharge required to achieve the required drawdown for each 5-year mine block is given in Table IV3-3. The average steady-state discharge is 108 m^3/h, with minimum and maximum steady-state discharges averaging 32 and 276 m^3/h over the life of the mine.

The transient discharge rates for each 5-year mine block are given in Table IV-4a, and are summarized on a year-by-year basis in Table IV3-4b. The average rate over the life of the mine is 218 m^3/h, or approximately 5200 m^3/d. From Table IV3-4, mean discharge rate over the 23-year period ranges from 9075 to 459,526 m^3/h. The discharge rate peaks in 2012, with an average of 459 m^3/r, and a range from 194 to 1018 m^3/h. All of this water will be used for oil sands processing.

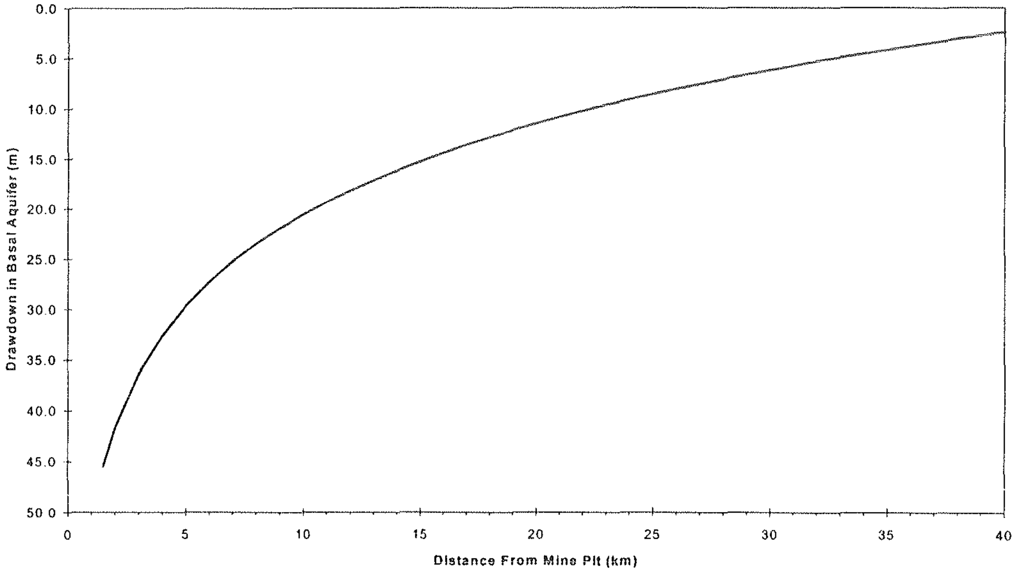
The withdrawal of groundwater at these rates will produce a cone of depression around the mine pit that will eventually extend to a distance of 30 to 40 km, although the greatest drawdown will occur within a few kilometers of the mine pit. Figure IV3-9 shows the distance-drawdown relationship for the Basal Aquifer, for long-term steady-state pumping at the discharge rate (107 $m^{3/}h$) required to produce the average required drawdown (48m) assuming average transmissivity. As this graph shows, drawdown of greater than 20 m will be restricted to distances of less than 11 km from the mine pit.

IV.6 MINE PIT AND CT SEEPAGE

Five of the six mine pits will be backfilled with mined materials, four with consolidated tailings (CT) and one with mined overburden. Calculations of seepage from the backfilled mine pits were done for nine snapshot times, as follows:

Figure IV3-9

FIGURE IV-9
STEADY-STATE DRAWDOWN IN BASAL AQUIFER WITH DISTANCE FROM THE MINE PIT



Construction Phase

2000	Pre-Construction Drainage
2001	Pre-Pit Opening

Operation Phase

2003	First year of Production without recycle
2005	Production with Recycle, without CT manufacture
2010	CT Production at 75% capacity
2020/2222	CT Production at 95% Capacity and Processing Complete
2025	Mine Closure in Progress

Far-Future Phase

2030	Second year after Closure
Far Future	Equilibrium Closure condition

IV.6.1 Approach

The calculations focused on a series of vertical cross-sections, one or more per pit. The cross-sections were selected to represent settings where seepage from the mine could potentially reach a receiving stream or surface waterbody. The location of the cross-section is shown in Figure IV3-6. The cross-sections generally extend from near the centre of a pit, across the mine highwall, to a point of potential groundwater discharge outside the mine. Where the pit is located near a stream, the cross-section was selected at the point where the pit is closest to the stream.

The seepage calculations were done using a two-dimensional, finite element, groundwater flow model. The modelling software was SEEP/W (Version 3.02) by Geo-slope International of Calgary, Alberta. For each of the five backfilled mine pits, the vertical cross-section models were used to calculate seepage discharge for a unit length of the pit perimeter.

For each of the snapshot periods after which a pit was opened, a simulation model was developed for each relevant cross-section, reflecting conditions in the pit at the time (e.g., open pit; partially filled pit; filled and capped). Each simulation was run as a steady-state model, assuming that equilibrium or near equilibrium conditions are reached at each snapshot time. The model results were used to calculate the seepage flux into or out of the receiving stream at each of the applicable snapshot periods. This seepage flux (volume of water per unit length of cross-section per unit time) was multiplied by the total length of the corresponding pit wall to obtain a total discharge to the receiving stream.

Each vertical cross-section model was constructed based on the following general characteristics:

- native materials beyond the limit of mining consisted of oil sands underlain by Basal Aquifer, with or without a lean oil sandss layer, and overlain by surficial sand and till.
- mined backfill materials consisted of CT or mined overburden, underlain by Basal Aquifer with or without a lean oil sandss layer, and overlain by mined overburden or tailings sand;
- no-flow (Type 2) boundary conditions were applied to left and right vertical ends;
- a specified-head (Type 1) boundary was applied in the Basal Aquifer, with head values corresponding to depressurized piezometric surface elevation during the operations period. At the end of mining, hydraulic head in the Basal Aquifer head gradually recovers to levels corresponding to the pre-mining piezometric surface;
- recharge flux is applied to the reclaimed land surface; the recharge rate was determined for each cross-section, based on achieving a reasonable water table configuration;
- where surface ponds or streams were present and on the cross-section, they were represented as specified-head (Type 1) boundaries. The head value specified corresponded to the estimated elevation of the surface water at such locations.

Although the SEEP/W modelling software is capable of simulating unsaturated and saturated flow, the simulations were conducted considering only saturated flow. Nonetheless, contours of hydraulic head are displayed for both the saturated and unsaturated zones in the vertical cross-sections. Discharge to surface waterbodies and to the Basal Aquifer was determined using the "flux section" feature of SEEP/W.

The hydraulic conductivity values of natural and mined materials used in all cross-sections are given in Table IV3-5. The lean oil snads considered in this series of simulations represent material with less than 7% bitumen (by weight). Seven percent bitumen is assumed to correspond to approximately 50% bitumen saturation. The corresponding hydraulic conductivity was estimated to be approximately one order of magnitude less than the K of water-saturated Basal Aquifer. That is, the lean oil sand was assumed to have a K of 5x10[illegible] m/s.

IV.6.2 Results and Discussion

The cross-section models constructed for each snapshot time, along with a summary of the physical and hydraulic conditions represented in the model, are summarized in Table IV3-6. Seepage results are summarized in Table IV3-7.

No formal mass balance calculations were performed for this series of models; in general, mass balance between known sources of inflow to a cross-section, and total outflows, agreed within a range from 1 to 30%, as discussed in Section IV3-6.

Each cross-section model represents a single set of assumptions, reflecting the individual hydraulic conductivity and recharge values used. No formal sensitivity analysis was conducted, due to the large number of cross-sections simulated.

Model simulation results for each of the snapshot items are presented in Figures IV3-10 to IV3-42.

In 2003, Pit 1 is open, and seepage is directed into the pit from unmined land to the east and south, including from the Muskeg River, as shown in Figures IV3-10 and IV3-11.

In 2005 (Figures IV3-12, IV3-13) and 2010 (Figures IV3-14 and IV3-15), Pit 1 is partially infilled with CT, with downward seepage into the Basal Aquifer. Seepage from unmined land is toward the pit as in 2003. In 2010, Pit 2 is open with seepage toward the pit from unmined land to the east, including seepage from the Muskeg River (Figure IV3-16).

In 2022, Pits 1 to 4 have been backfilled, and seepage conditions are similar to those for 2025, as discussed below. Pit 5 is partially backfilled with CT (Figure IV3-17), with downward seepage into the Basal Aquifer. There is aslo lateral seepage toward Pit 5 from unmined land to the east, including the Muskeg River.

In 2025, Pits 1 to 4 are at their final backfill elevations. Hydraulic heads in the Basal Aquifer are still low, with an estimated 35 m of residual drawdown persisting below the mine. As shown in Figures IV3-18 to 22, the low head in the Basal Aquifer maintains relatively deep water table conditions in the reclaimed pits. Most shallow groundwater in the surrounding unmined land is flowing toward the mine pits. There is no seepage to the Muskeg River, which is still losing water to the mine pits. Pits 5 and 6 are partially backfilled (Figures IV3-23, 24), and there is seepage into both pits from unmined land. There is also seepage from the Muskeg River into Pit 5.

In 2030, recovery of head in the Basal Aquifer is estimated to be 85% complete. All pits are at their final backfilled elevations. Although there is a small amount of seepage (8.8 m^3/d) from Pit 2 to the Muskeg River (Figure IV3-20), in all other pits shallow groundwater flow is still directed into the mine.

Table IV-5
Hydraulic Conductivity Values Used For CT and Tailings Pond Seepage Modeling

Hydrostratigraphic Unit	Kh (m/s)	Kh/Kv	Source of Value
Surficial Sand	1.00E-04	1	Golder (1997) Test Ditching Pumping Test
Cretaceous-Oil Sands	2.00E-09	1	Golder (1996) Calibrated groundwater flow model (Appendix D, Detailed Supporting Calculations, Hydrogeology Impact Assessment, Bovar Environmental Ltd., 1996)
Cretaceous-Basal Aquifer	3.00E-05	1	Komex (1997) Baseline Hydrogeology Study
Lean Oil Sands (Tailings Pond Area)	2.00E-08	1	Estimated (experience and professional judgment)
Lean Oil Sands (Pit Floor)	5.00E-06	1	Estimated (experience and professional judgment)
In-pit and Perimeter Dykes	1.00E-07	1	Estimated (experience and professional judgment)
Consolidated Tailings	1.00E-09	1	AGRA, pers. com. from E. McRoberts, 97-08-07
Mined Overburden Capping Material	1.00E-07	1	Estimated (experience and professional judgment)
Tailings Sand Capping Material	1.00E-06	1	Estimated (experience and professional judgment)
Tailings Sand	1.00E-06	5	AGRA, pers. com. from E. McRoberts, 97-09-24
Mature Fine Tails	4.00E-07	1	Golder Associates, pers. com. from D. Long, 97-10-10 fax

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Table IV-7 Summary of Conditons Simulated in Cross-Section Models and Mine Pits

Snapshot Time	Pit No.	X-Section No.	Total Discharge to Surface Water (m^3/d)	Receiving Stream	Source Material of Discharge	Receiving Surface Water Node	Total Seepage to Basal Aquifer (m^3/d)
2000 Pre-construction Drainage	1	1-1	NA	NA	NA	S16	NA
	1	1-2	NA	NA	NA	S16	NA
	2	2-1	NA	NA	NA	S16	NA
	3	3-1	NA	NA	NA	S16	NA
	4	4-1	NA	NA	NA	S32	NA
	5	5-1	NA	NA	NA	S16	NA
	6	6-1	NA	NA	NA	S32	NA
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	NA	NA	NA	S16	NA
	Tailings Pond, W	7R	NA	NA	NA	S17	NA
	Tailings Pond, W	7R	NA	NA	NA	S33	NA
	Tailing Pond, All	7R	NA	NA	NA	NA	NA
2002 Pre pit opening	1	1-1	-68.8	Muskeg River	Mined Overburden	S16	0
	1	1-2	-107.5	Muskeg River	Mined Overburden	S16	0
	2	2-1	NA	NA	NA	S16	NA
	3	3-1	NA	NA	NA	S16	NA
	4	4-1	NA	NA	NA	S32	NA
	5	5-1	NA	NA	NA	S16	NA
	6	6-1	NA	NA	NA	S32	NA
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	245.6	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	65.1	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	65.1	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	1540

Snapshot Time	Pit No.	X-Section No.	Total Discharge to Surface Water (m^3/d)	Receiving Stream	Source Material of Discharge	Receiving Surface Water Node	Total Seepage to Basal Aquifer (m^3/d)
2003 1st Year Prod.	1	1-1	-68.8	Muskeg River	Mined Overburden	S16	0
	1	1-2	-107.5	Muskeg River	Mined Overburden	S16	0
	2	2-1	NA	NA	NA	S16	NA
	3	3-1	NA	NA	NA	S16	NA
	4	4-1	NA	NA	NA	S32	NA
	5	5-1	NA	NA	NA	S16	NA
	6	6-1	NA	NA	NA	S32	NA
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	374.3	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	72.2	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	72.2	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	1760
2005 Prod./recycle, no CT	1	1-1	-68.4	Muskeg River	Mined Overburden	S16	59
	1	1-2	-107.4	Muskeg River	Mined Overburden	S16	60
	2	2-1	-55.3	Muskeg River	Mined Overburden	S16	NA
	3	3-1	NA	NA	NA	S16	NA
	4	4-1	NA	NA	NA	S32	NA
	5	5-1	NA	NA	NA	S16	NA
	6	6-1	NA	NA	NA	S32	NA
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	499.0	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	79.1	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	79.1	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	1964

Snapshot Time	Pit No.	X-Section No.	Total Discharge to Surface Water (m^3/d)	Receiving Stream	Source Material of Discharge	Receiving Surface Water Node	Total Seepage to Basal Aquifer (m^3/d)
2010 75% of capacity	1	1-1	-67.2	Muskeg River	Mined Overburden	S16	59
	1	1-2	-106.5	Muskeg River	Mined Overburden	S16	60
	2	2-1	-121.3	Muskeg River	Mined Overburden	S16	0
	3	3-1	0.0	Muskeg River	Mined Overburden	S16	0
	4	4-1	NA	NA	NA	S32	NA
	5	5-1	NA	NA	NA	S16	NA
	6	6-1	NA	NA	NA	S32	NA
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	692.8	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	89.7	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	89.7	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	2253
2022 Processing complete	1	1-1	-63.7	Muskeg River	Mined Overburden	S16	71
	1	1-2	-76.5	Muskeg River	Mined Overburden	S16	74
	2	2-1	-38.4	Muskeg River	Mined Overburden	S16	88
	3	3-1	0.0	Muskeg River	Mined Overburden	S16	75
	4	4-1	0.0	NA	Mined Overburden	S32	160
	5	5-1	-93.8	Muskeg River	Recast Tailing Sand	S16	255
	6	6-1	0.0	NA	Mined Overburden	S16	0
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	1080.2	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	89.9	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	89.9	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	2484

Snapshot Time	Pit No.	X-Section No.	Total Discharge to Surface Water (m^3/d)	Receiving Stream	Source Material of Discharge	Receiving Surface Water Node	Total Seepage to Basal Aquifer (m^3/d)
2025 Closure in progress	1	1-1	-63.7	Muskeg River	Mined Overburden	S16	71
	1	1-2	-76.5	Muskeg River	Mined Overburden	S16	74
	2	2-1	-38.4	Muskeg River	Mined Overburden	S16	88
	3	3-1	0.0	Muskeg River	Mined Overburden	S16	75
	4	4-1	0.0	NA	Mined Overburden	S32	160
	5	5-1	-94.7	Muskeg River	Recast Tailing Sand	S16	100
	6	6-1	NA	NA	Mined Overburden	S16	189
	End-pit Lake	EPL	NA	NA	NA	S32	NA
	Tailings Pond, E	7R	262.7	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	207.7	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	207.7	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	1617
2030 2nd year after closure	1	1-1	-2.3	Muskeg River	Mined Overburden	S16	36
	1	1-2	-12.9	Muskeg River	Mined Overburden	S16	39
	2	2-1	8.8	Muskeg River	Mined Overburden	S16	50
	3	3-1	0	Muskeg River	Mined Overburden	S16	47
	4	4-2	-1.8	End-pit Lake	Recast Tailing Sand	S32	167
	5	5-1	-1.9	Muskeg River	Recast Tailing Sand	S16	87
	5	5-2	-1410.9	End-pit Lake	ned Overburden/Tailings Sa	S32	NA
	6	6-1	NA	NA	Mined Overburden	S16	186
	6	6-2	22.1	End-pit Lake	ned Overburden/Tailings Sa	S32	NA
	End-pit Lake	EPL	0.0	NA	Water	S32	2837
	Tailings Pond, E	7R	262.7	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	207.7	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	207.7	Isadore's Lake	Tailings Sand	S33	NA
	Tailing Pond, All	7R	NA	NA	Tailings Sand	NA	1617

Snapshot Time	Pit No.	X-Section No.	Total Discharge to Surface Water (m^3/d)	Receiving Stream	Source Material of Discharge	Receiving Surface Water Node	Total Seepage to Basal Aquifer (m^3/d)
Far Future	1	1-1	31.0	Muskeg River	Mined Overburden	S16	17
	1	1-2	28.8	Muskeg River	Mined Overburden	S16	17
	2	2-1	15.0	Muskeg River	Mined Overburden	S16	17
	3	3-1	0.0	Muskeg River	Mined Overburden	S16	32
	4	4-2	-6.2	End-pit Lake	Recast Tailings Sand	S32	104
	5	5-1	31.3	Muskeg River	Recast Tailing Sand	S16	68
	5	5-2	-944.4	End-pit Lake	ned Overburden/Tailings Sa	S32	NA
	6	6-1	NA	NA	Mined Overburden	S16	1285
	6	6-2	6.3	End-pit Lake	ned Overburden/Tailings Sa	S32	NA
	End-pit Lake	EPL	26.6	Isadore's Lake	Water	S33	103
	Tailings Pond, E	7R	262.7	Muskeg River	Tailings Sand	S16	NA
	Tailings Pond, W	7R	207.7	Athabasca River	Tailings Sand	S17	NA
	Tailings Pond, W	7R	207.7	Isadore's Lake	Tailings Sand	S33	NA
	Tailings Pond, All	7R	NA	NA	Tailings Sand	NA	1617

Note: NA - Not Applicable

Table IV-7
Summary of Conditions Simulated in Cross-Section Models, Mine Pits, and

Snapshot Year	Pit No.	Cross-section No.	Figure No.	Pit Status	CT Elevation	Overburden Backfill Elevation	Overburden Cap Elevation	Tailings Sand Cap Elevation	Recharge Flux (m/s)	Basal aquifer Head (masl)	Comments
2000	--	--		No Excavation	--	--	--	--	--	--	--
2002	--	--		No Excavation	--	--	--	--	--	--	--
2003	1	1	H3-10	Open Pit	--	--	--	--	none	210	Basal Aquifer Drawdown to base of pit
	1	2	H3-11	Open Pit	--	--	--	--	none	210 (SW) to 213 (NE)	Basal Aquifer Drawdown to base of pit
2005	1	1	H3-12	Part. Backfilled	230	--	none	--	4.00E-10	210	Basal Aquifer Drawdown to base of pit
	1	2	H3-13	Part. Backfilled	230	--	none	--	5.00E-10	210 (SW) to 213 (NE)	Basal Aquifer Drawdown to base of pit
	2	--		Open Pit	--	--	--	--	none	200	Basal Aquifer Drawdown to base of pit
2010	1	1	H3-14	Backfilled	272	--	287(SE) to 284N(W)	--	4.00E-10	210	Basal Aquifer Drawdown to base of pit
	1	2	H3-15	Backfilled	272	--	287(SW) to 284(NE)	--	5.00E-10	210 (SW) to 213 (NE)	Basal Aquifer Drawdown to base of pit
	2	1	H3-16	Open Pit	--	--	--	--	none	200	Basal Aquifer Drawdown to base of pit
	3	1		Open Pit	--	--	--	--	none	--	--
2022	1	1		Backfilled	272	--	287(SE) to 284N(W)	--	4.00E-10	238	35 m Residual Drawdown in Basal Aquifer
	1	2		Backfilled	272	--	287(SW) to 284(NE)	--	5.00E-10	236 (SW) to 239 (NE)	35 m Residual Drawdown in Basal Aquifer
	2	1		Backfilled	279	--	286.5; 285.6 (Lake)	--	1.60E-10	243	35 m Residual Drawdown in Basal Aquifer
	3	1		Backfilled	279	--	295(N) to 293(S)	--	5.00E-10	245	35 m Residual Drawdown in Basal Aquifer
	4	1		Backfilled	281	--	--	292(S) to 293(NE)	5.00E-10	242	35 m Residual Drawdown in Basal Aquifer
	5	1	H3-17	Part. Backfilled	283	--	--	none	1.00E-09	240	35 m Residual Drawdown in Basal Aquifer
2025	1	1	H3-18	Backfilled	272	--	287(SE) to 284N(W)	--	4.00E-10	238	35 m Residual Drawdown in Basal Aquifer
	1	2	H3-19	Backfilled	272	--	287(SW) to 284(NE)	--	5.00E-10	236 (SW) to 239 (NE)	35 m Residual Drawdown in Basal Aquifer
	2	1	H3-20	Backfilled	279	--	286 5; 285 6 (Lake)	--	1.60E-10	243	35 m Residual Drawdown in Basal Aquifer
	3	1	H3-21	Backfilled	279	--	295(N) to 293(S)	--	5.00E-10	245	35 m Residual Drawdown in Basal Aquifer
	4	1	H3-22	Backfilled	280	--	--	292(S) to 293(NE)	5.00E-10	242	35 m Residual Drawdown in Basal Aquifer
	5	1	H3-23	Part. Backfilled	278	--	--	none	1.00E-09	240	35 m Residual Drawdown in Basal Aquifer
	6	1	H3-24	Part. Backfilled		273	--	none	5.00E-10	238 (S) to 237 (N)	35 m Residual Drawdown in Basal Aquifer
2030	1	1	H3-25	Backfilled	272	--	287(SE) to 284N(W)	--	4.00E-10	260.6	85% Recovery in Basal Aquifer
	1	2	H3-26	Backfilled	272	--	287(SW) to 284(NE)	--	5.00E-10	257.4 (SW) to 260.4 (NE)	85% Recovery in Basal Aquifer
	2	1	H3-27	Backfilled	279	--	286 5, 285 6 (Lake)	--	1 60E-10	261.8	85% Recovery in Basal Aquifer
	3	1	H3-28	Backfilled	279	--	295(N) to 293(S)	--	5.00E-10	268	85% Recovery in Basal Aquifer
	4	2		Backfilled	278	--	--	288(NE) to 292(SW)	5.00E-09	259.5 (SW) to 261.2 (NE)	85% Recovery in Basal Aquifer
	5	1	H3-29	Backfilled	276	--	--	290	1.00E-09	265.2	85% Recovery in Basal Aquifer
	5	2		Backfilled	276	--	--	286(SE) to 285(NW), 282 6 (Lake)	5 00E-10	263.6 (NW) to 262.7 (SE)	85% Recovery in Basal Aquifer
	6	1	H3-30	Backfilled		273	--	283(S) to 286(N), 282.5 (Lake)	5.00E-10	262.7 (S) to 264.4 (N)	85% Recovery in Basal Aquifer
	6	2		Backfilled		273	--	299(SW) to 285(NE), 282 5 (Lake)	--	261.2 (S) to 263.2 (N)	85% Recovery in Basal Aquifer
	EPL		H3-31	Lake Full	247 5 (MFT)	--	--	--	--	252.5 (SW) to 262.5 (NE)	85% Recovery in Basal Aquifer
Far Future	1	1	H3-32	Reclaimed	272	--	287(SE) to 284N(W)	--	4 00E-10	273	--
	1	2	H3-33	Reclaimed	272	--	287(SW) to 284(NE)	--	5 00E-10	271 (SW) to 274 (NE)	--
	2	1	H3-34	Reclaimed	279	--	286 5, 285 6 (Lake)	--	1 60E-10	278	--
	3	1	H3-35	Reclaimed	279	--	295(N) to 293(S)	--	5 00E-10	278	--
	4	1	H3-36	Reclaimed	278	--	--	292(S) to 293(NE)	5 00E-10	273	--
	4	2	H3-37	Reclaimed	278	--	--	288(NE) to 292(SW)	5 00E-09	270 (SW) to 272 (NE)	--
	5	1	H3-38	Reclaimed	273	--	--	290	1 00E-09	275	--
	5	2	H3-39	Reclaimed	274	--	--	286(SE) to 285(NW); 282.6 (Lake)	5 00E-10	273 (NW) to 272 (SE)	--
	6	1	H3-40	Reclaimed	--	273	--	283(S) to 286(N); 282 5 (Lake)	5 00E-10	272 (S) to 274 (N)	--
	6	2	H3-41	Reclaimed	--	273	--	299(SW) to 285(NE); 282.5 (Lake)	--	270 (SW) to 272 (NE)	--
	EPL		H3-42	Lake Full	247 5 (MFT)	--	--	--	--	260 (SW) to 270 (NE)	--

In the far-future, the head in the Basal Aquifer is assumed to have recovered to pre-mining levels. Groundwater flow from Pit 1 discharges to the Muskeg River to the southeast (Cross-section 1-1, Figure IV3-32) flowing through unmined oil sandss, and to the southwest (Cross-section 1-2, Figure IV3-33) by flow through unmined surficial aquifers. Groundwater flow from Pit 2 also discharges to the Muskeg River, with flow occurring through unmined oil sandss (Figure IV3-34).

Seepage from Pits 3 and 4 flows outward into unmined land (Figures IV3-35, 36 and 37), however, this seepage is redirected vertically downward, toward the Basal Aquifer before it can discharge to receiving surface water.

Seepage from pit 5 can discharge southeast to the Muskeg River, with flow through the unmined oil sandss (Figure IV3-38).

The reclaimed surface in pit 6 is below the elevation of the unmined land, as shown in Figure IV3-40. Therefore, all seepage is toward the pit from unmined land.

IV.6.3 End pit lake Simulations

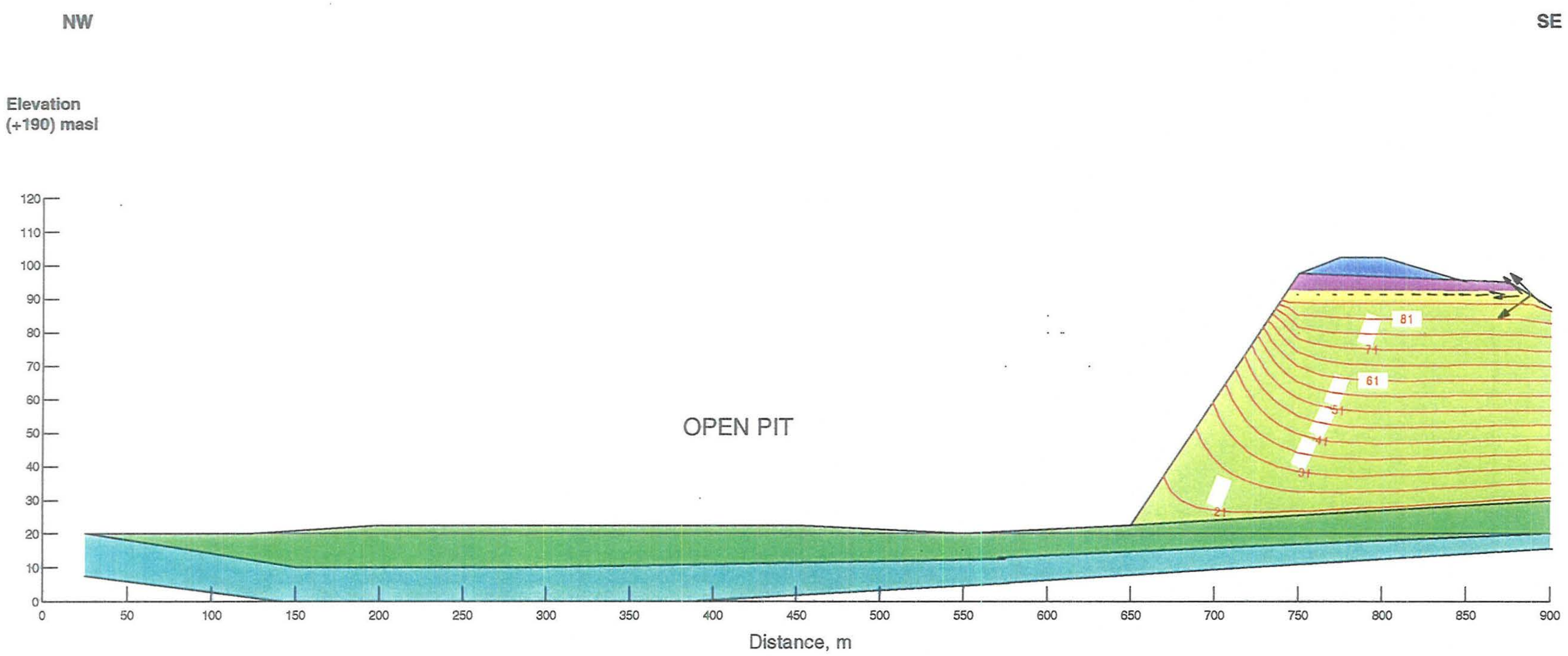
The long-term water balance of the End pit lake, and potential impacts on lake water quality due to seepage from the mined areas, warranted special consideration as part of the overall seepage analyses conducted for the mine.

Simulation models were developed for Cross-sections 4-2, 5-2 and 6-2 (Figure IV3-6) for the purpose of evaluating hdyrogeologic relationships between the End pit lake and the adjacent mine pits, including in-pit dykes. A model was developed for Cross-section EPL (Figure IV3-6) to assess interactions between the lake and the surrounding unmined land.

The lake was assumed to be filled by 2030. The lower half of the lake's depth was assumed to be filled with mature fine tails (MFT). Simulations for the cross-sections were conducted for 2030 and far-future snapshot times.

Seepage results for these simulations are summarized in Table IV3-7. Simulation results for cross-sections related to the end pit lake are shown in Figure IV3-31 (2030, EPL) and Figures IV3-37, 39, 41 and 42 for the far-future.

Seepage from the end pit lake will be directed toward both unmined land to the west, and into the Basal Aquifer (Figure IV3-42). The lateral seepage to Isadore's Lake will be fresh water from the water cap of the Lake. Any



NOTES

— Contours are hydraulic head, (+190 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2003, PIT 1
VERTICAL CROSS-SECTION 1-1
SIMULATION MODEL RESULTS

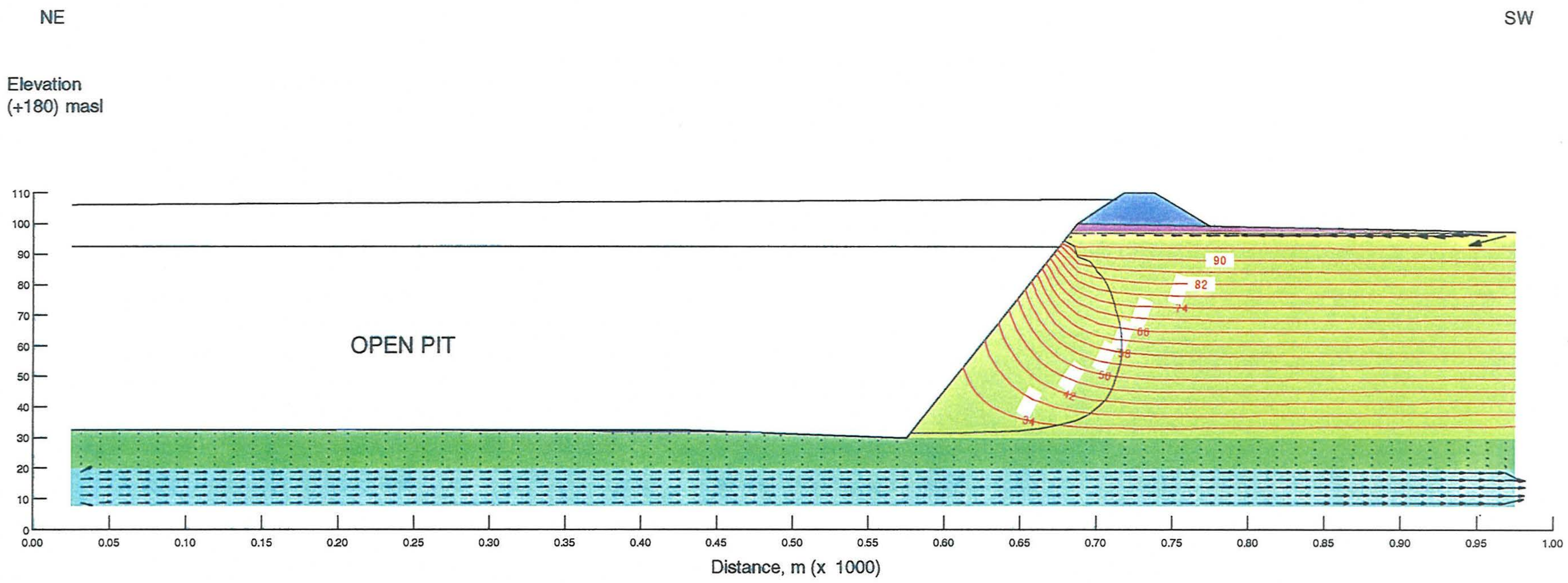
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/24

PROJECT NO: 4577

FIGURE IV-10



NOTES

— Contours are hydraulic head, (+180 m) asl

— Groundwater surface

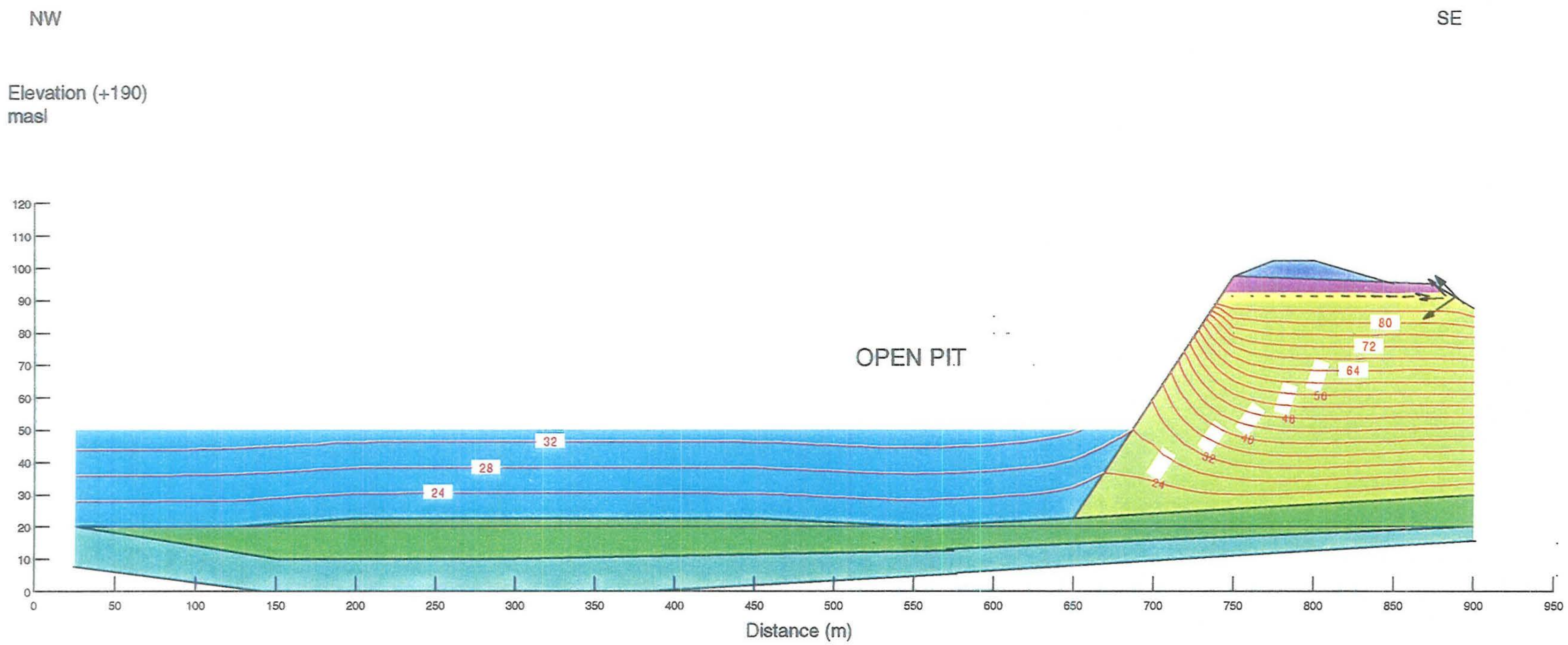
Geologic units and Geographic Features
are labelled in Figure H3-33

Location of Cross Section 1-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2003, PIT 1 VERTICAL CROSS-SECTION 1-2 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/24
	PROJECT NO: 4577		**FIGURE** **IV-11**



NOTES

— Contours are hydraulic head, (+190 m) asl

— Groundwater surface

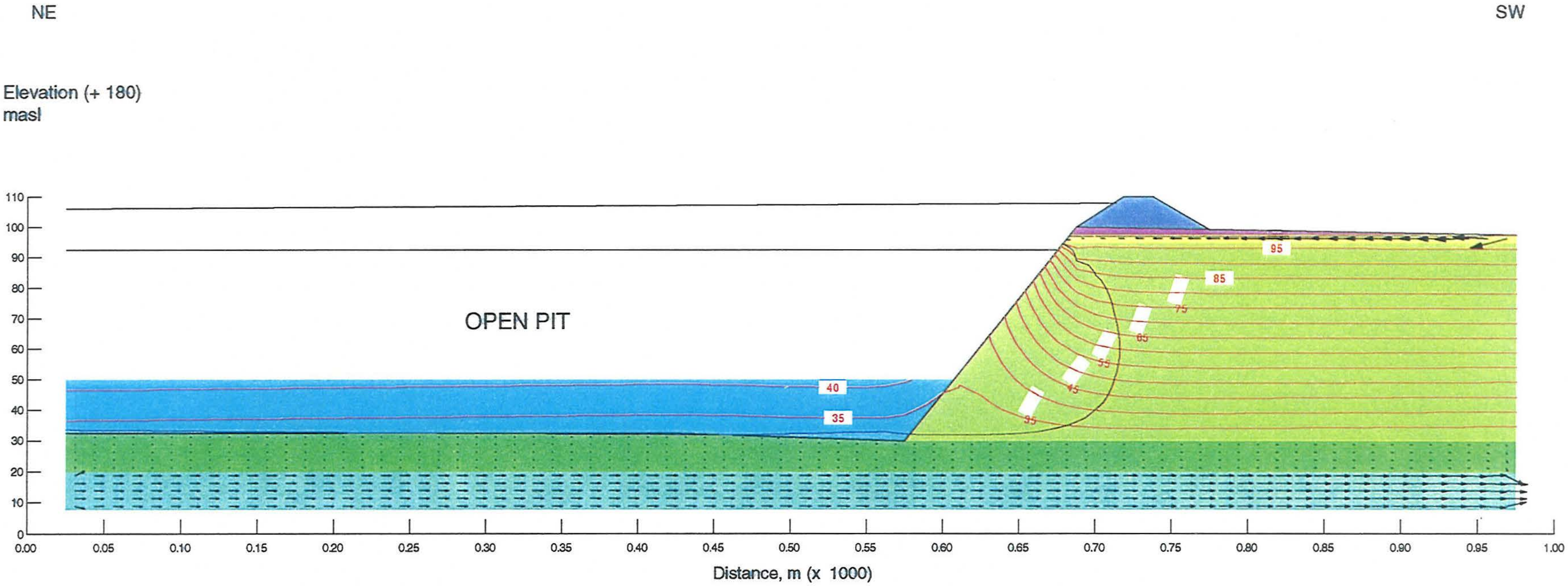
Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2005, PIT 1 VERTICAL CROSS-SECTION 1-1 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/24
	PROJECT NO: 4577	**FIGURE** **IV-12**	



NOTES

— Contours are hydraulic head, (+180 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-33

Location of Cross Section 1-2 shown in Figure H3-6

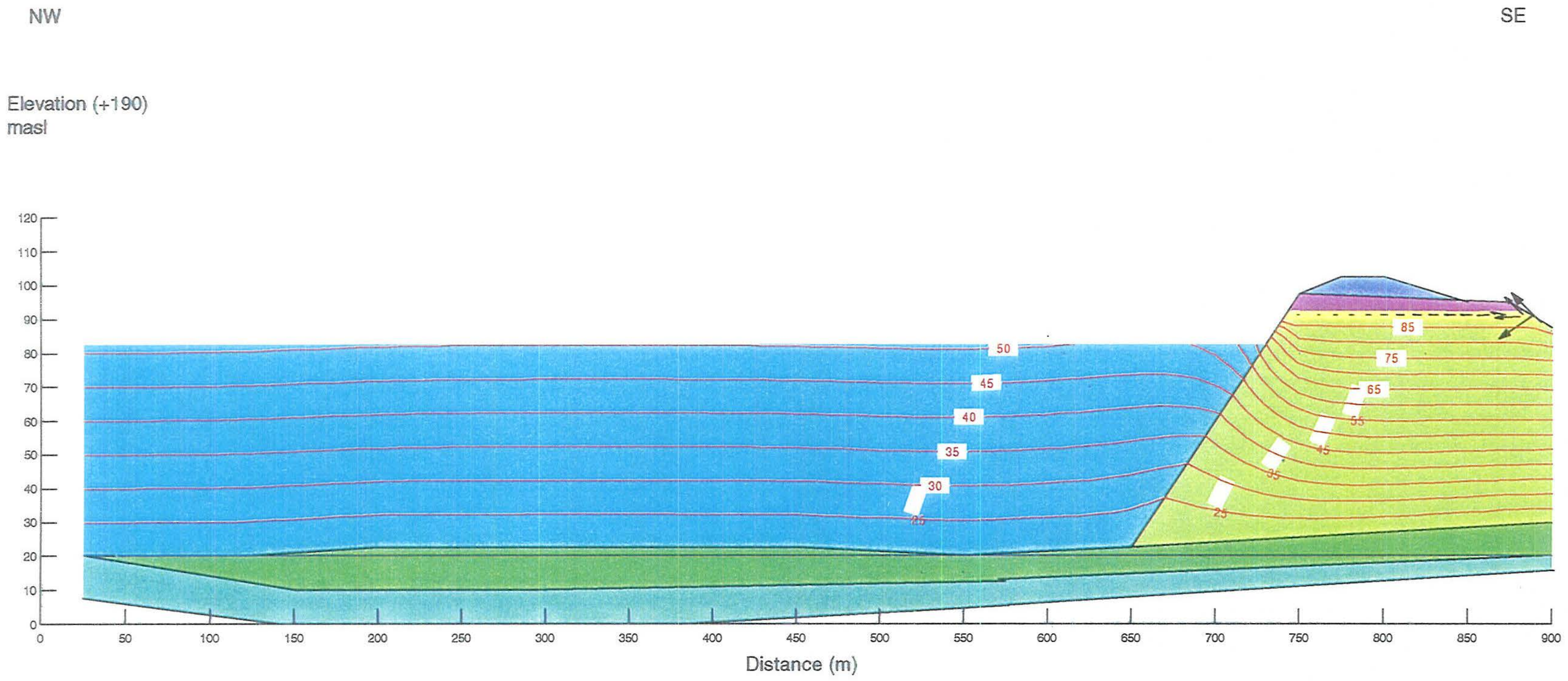
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2005, PIT 1
VERTICAL CROSS-SECTION 1-2
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-13



NOTES

Contours are hydraulic head, (+190 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

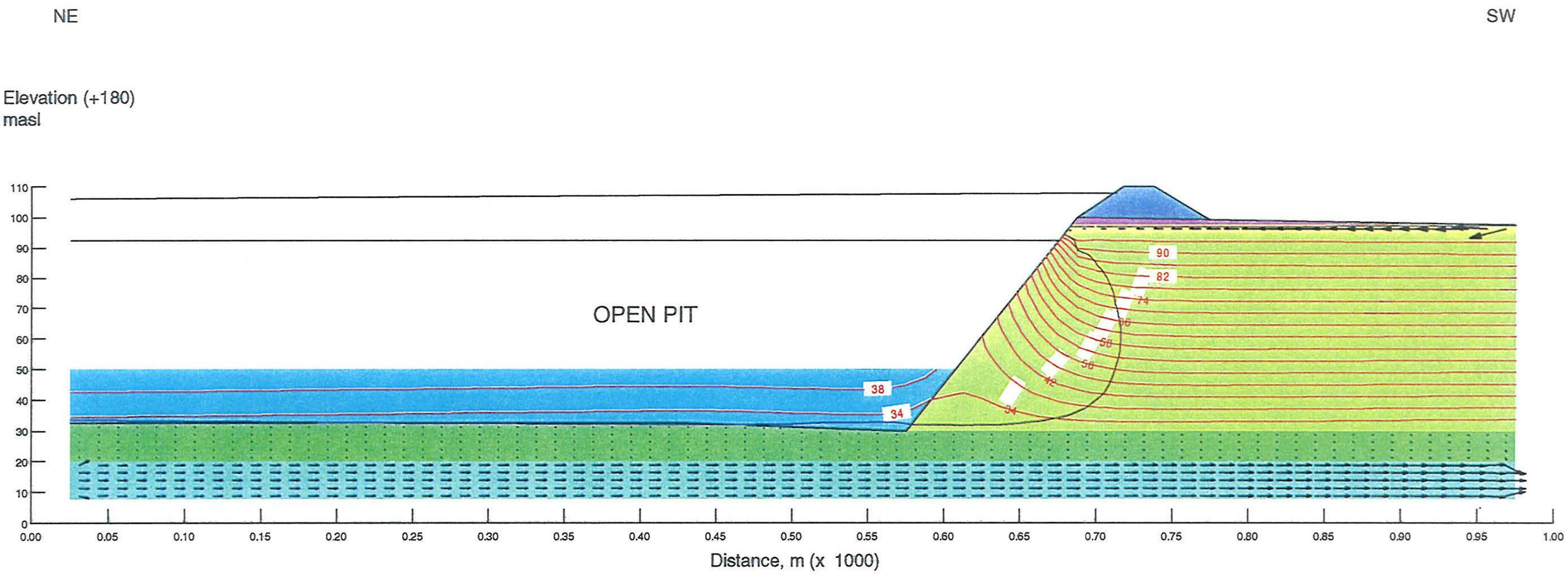
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2010, PIT 1
VERTICAL CROSS-SECTION 1-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-14



NOTES

Contours are hydraulic head, (+180 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-33

Location of Cross Section 1-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2010, PIT 1
VERTICAL CROSS-SECTION 1-2
SIMULATION MODEL RESULTS

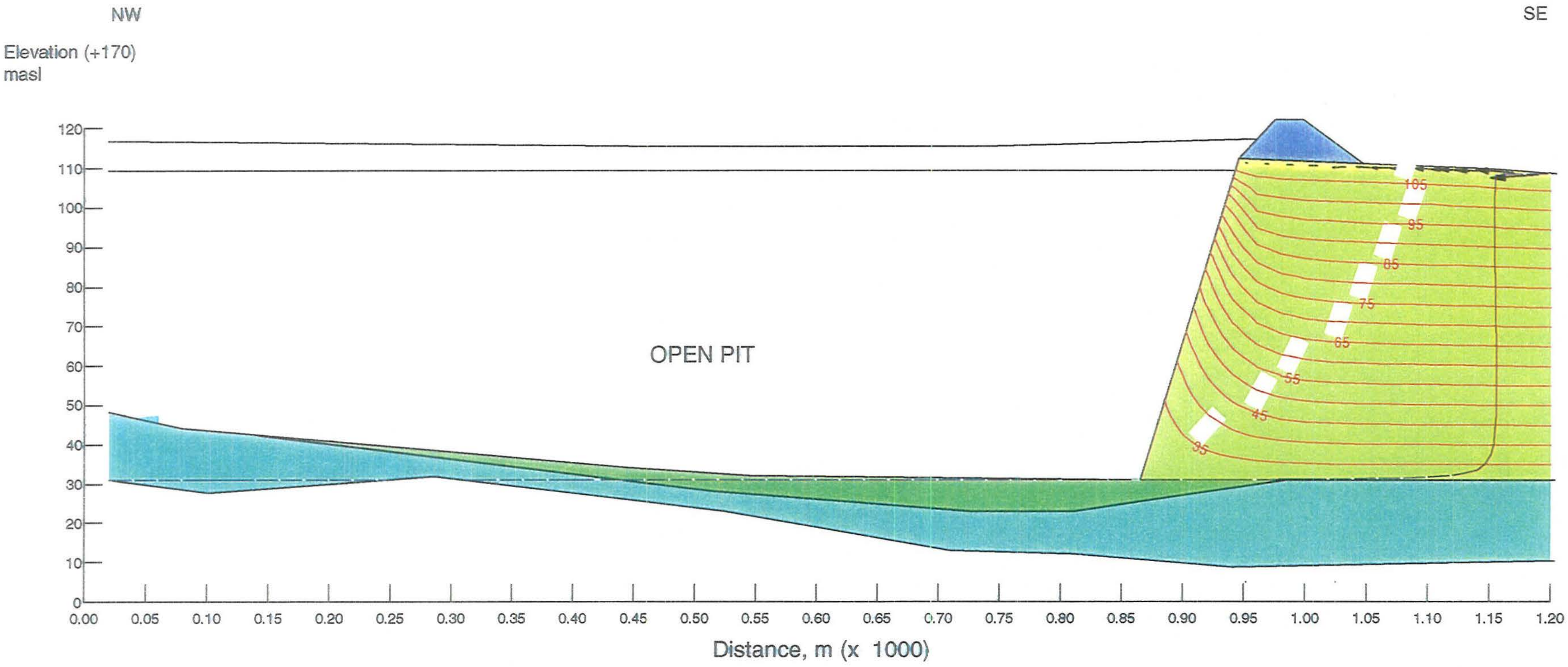
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/24

PROJECT NO: 4577

FIGURE IV-15



NOTES

Contours are hydraulic head, (+170 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-34

Location of Cross Section 2-1 shown in Figure H3-6

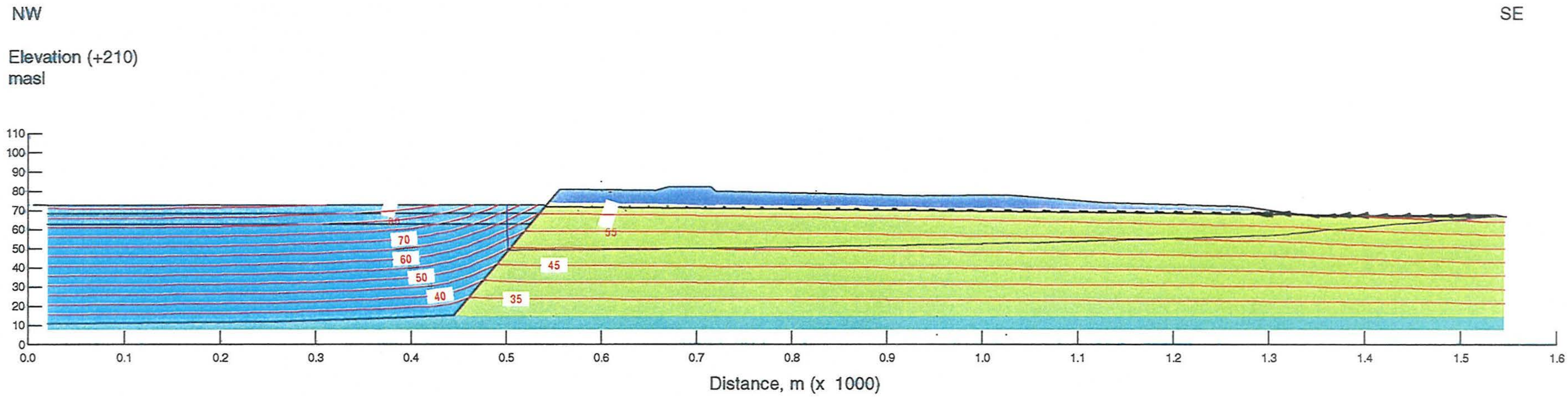
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2010, PIT 2
VERTICAL CROSS-SECTION 2-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-16



NOTES

— Contours are hydraulic head, (+210 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-38

Location of Cross Section 5-1 shown in Figure H3-6

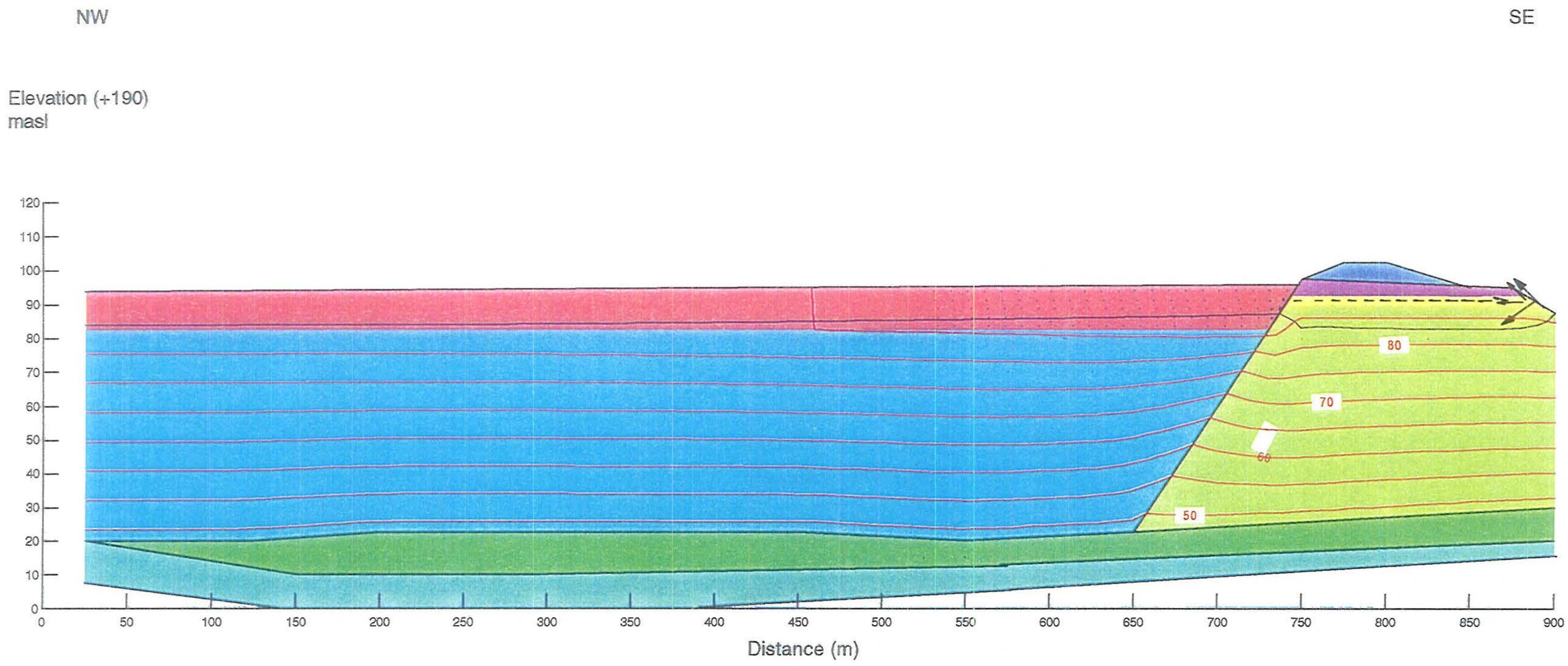
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2022, PIT 5
VERTICAL CROSS-SECTION 5-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-17



NOTES

— Contours are hydraulic head, (+190 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 1
VERTICAL CROSS-SECTION 1-1
SIMULATION MODEL RESULTS

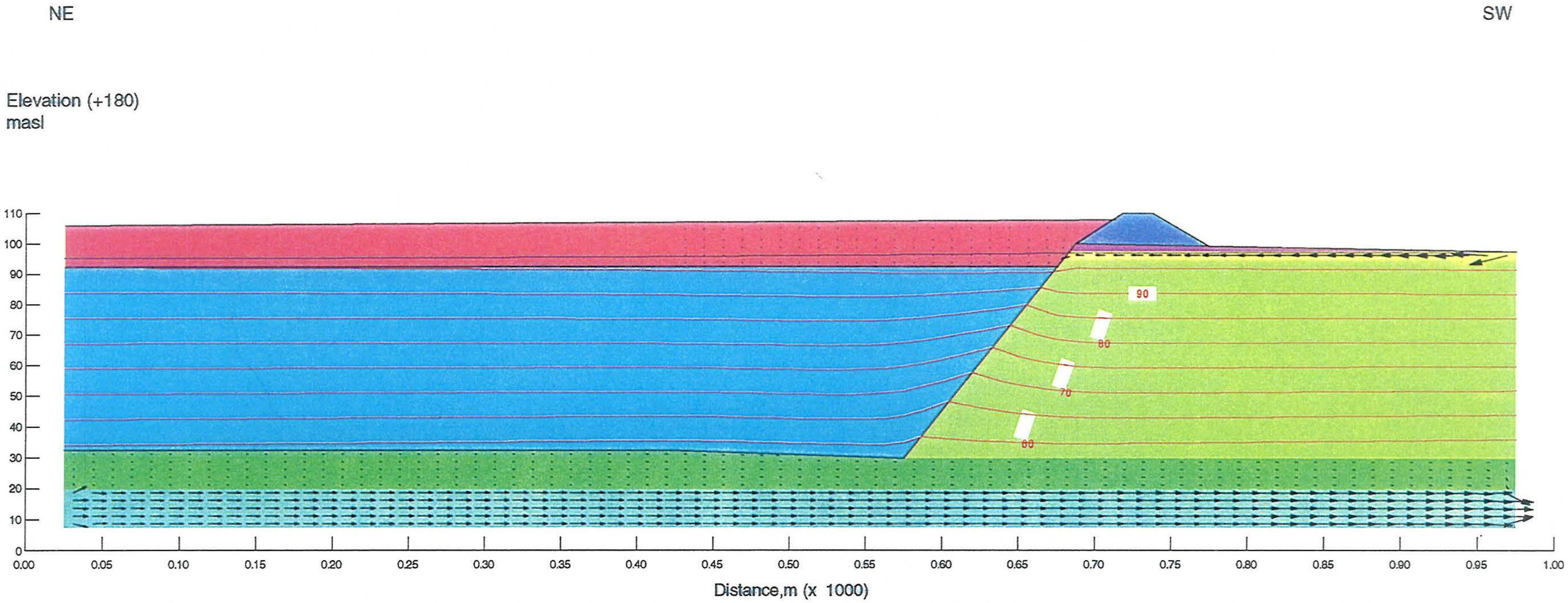
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/24

PROJECT NO: 4577

FIGURE IV-18



NOTES

Contours are hydraulic head, (+180 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-33

Location of Cross Section 1-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 1
VERTICAL CROSS-SECTION 1-2
SIMULATION MODEL RESULTS

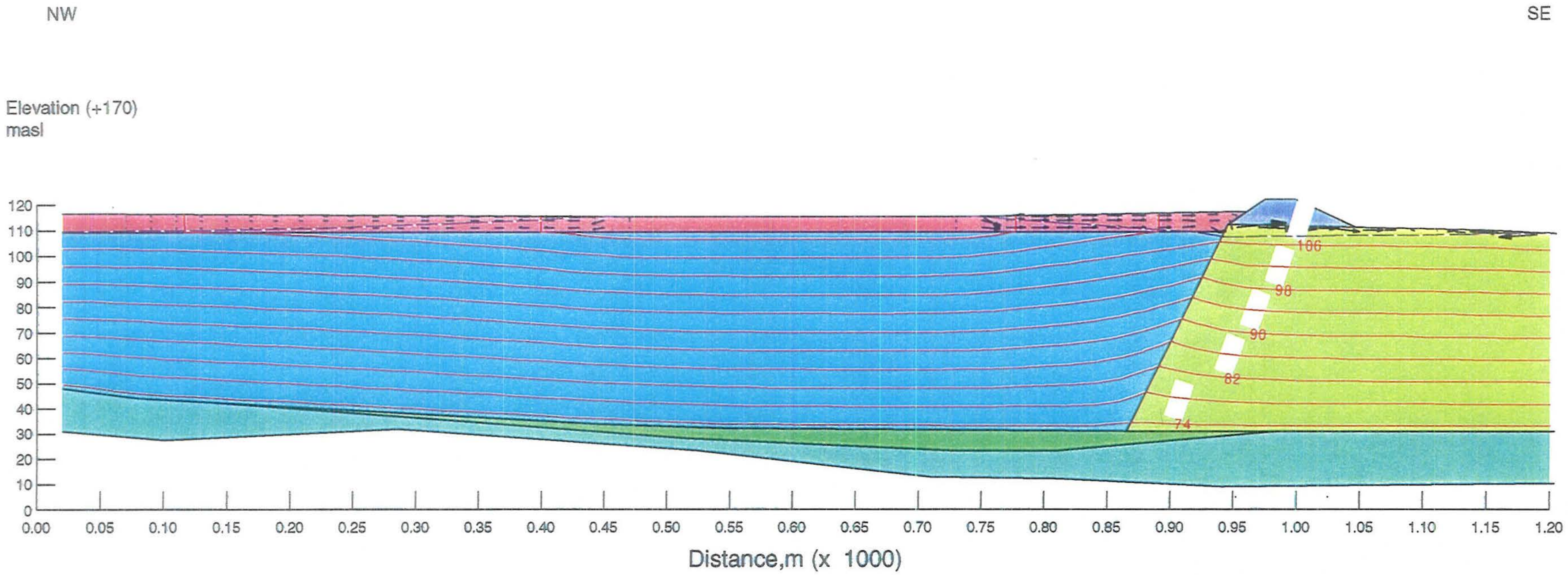
APPROVED BY: M.T.

DRAWN BY: F.R..

DATE: 97/11/24

PROJECT NO: 4577

FIGURE IV-19



NOTES

— Contours are hydraulic head, (+170 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-34

Location of Cross Section 2-1 shown in Figure H3-6

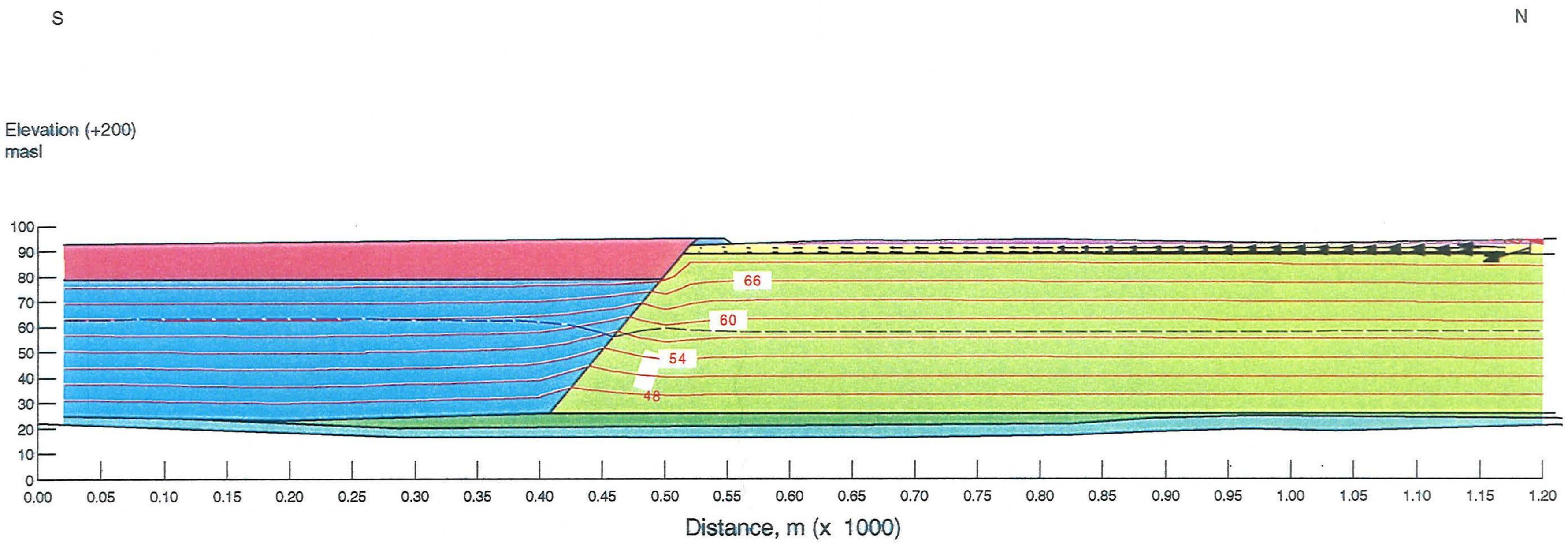
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 2
VERTICAL CROSS-SECTION 2-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-20



NOTES

🟥 Contours are hydraulic head, (+200 m) asl

🟦 Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-35

Location of Cross Section 3-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 3
VERTICAL CROSS-SECTION 3-1
SIMULATION MODEL RESULTS

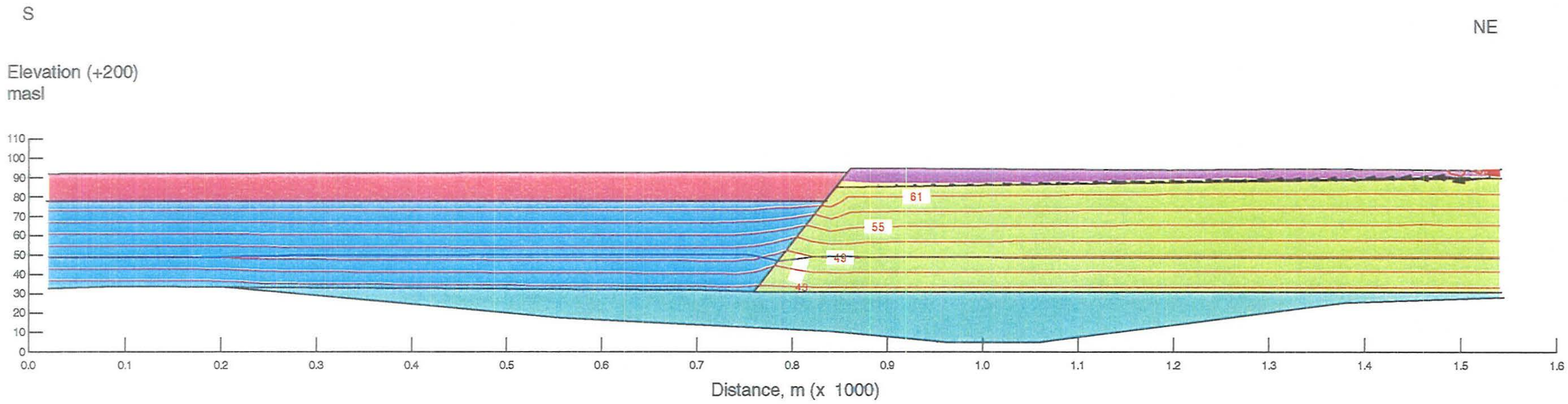
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/24

PROJECT NO: 4577

FIGURE IV-21



NOTES

▬ Contours are hydraulic head, (+200 m) asl

▬ Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-36

Location of Cross Section 4-1 shown in Figure H3-6

Vertical Exaggeration 2x

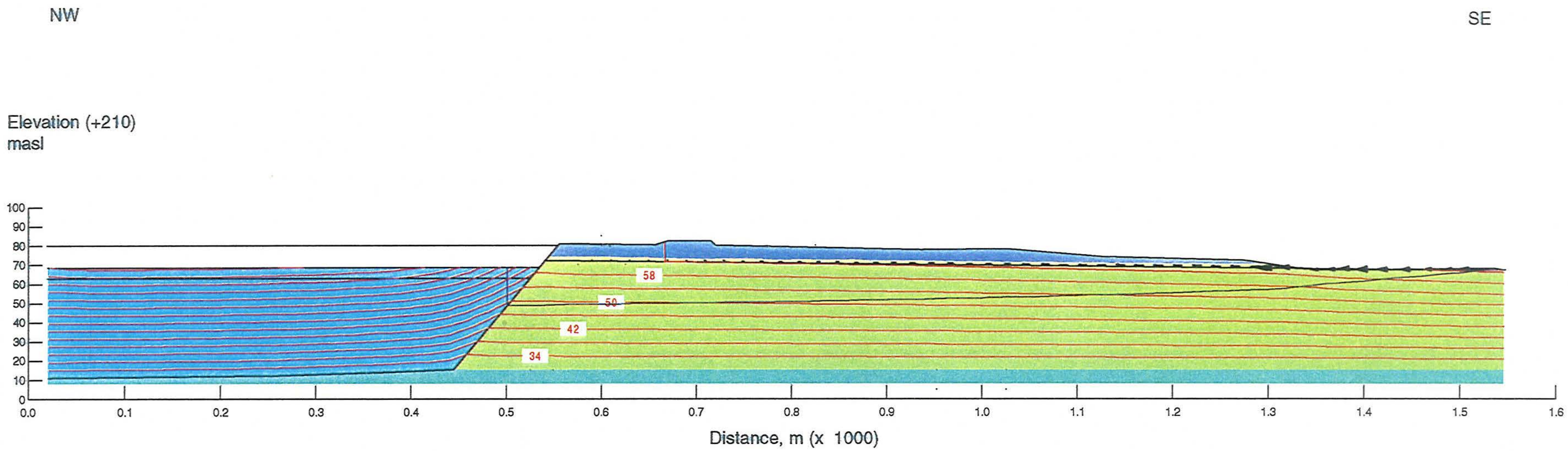
SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 4
VERTICAL CROSS-SECTION 4-1
SIMULATION MODEL RESULTS

APPROVED BY:	DRAWN BY:	DATE:
M.T.	F.R.	97/11/24

PROJECT NO:	**FIGURE**
4577	**IV-22**



NOTES

— Contours are hydraulic head, (+210 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-38

Location of Cross Section 5-1 shown in Figure H3-6

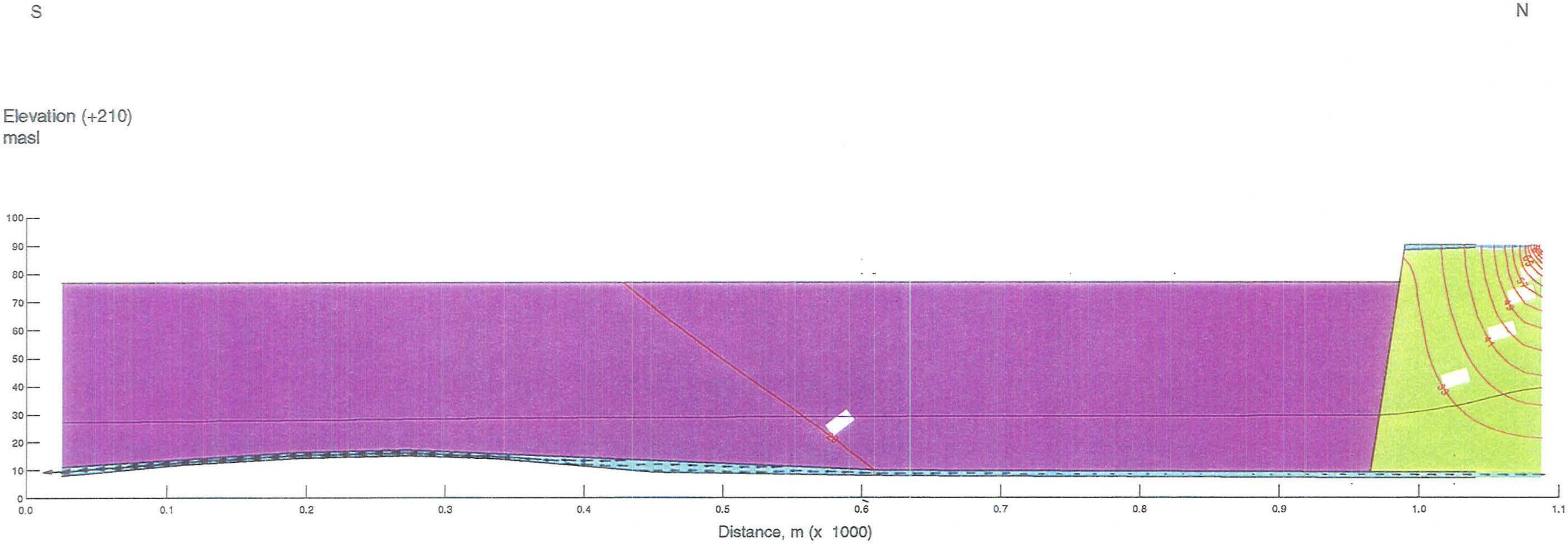
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2025, PIT 5
VERTICAL CROSS-SECTION 5-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/24
PROJECT NO: 4577
FIGURE IV-23



NOTES

Contours are hydraulic head, (+210 m) asl

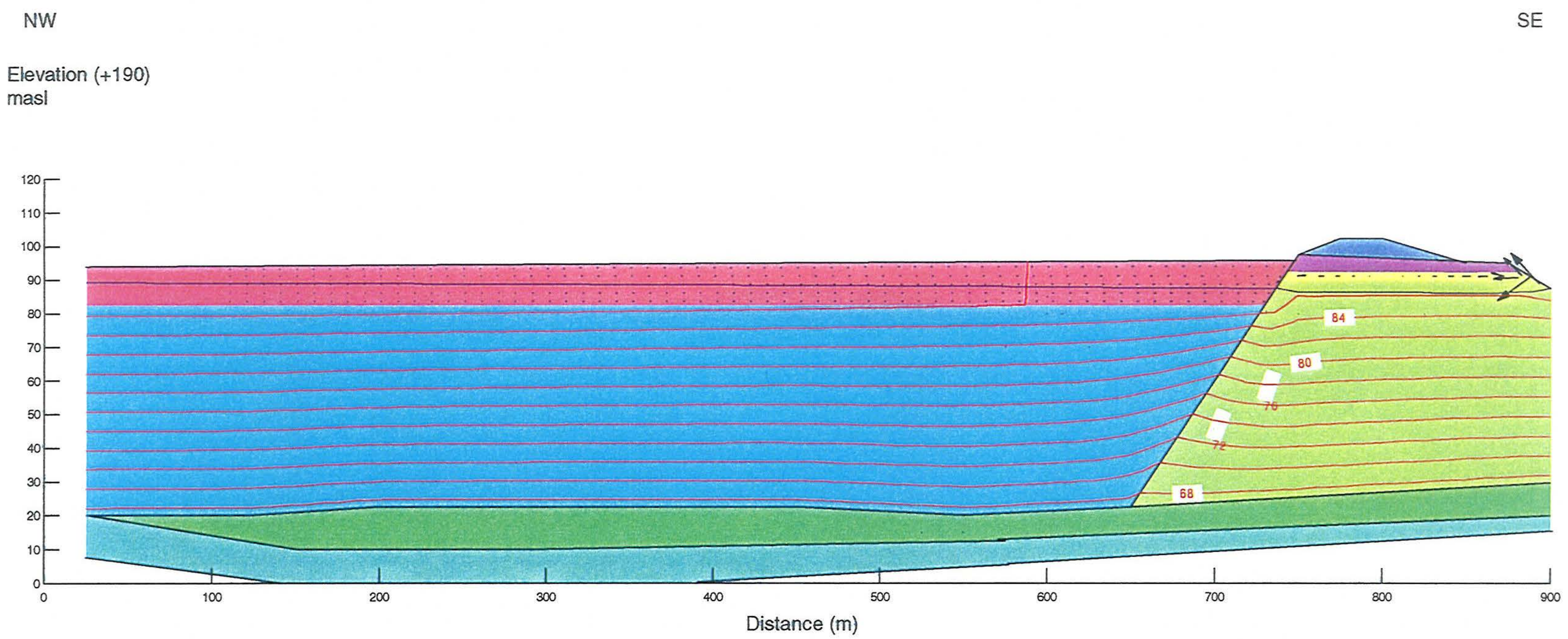
Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-40

Location of Cross Section 6-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS		
2025, PIT 6 VERTICAL CROSS-SECTION 6-1 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/24
	PROJECT NO: 4577	**FIGURE** **IV-24**	



NOTES

Contours are hydraulic head, (+190 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

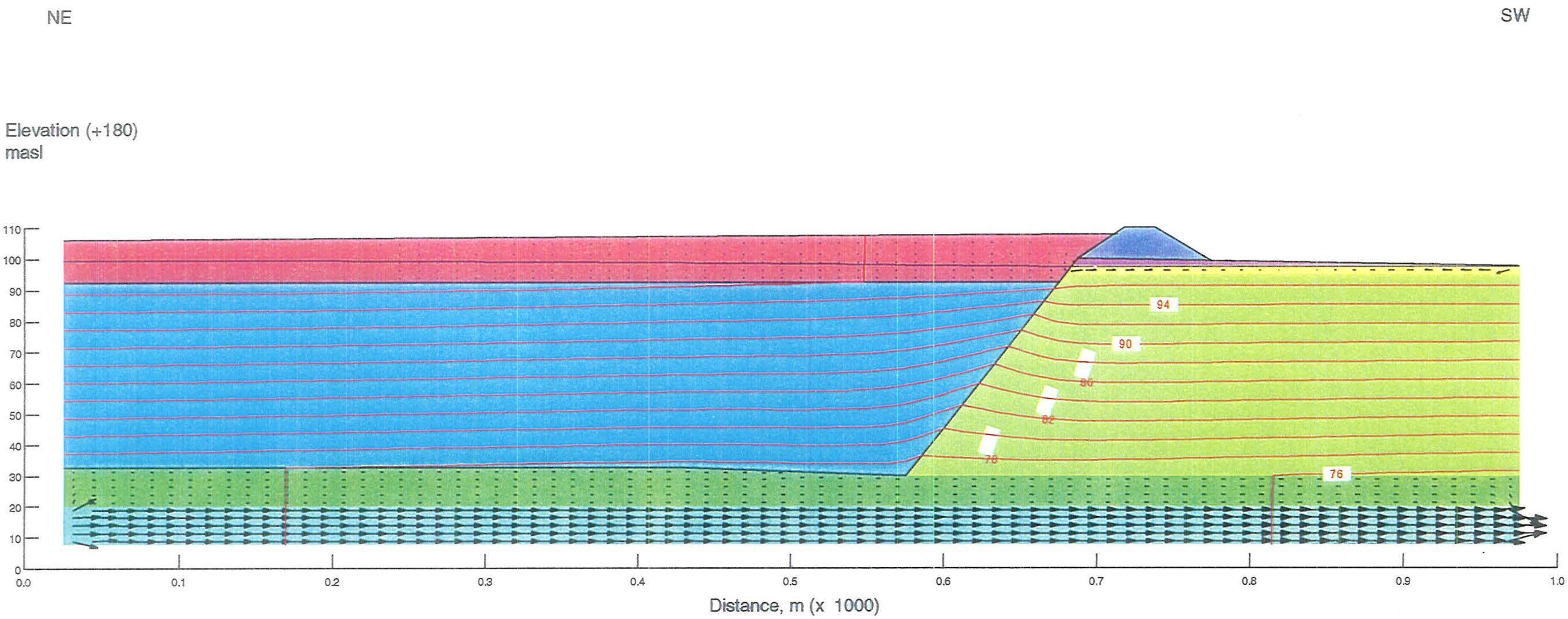
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 1
VERTICAL CROSS-SECTION 1-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-25



NOTES

— Contours are hydraulic head, (+180 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-33

Location of Cross Section 1-2 shown in Figure H3-6

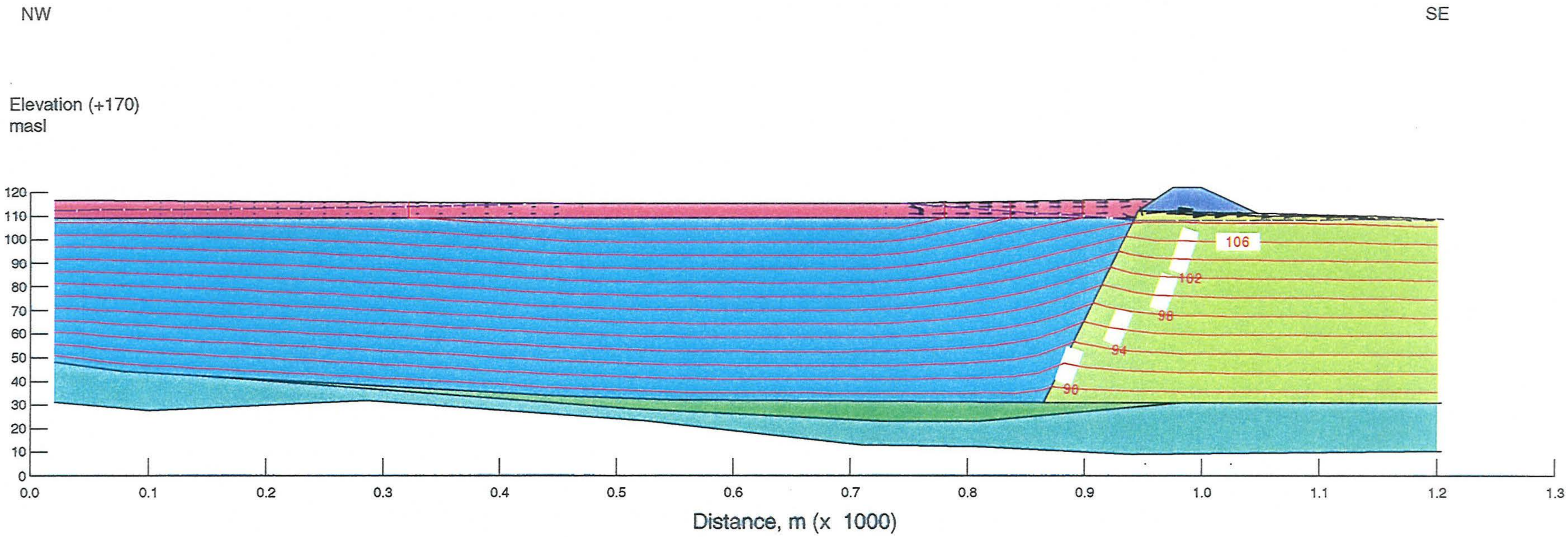
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 1
VERTICAL CROSS-SECTION 1-2
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-26



NOTES

Contours are hydraulic head, (+170 m) asl

Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-34

Location of Cross Section 2-1 shown in Figure H3-6

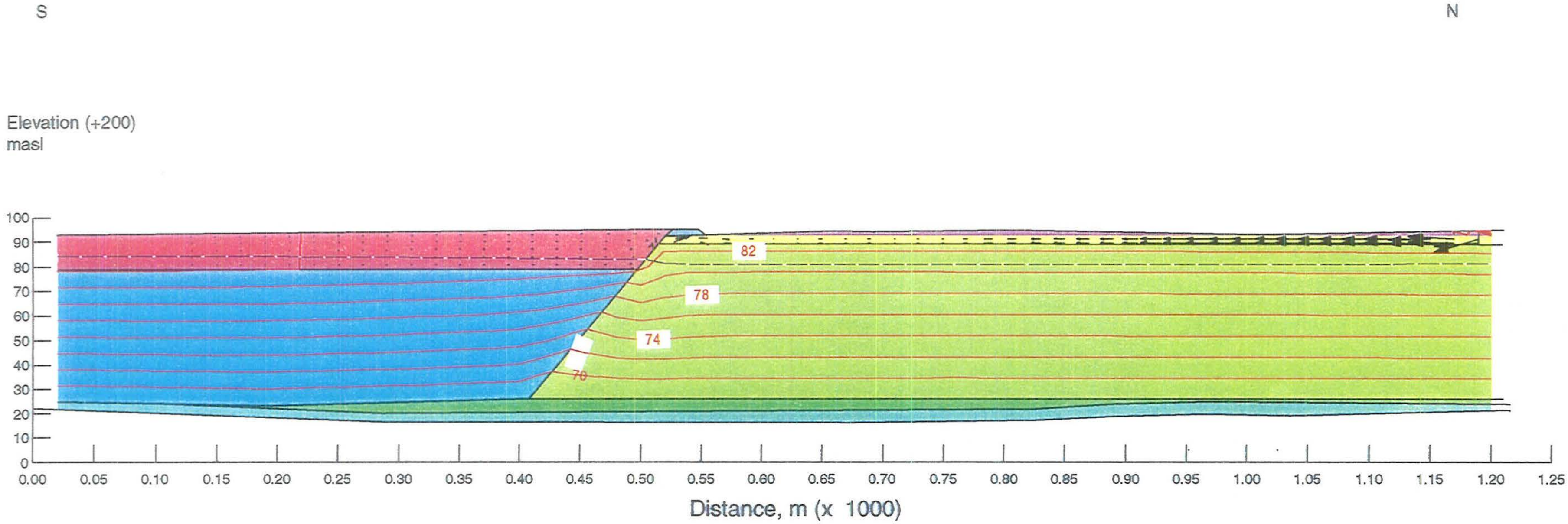
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 2
VERTICAL CROSS-SECTION 2-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
PROJECT NO: 4577	**FIGURE IV-27**	



NOTES

— Contours are hydraulic head, (+200 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-35

Location of Cross Section 3-1 shown in Figure H3-6

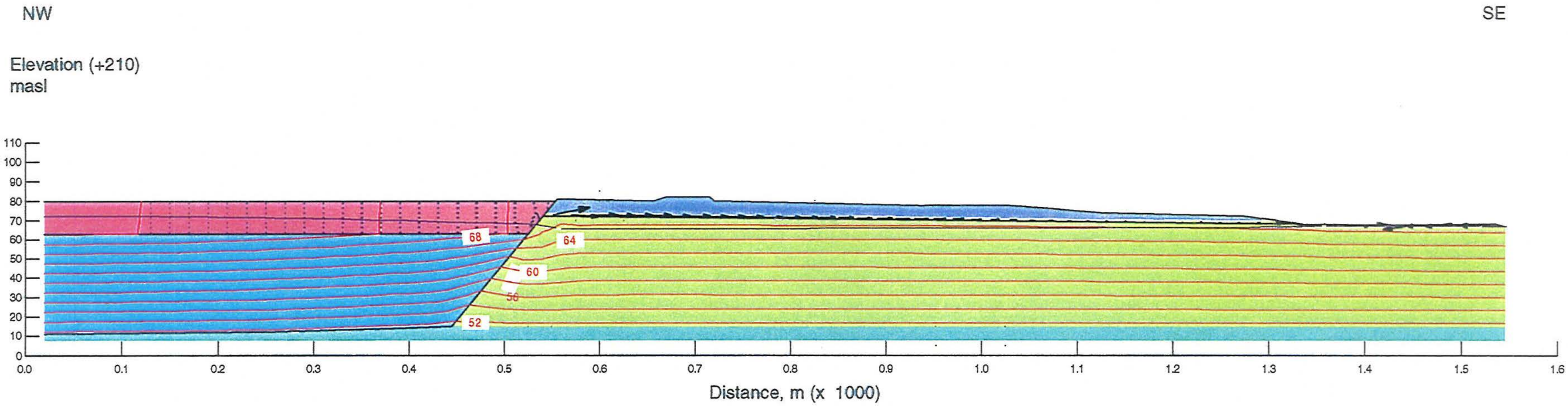
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 3
VERTICAL CROSS-SECTION 3-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R..
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-28



NOTES

—— Contours are hydraulic head, (+210 m) asl

—— Groundwater surface

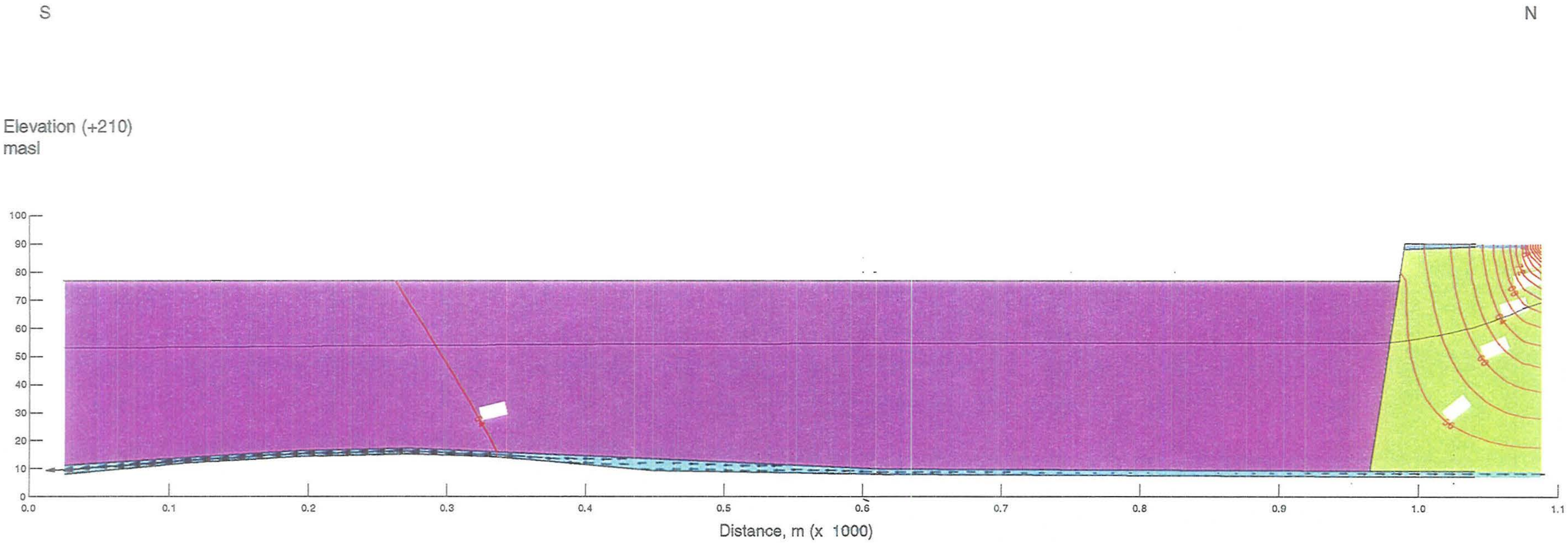
Geologic units and Geographic Features
are labelled in Figure H3-38

Location of Cross Section 5-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 5 VERTICAL CROSS-SECTION 5-1 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577	**FIGURE** **IV-29**	



NOTES

——Contours are hydraulic head, (+210 m) asl

——Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-40

Location of Cross Section 6-1 shown in Figure H3-6

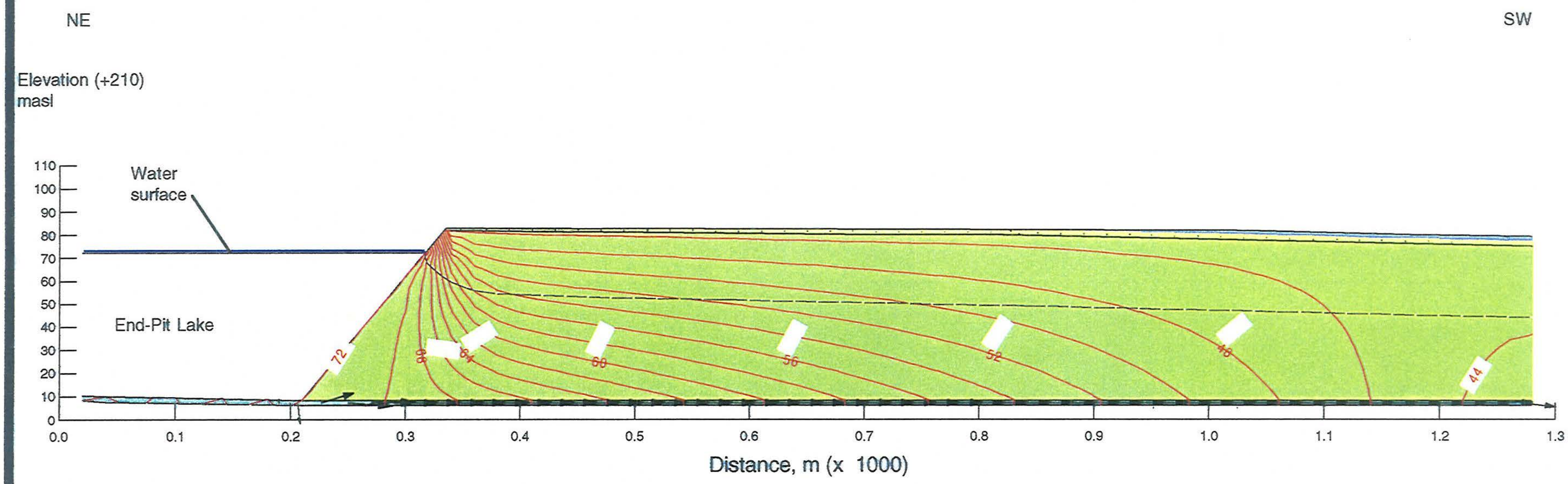
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, PIT 6
VERTICAL CROSS-SECTION 6-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-30



NOTES

— Contours are hydraulic head, (+210 m) asl

— Groundwater surface

Geologic units and Geographic Features are labelled in Figure H3-42

Location of Cross Section EPL shown in Figure H3-6

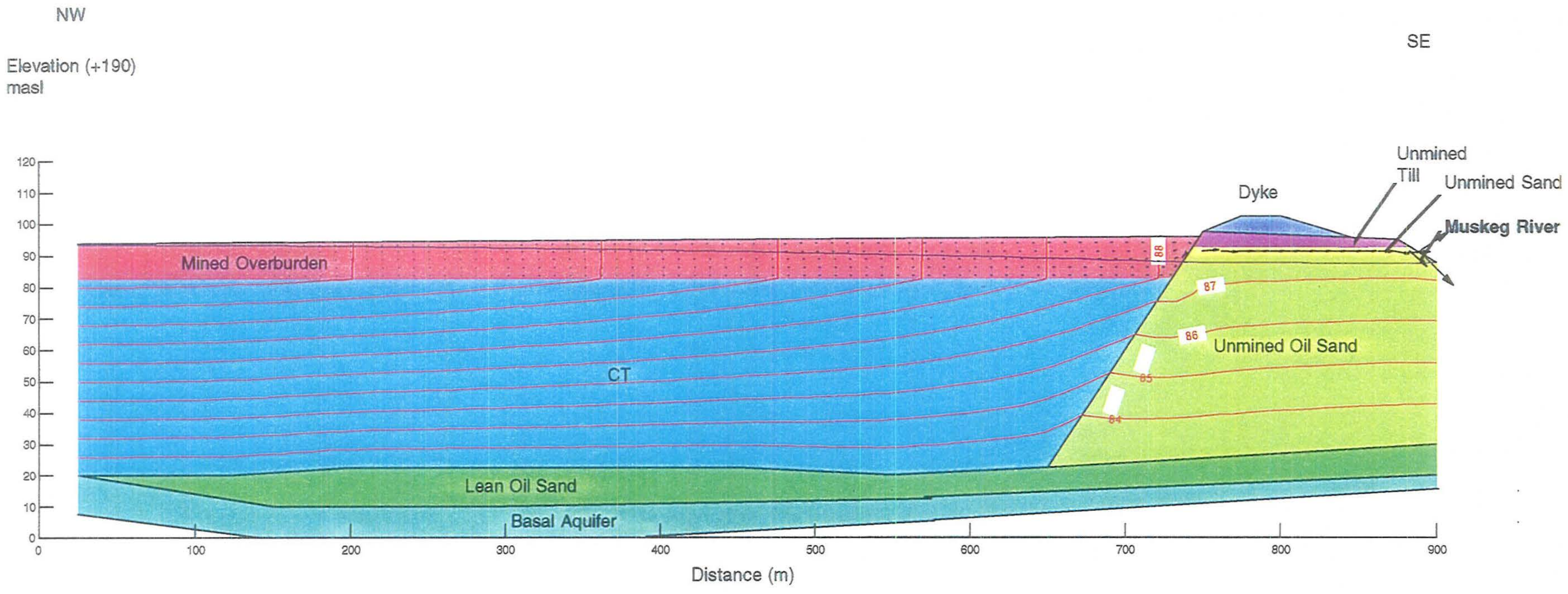
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2030, END-PIT LAKE
VERTICAL CROSS-SECTION EPL
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-31



NOTES

🟥 Contours are hydraulic head, (+190 m) asl

🟦 Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-32

Location of Cross Section 1-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 1
VERTICAL CROSS-SECTION 1-1
SIMULATION MODEL RESULTS

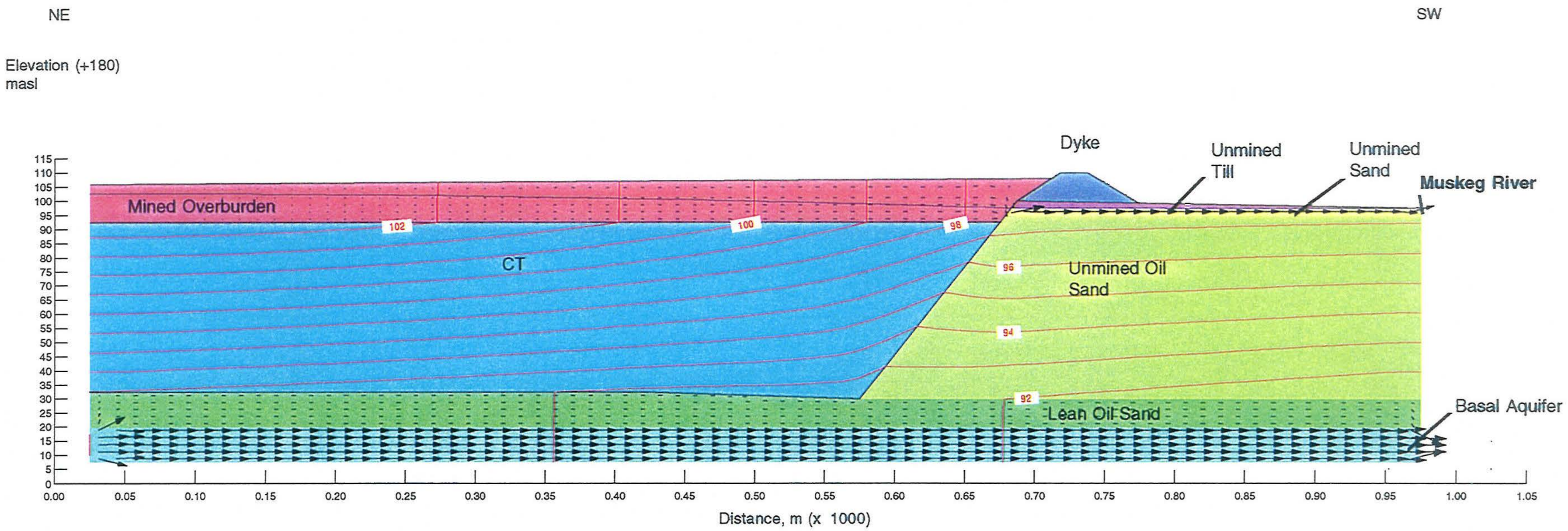
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/25

PROJECT NO: 4577

FIGURE IV-32



NOTES

🟥 Contours are hydraulic head, (+180 m) asl

🟦 Groundwater surface

Location of Cross Section 1-2 shown in Figure H3-6

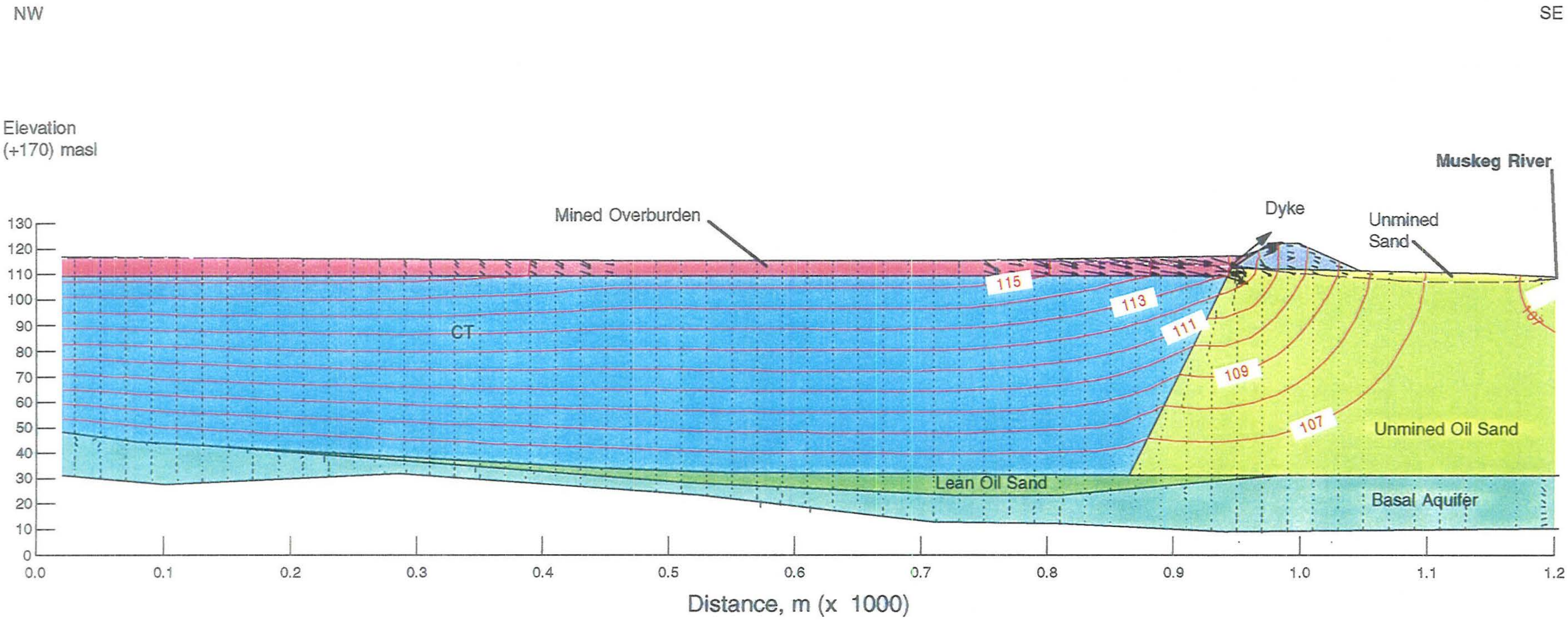
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 1
VERTICAL CROSS-SECTION 1-2
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-33



NOTES

- Contours are hydraulic head, (+170 m) asl
- Groundwater surface

Location of Cross Section 2-1 shown in Figure H3-6

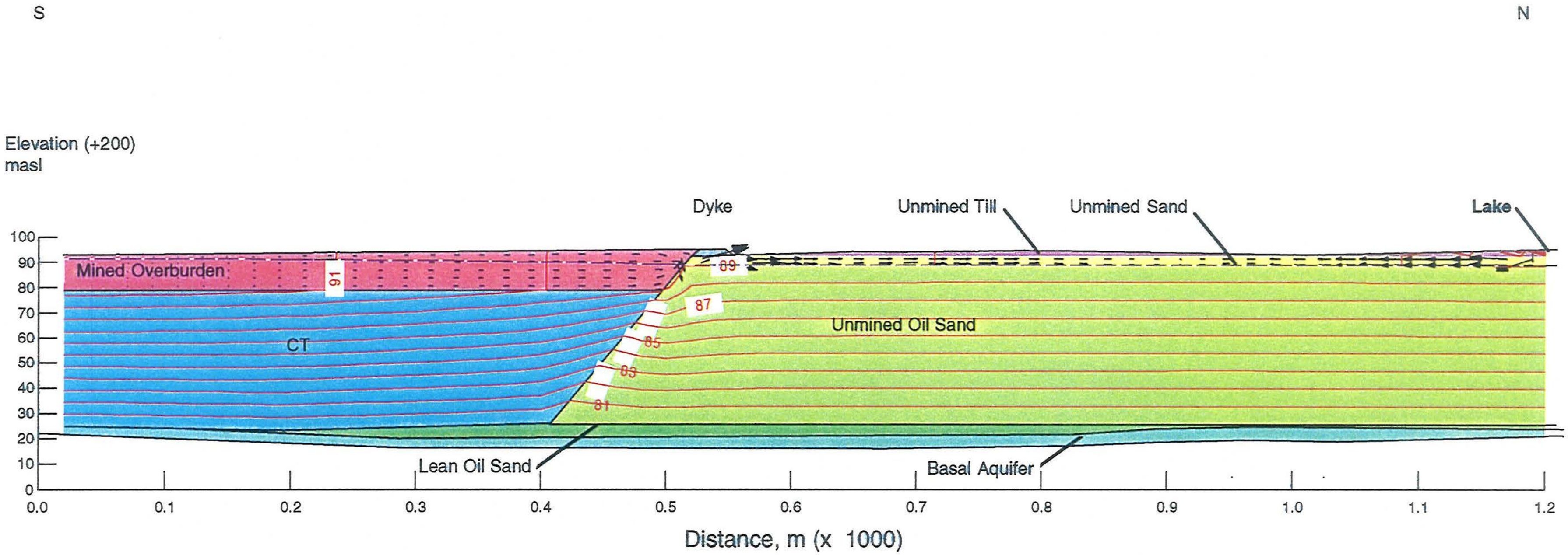
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 2
VERTICAL CROSS-SECTION 2-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-34



NOTES

🟥 Contours are hydraulic head, (+200 m) asl

🟦 Groundwater surface

Location of Cross Section 3-1 shown in Figure H3-6

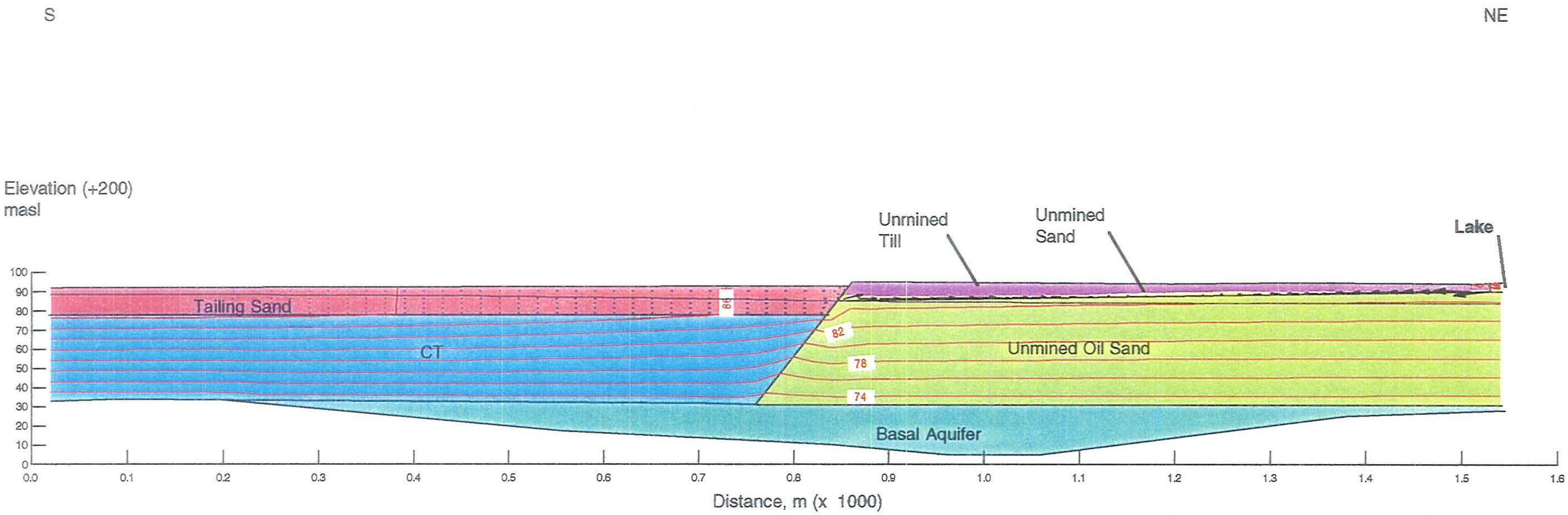
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 3
VERTICAL CROSS-SECTION 3-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577B
FIGURE IV-35



NOTES

Contours are hydraulic head, (+200 m) asl

Groundwater surface

Location of Cross Section 4-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 4
VERTICAL CROSS-SECTION 4-1
SIMULATION MODEL RESULTS

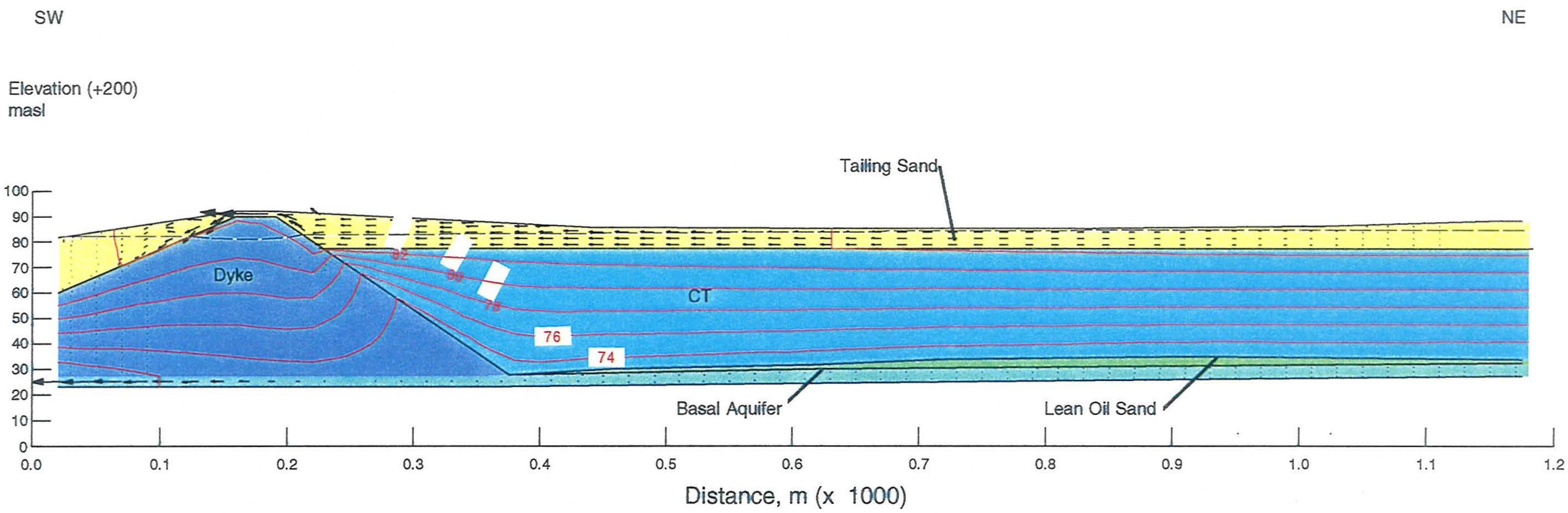
APPROVED BY: M.T.

DRAWN BY: F.R.

DATE: 97/11/25

PROJECT NO: 4577

FIGURE IV-36



NOTES

Contours are hydraulic head, (+200 m) asl

Groundwater surface

Location of Cross Section 4-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

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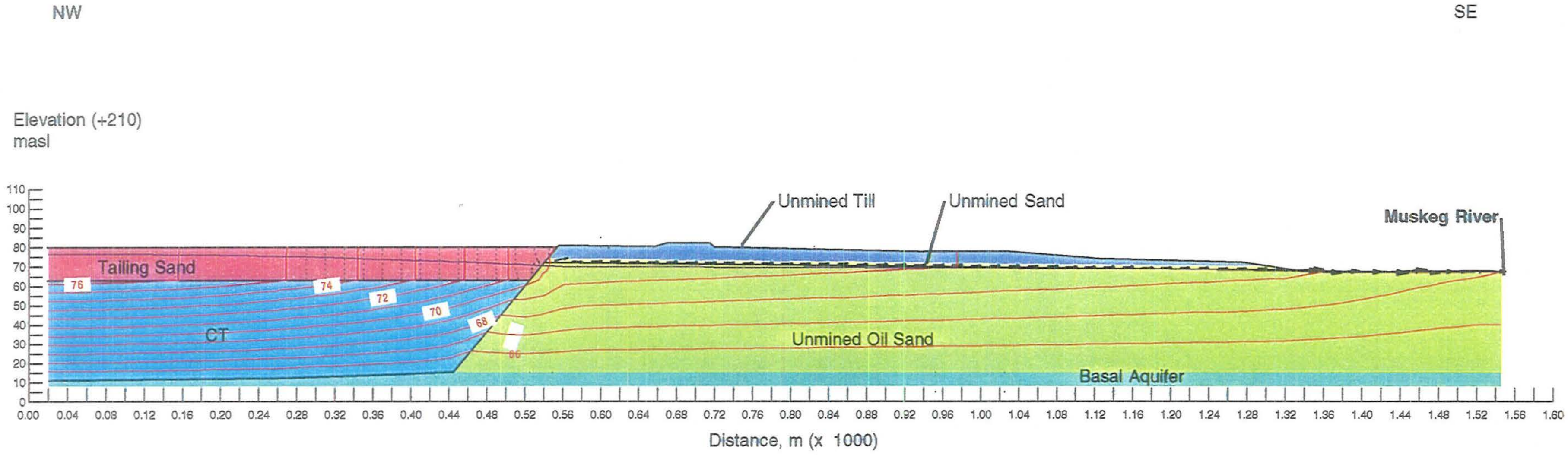
FAR FUTURE, PIT 4
VERTICAL CROSS-SECTION 4-2
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-37



NOTES

— Contours are hydraulic head, (+210 m) asl

— Groundwater surface

Location of Cross Section 5-1 shown in Figure H3-6

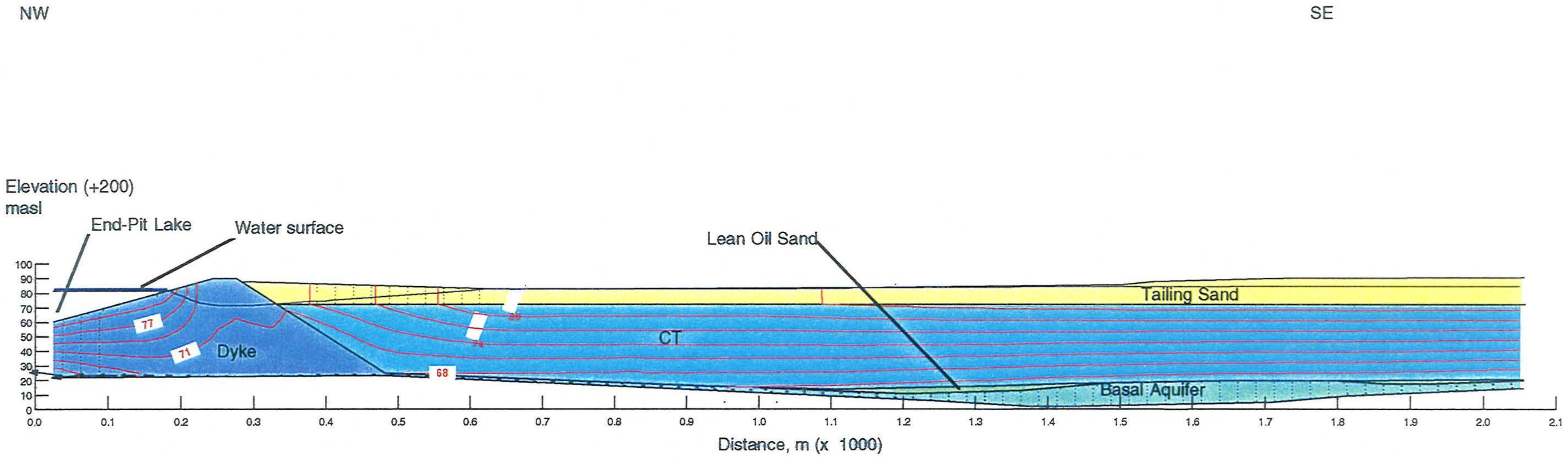
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 5
VERTICAL CROSS-SECTION 5-1
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-38



NOTES

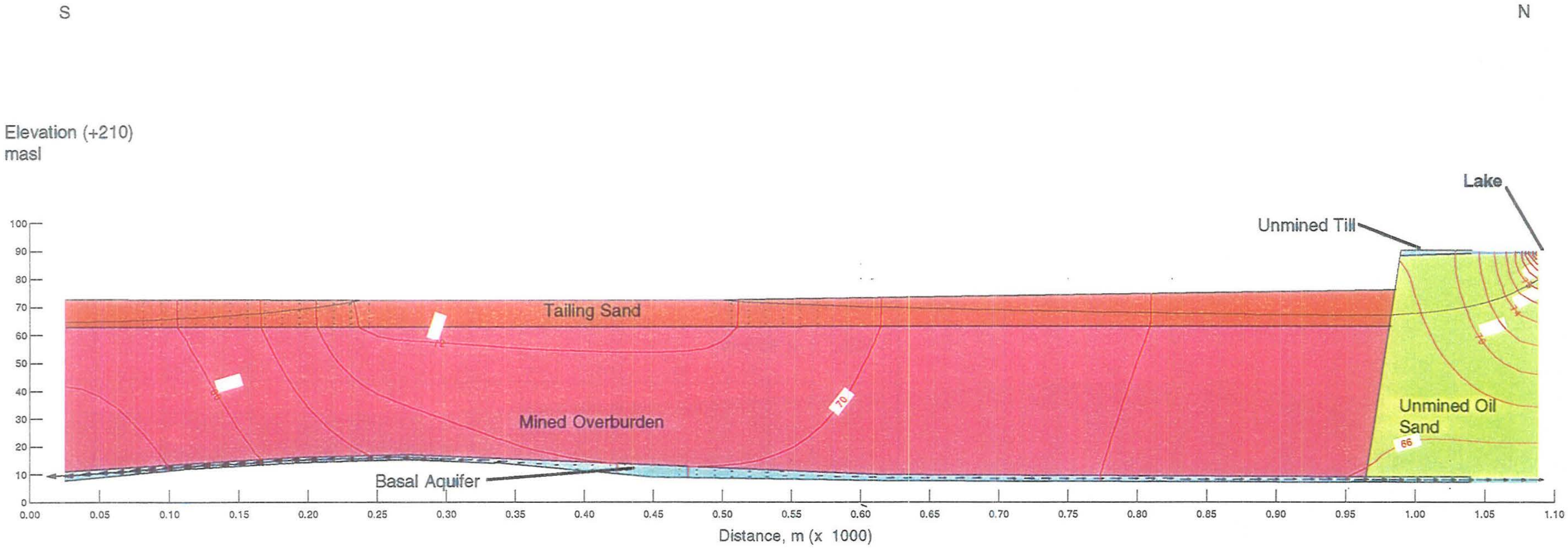
- Contours are hydraulic head, (+200 m) asl
- Groundwater surface

Location of Cross Section 5-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 5 VERTICAL CROSS-SECTION 5-2 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577	**FIGURE** **IV-39**	



NOTES

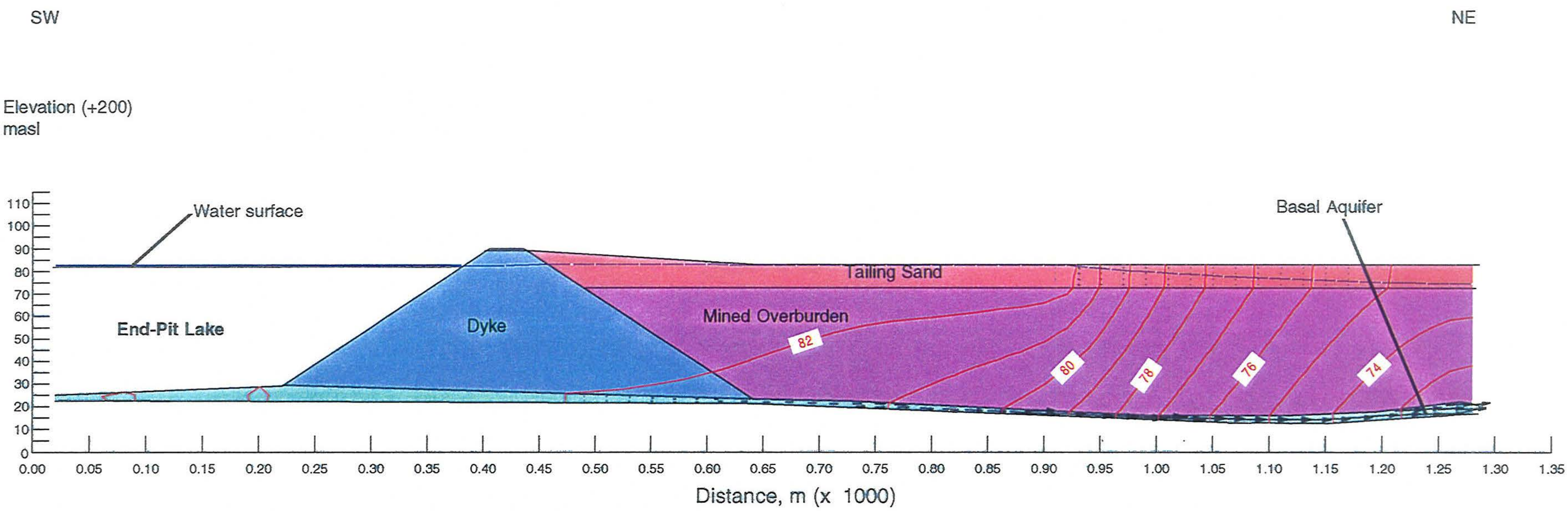
- Contours are hydraulic head, (+210 m) asl
- Groundwater surface

Location of Cross Section 6-1 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, PIT 6 VERTICAL CROSS-SECTION 6-1 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577		**FIGURE IV-40**



NOTES

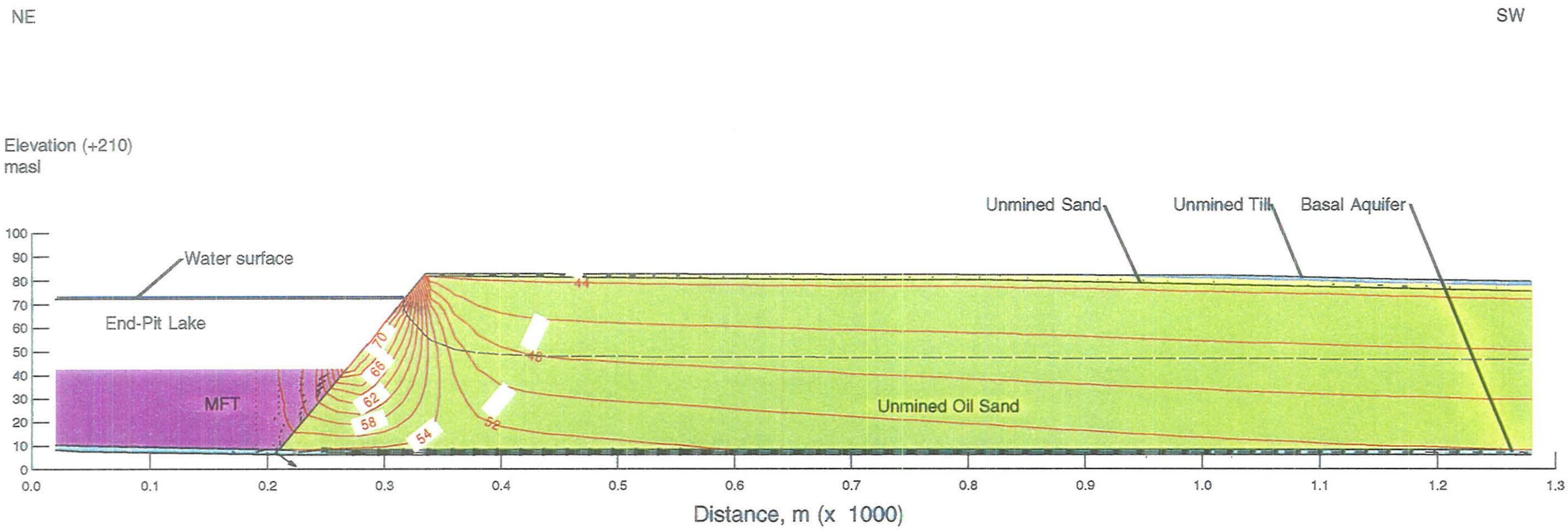
— Contours are hydraulic head, (+200 m) asl

— Groundwater surface

Location of Cross Section 6-2 shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS		
FAR FUTURE, PIT 6 VERTICAL CROSS-SECTION 6-2 SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577	**FIGURE** **IV-41**	



NOTES

Contours are hydraulic head, (+210 m) asl

Groundwater surface

Location of Cross Section EPL shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, END-PIT LAKE
VERTICAL CROSS-SECTION EPL
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-42

seepage through the MFT moves vertically downward into the Basal Aquifer and becomes seepage to the Basal Aquifer.

As shown in Figures IV3-37, 39 and 41, the End pit lake is expected to lose water through seepage to Pits 4, 5 and 6, respectively. This is largely due to the seepage into the in-pit dykes, and subsequently directed downward into the Basal Aquifer, which is expected to have a hydraulic head about 10 m below the water level in the end pit lake.

IV.7 TAILINGS POND SEEPAGE

The tailings settling pond will hold mature fine tails (MFT) and water during the operation phase of the mine, and will gradually increase in height as the operation phase progresses. At the end of mining, MFT will be removed from the pond, and the reclaimed pond will be a predominantly dry structure.

IV.7.1 Approach

Seepage from the tailings settling pond was calculated in a similar manner as seepage from the backfilled mine pits. A two-dimensional, finite element groundwater flow model was developed for a vertical cross-section (7R, Figure IV3-6) extending from the Athabasca River on the west, to the Muskeg River on the east. The cross-section transects the tailings settling pond transects at its southern end, where the tailings pond is nearest to both rivers, as shown in Figure IV3-6. SEEP/W modelling software was also used for these calculations.

A finite element model was constructed for each of the first five snapshot times, and another was constructed for closure/far-future conditions. Each model reflects the approximate tailings pond configuration and MFT/water elevations expected for that time. The tailings settling pond models include perimeter ditches 5 m deep on the east side and 2 m deep on the west side of the tailings settling pond. In the model, the east perimeter ditch extends through the entire thickness of overburden and muskeg, estimated to be approximately 2 to 3 m, and into the underlying lean oil sands. The model results were used to calculate seepage discharge for each snapshot time. For each snapshot time, the model, which is run on a steady-state flow simulation, assumes that equilibrium or near equilibrium conditions have been attained.

The hydraulic conductivity of materials used in the modelling is given in Table E3-5. The tailings settling pond is assumed to be constructed on undisturbed muskeg and overburden materials. Together, these materials have a hydraulic conductivity of 1×10^{-4} m/s. No consideration was given to consolidation of these materials due to the weight of the overlying tailings setling pond structure.

The surficial sediments and muskeg beneath the tailings settling pond are underlain by the McMurray Formation. In the location of the tailings settling pond this formation is assumed to consist of lean oil sands with a hydraulic conductivity one order of magnitude higher than the ore-grade oil sands, i.e., 2×10^{-8} m/s vs. 2×10^{-9} m/s for mineable oil sands. However, there are no direct measurements of hydraulic conductivity of this material.

Each tailings pond model was constructed with the following general characteristics:

- no-flow (Type 2) boundary conditions were applied to west and east vertical boundaries;
- the bottom of the Model is a no-flow (Type 2) boundary;
- the Athabasca and Muskeg Rivers were represented as specified-head (Type 1) boundaries. The head value specified corresponded to the river elevation at each location, and was assumed to be constant; and
- recharge flux is applied to tailings sand exposed at ground surface; the recharge rate (5×10^{-9} m/s) was the same for all snapshot times.

IV.7.2 Results and Discussion

The configuration of the tailings settling pond profile, at each snapshot time, is shown along with the simulation results for each time, in Figures IV3-43 to IV3-49. The seepage discharge results are given in Table IV3-7.

Seepage from the tailings settling pond will discharge to the perimeter ditches, the Muskeg River, Athabasca River and Isadore's Lake. In addition, downward seepage to the Basal Aquifer will occur; however, all such seepage will subsequently discharge to either the Athabasca River or Muskeg River, since there are no-flow boundaries on both ends and the bottom of the model cross-section.

As a check on the accuracy of the model results and the corresponding seepage estimates, the mass balance of flows was checked for the far-future simulation. Total inflows to the model cross-section, from recharge applied to tailings sand, were 1.1228×10^{-5} m^3/s. Total outflows to perimeter drainage ditches totalled 4.765×10^{-6} m^3/s, and outflows to Basal Aquifer seepage and discharge to the Athabasca and Muskeg rivers totaled 8.359×10^{-6} m^3/s. Total outflows were therefore 1.3125×10^{-5} m^3/s,. The total outflows exceed inflow by 16%. To a large extent, this error reflects the particular selection of flux sections used to calculate the components of inflow or outflow in SEEP/W. Experience suggests that such error ranges between 1 and 30%, but is generally less than 20%. With optimum flux section selection, numerical accuracy of the model is typically less than 1%. In aggregate, the error associated with the seepage estimates calculated with these models is expected to be less than 30 %.

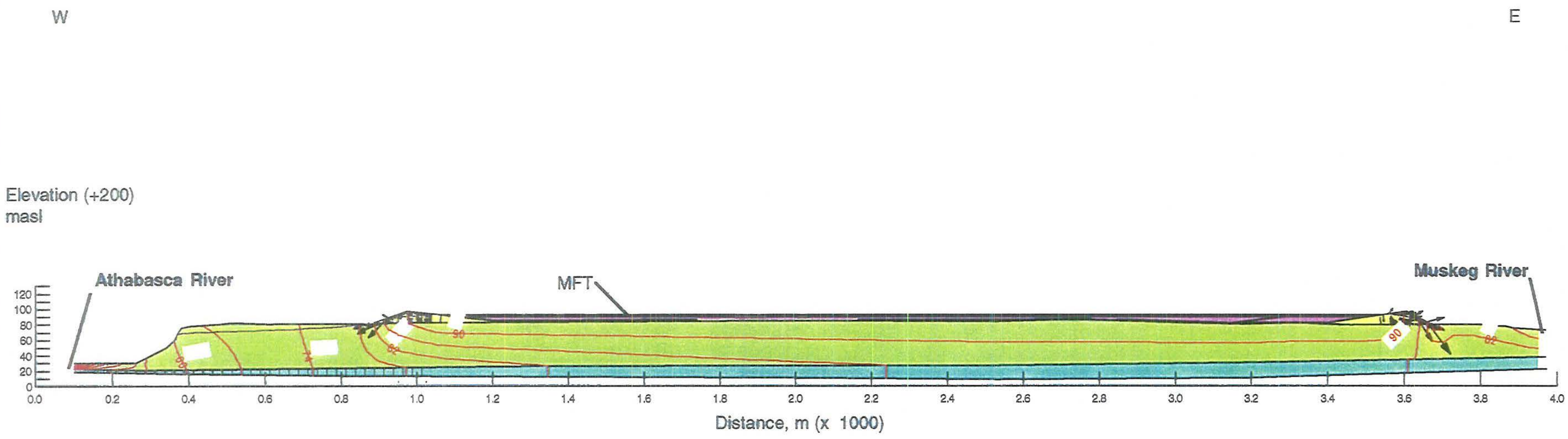
In 2002, seepage from the tailings settling pond (Figure IV3-43) discharges in four settings:

- the east perimeter ditch;
- the west perimeter ditch;
- the Athabasca River; and
- the Muskeg River

The perimeter ditches intercept seepage from the tailings settling pond dykes and from the surficial overburden beneath the tailings settling pond. These ditches are constructed through the surficial overburden. The only pathway for lateral seepage beyond the perimeter ditches is through the lean oil sands. Because of the large surface area of the tailings pond, downward seepage into the underlying lean oil sandss is significant. Once in the lean oil sandss, a component of seepage flows horizontally, toward the Athabasca or Muskeg Rivers. As this component of flow approaches the rivers, the direction of groundwater flow changes to vertical and this seepage discharges into the rivers. The component of seepage that moves vertically downward into the Basal Aquifer ultimately discharges to the Athabasca River.

This general pattern of seepage continues as the tailings settling pond is developed over time, as illustrated in Figures IV3-44 to 48. The proportion of seepage intercepted by the ditches, versus discharging into the rivers or into the Basal Aquifer changes over time. In general, the amount of seepage discharge to the Muskeg or Athabsasca Rivers is relatively constant during the operation phase. The main differences between the snapshot times is in the amount of discharge to the perimeter ditches and, to a lesser extent, in the amount of discharge to the Basal Aquifer.

When the tailings settling pond is emptied of MFT and water, as represented by the closure/far-future simulation Figure (IV3-48), the final water table beneath the centre of the tailings settling pond is about 4 m above the original ground surface, and about 15 m below the reclaimed ground surface of the pond. Vertical seepage downward into the Basal Aquifer is a significant component of the overall seepage from the pond, representing 70% of the seepage not intercepted by the perimeter ditches.



NOTES

🟥 Contours are hydraulic head, (+200 m) asl

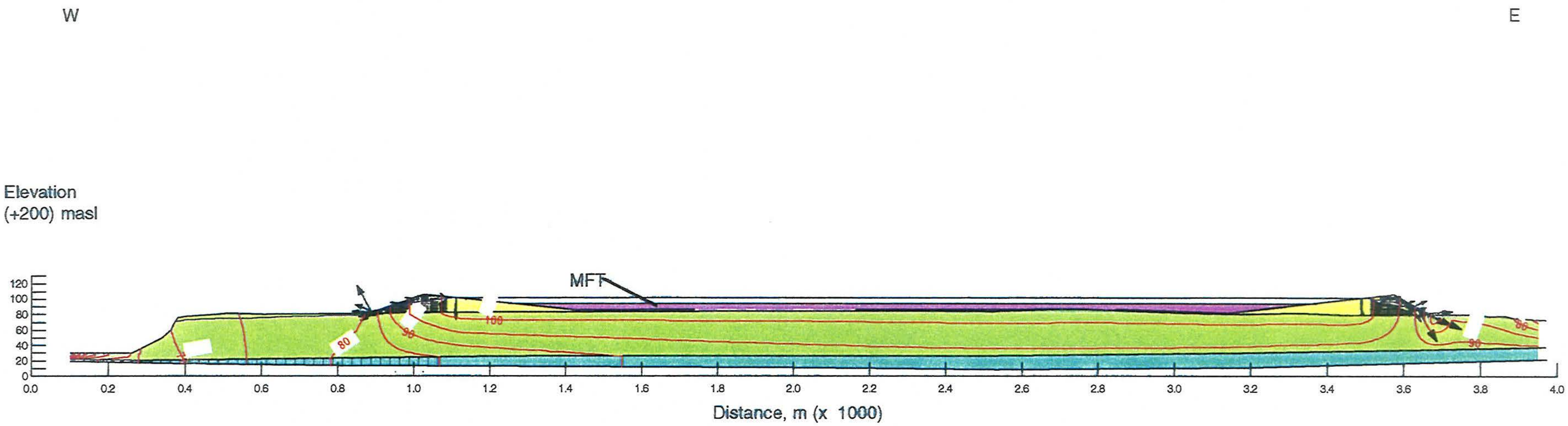
🟦 Groundwater surface

Geologic units and Geographic Features are labelled in Figure H3-48

Location of Cross Section 7R shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS		
2002, TAILINGS POND VERTICAL CROSS-SECTION 7R SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577B		**FIGURE IV-43**



NOTES

🟥 Contours are hydraulic head, (+200 m) asl

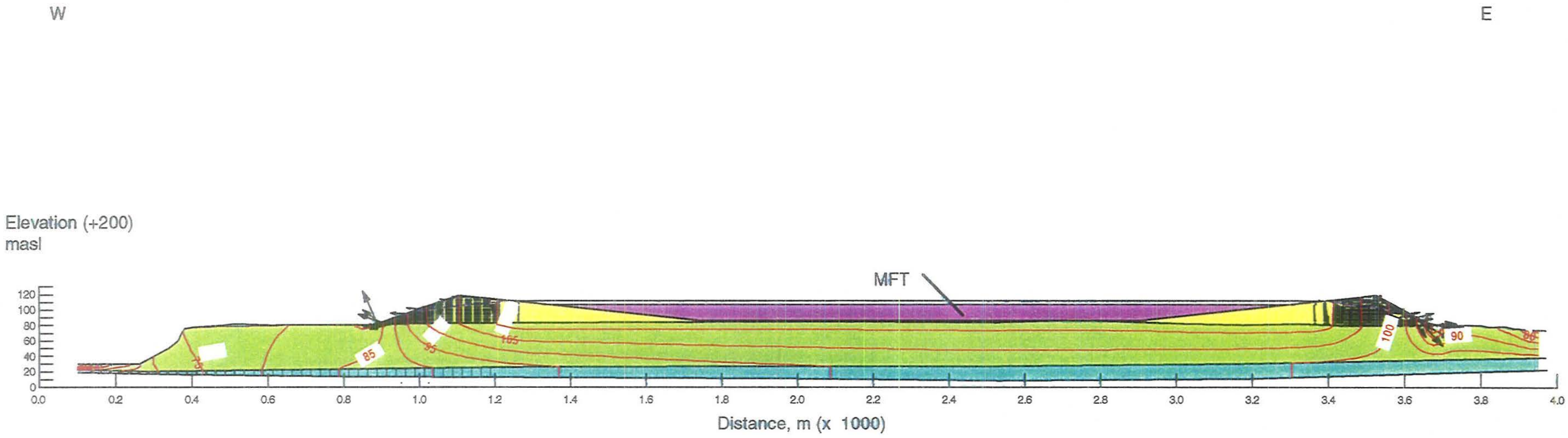
🟦 Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-48

Location of Cross Section 7R shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS		
2003, TAILINGS POND VERTICAL CROSS-SECTION 7R SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577		**FIGURE IV-44**



NOTES

— Contours are hydraulic head, (+200 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-48

Location of Cross Section 7R shown in Figure H3-6

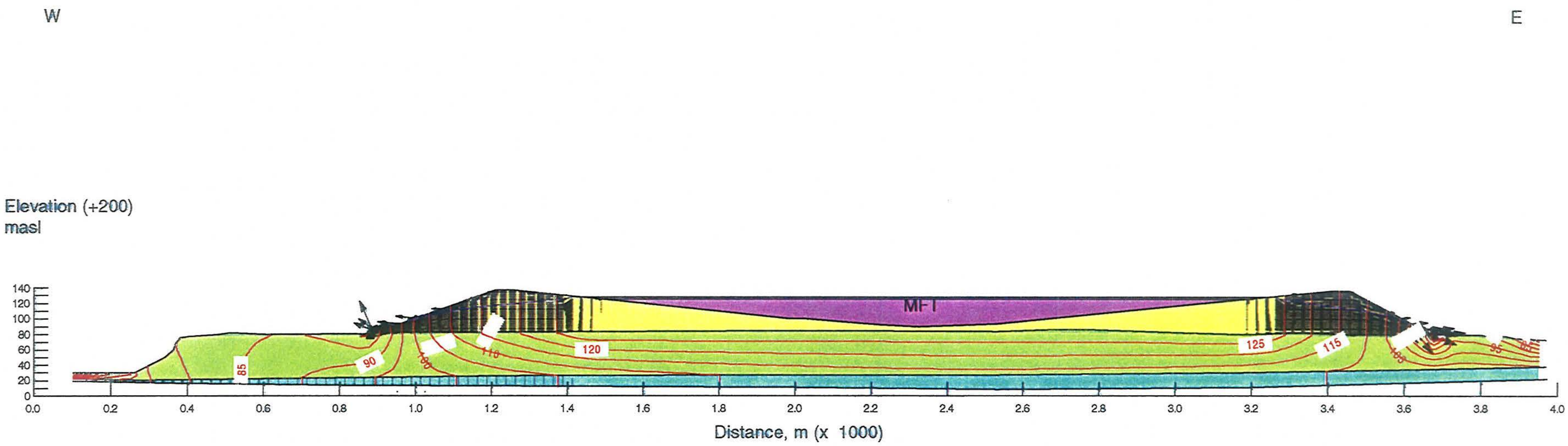
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2005, TAILINGS POND
VERTICAL CROSS-SECTION 7R
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-45



NOTES

Contours are hydraulic head, (+200 m) asl

Groundwater surface

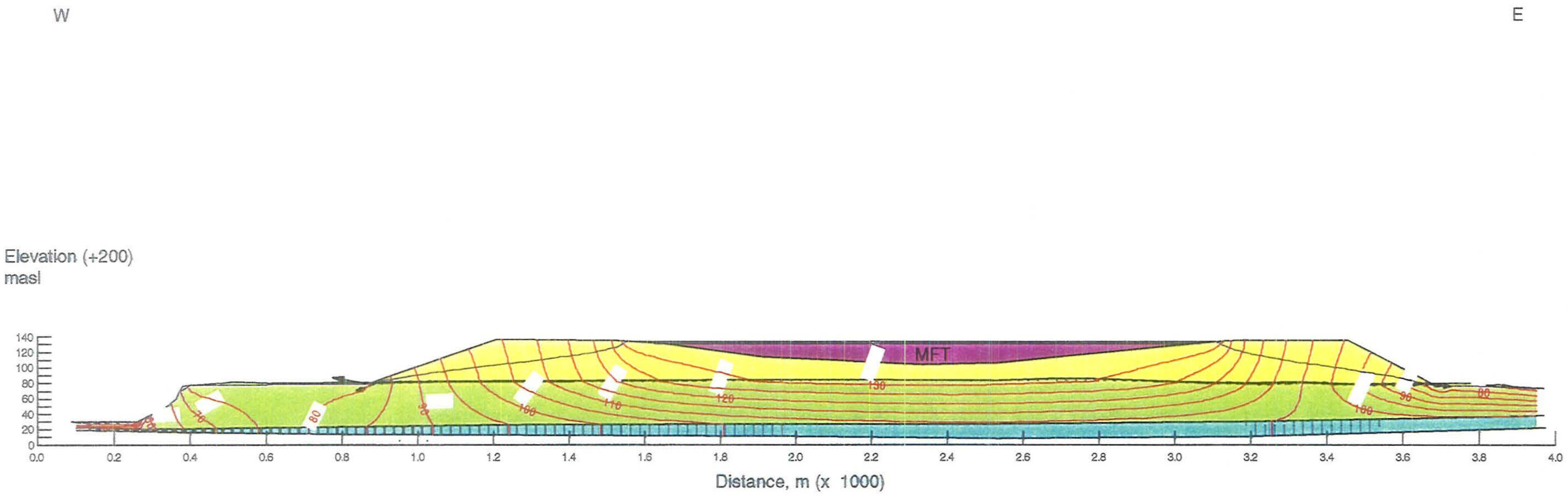
Geologic units and Geographic Features
are labelled in Figure H3-48

Location of Cross Section 7R shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED **MUSKEG RIVER MINE PROJECT** ENVIRONMENTAL IMPACT ASSESSMENT	KOMEX INTERNATIONAL LIMITED ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2010, TAILINGS POND VERTICAL CROSS-SECTION 7R SIMULATION MODEL RESULTS	APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
	PROJECT NO: 4577B		**FIGURE IV-46**



NOTES

— Contours are hydraulic head, (+200 m) asl

— Groundwater surface

Geologic units and Geographic Features
are labelled in Figure H3-48

Location of Cross Section 7R shown in Figure H3-6

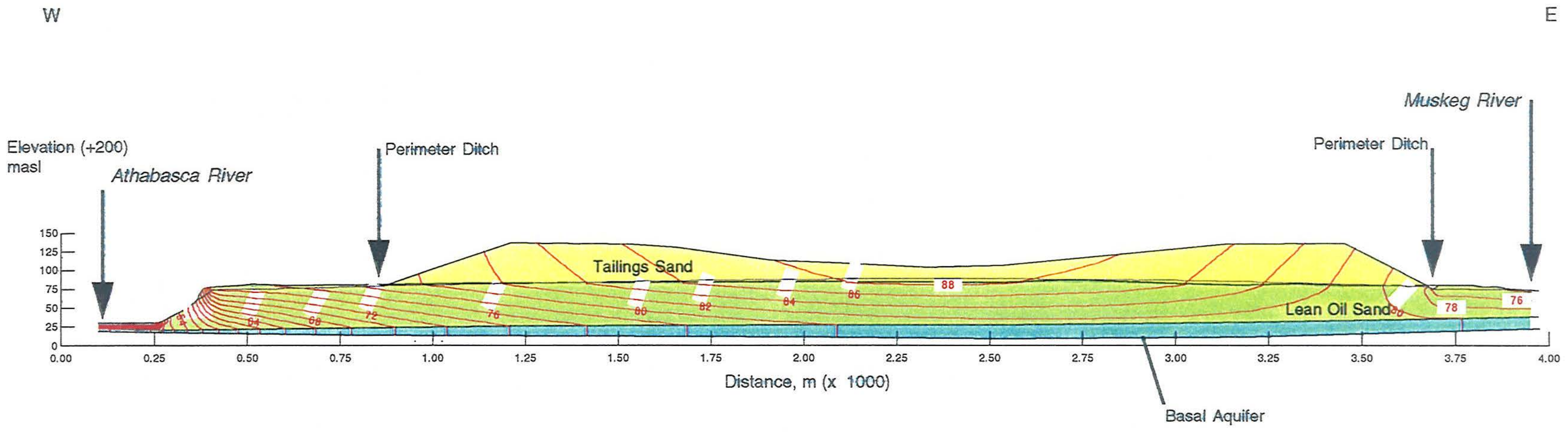
Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

2022, TAILINGS POND
VERTICAL CROSS-SECTION 7R
SIMULATION MODEL RESULTS

APPROVED BY: M.T.	DRAWN BY: F.R.	DATE: 97/11/25
PROJECT NO: 4577		**FIGURE** **IV-47**



NOTES

- 🟥 Contours are hydraulic head, (+200 m) asl
- 🟦 Groundwater surface

Location of Cross Section 7R shown in Figure H3-6

Vertical Exaggeration 2x

SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LIMITED
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

FAR FUTURE, TAILINGS POND
VERTICAL CROSS-SECTION 7R
SIMULATION MODEL RESULTS

APPROVED BY: M.T.
DRAWN BY: F.R.
DATE: 97/11/25
PROJECT NO: 4577
FIGURE IV-48

APPENDIX V

Surface Water Quality

V-1 SURFACE WATER QUALITY

V-1.1 Water Quality Screening Assumptions

V-1.1.1 Grouping Polyaromatic Hydrocarbons (PAHs)

For simplicity, individual PAHs were grouped according to methods described in Golder (1996f).

V-1.1.2 Operational and Reclamation Waters

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

Operational waters are:

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

The only operational waters to be released from the Project are muskeg and overburden dewatering waters. These waters are also the main sources of natural surface water in the region, since the drainage basins of the small streams are largely made up of areas covered with muskeg (Section 5-D).

OSWRTWG (1996) described reclamation waters as:

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

Tables V-1 and V-2 summarize the water quality associated with Shell, Suncor and Syncrude's operational and reclamation waters.

V-1.1.3 Water Quality Guidelines

Table V-3 summarizes the water quality guidelines used for assessing water quality impacts associated with the Muskeg River Mine Project.

V-1.1.4 Thermal Regime of Muskeg River

- The temperature of shallow groundwater in the vicinity of the proposed Muskeg River Mine varies from 2 to 4°C in the winter, and from 2 to 6°C in the summer (T. Dabrowski, Komex International Limited, pers. comm.). Using this information as a starting point, monthly mean temperatures were estimated for muskeg and overburden drainage waters, assuming the water heats up 1°C per month beginning in May at 2°C, reaching a peak of 6°C in August, and then cooling again at the same rate to 2°C by November (Figure V-17).

- Grab sample data taken from Lake Athabasca, Christina Lake and Gregoire Lake (Mitchell and Prepas 1990) were used to approximate the surface temperature of the end pit lake during the open water period on a monthly basis (April through October). To be conservative, these temperatures were scaled down by up to 5°C from April to August and scaled up (maximum 5°C) from September to November to obtain monthly mean temperatures that would occur in a large, deep lake. This was based on the expectation that the end pit lake would seasonally warm up and cool down over a longer period of time than smaller water bodies. During the ice cover period, near-surface temperature was estimated as 1°C. The resulting monthly mean end pit lake temperatures are compared with monthly median temperatures measured in the Muskeg River in Figure V-17.

- There will be complete mixing of the incoming and receiving waters.

- Discharge of muskeg and overburden drainage waters will not occur in the winter due to freezing of channel walls and water in the channels in dewatering areas.

- The temperature of muskeg and overburden drainage waters will not change during travel to the Muskeg River.

- The temperature of end pit lake discharge water will not change during travel to the Muskeg River.

V-1.1.5 Seepages

- The nature and timing of sand and CT seepages are discussed in Section E3. Even if seepage waters do reach the Muskeg River, it is probable that the toxic fraction (naphthenates) will likely undergo some level of biological decay prior to seeping into the river. Under aerobic conditions, the half-life for naphthenates is in the order of one year (Table V-4). In groundwater, under anaerobic conditions, biodegradation would be much reduced, perhaps to a level of only 1% of those measured in aerobic waters. Even so, given that seepage waters are expected to take hundreds of years to reach the Muskeg River, a half-life of 100 years is significant and concentrations of naphthenic acids would be greatly reduced prior to discharge to the river.

- From a modelling perspective, the seepages occurring during operation and reclamation phases are modelled as increased flows of surficial aquifer water with its associated chemistry. Substances associated with sand and CT seepages are not introduced until far future consistent with the time estimated for those waters to reach the Muskeg River (Section E3).

V-1.1.6 Muskeg River and Isadore's Lake

The small streams model used to assess water quality in the Muskeg River and Isadore's Lake made use of the following assumptions:

- operational and reclamation discharges released from the Muskeg River Mine Site mix completely with the receiving water body;
- shallow, above-ground flows freeze in winter, so muskeg and overburden drainage waters only enter the Muskeg River Watershed during the open water season;
- the end pit lake, present in 2030 and beyond, only produces a discharge flow in the open water season;
- operational and reclamation seepages flow year round;
- operational and reclamation seepages released from the Project site take an average of 284 years (M. Trudell, Komex International Ltd., pers. comm.) to reach the Muskeg River; during this time, organic components of these seepages experience decay; the employed decay rates are summarized in Table V-4;
- prior to the "far future" scenario, seepages released from the Project site were modelled as increased surficial aquifer flows;
- operational and reclamation seepages do not reach Isadore's Lake;
- above-ground discharges do not undergo decay;
- similarly, there is no chemical decay occurring in the two receiving water bodies;

- chemicals released into Isadore's Lake or the Muskeg River remain in the water column; chemical precipitation, settling and sediment partitioning were ignored.

V-1.1.7 End Pit Lake

The following assumptions and boundary conditions were incorporated into the end pit lake model:

- total volume of the end pit lake is 130 million m^3;
- the end pit lake will begin to fill in 2023;
- inflows into the end pit lake include CT porewater, runoff from natural and reclaimed areas, tailings sand porewater, MFT porewater and MFT;
- initially, 19 million m^3 of CT porewater collected from in-pit CT deposits will be transferred into the end pit lake; CT inflow rates drop sharply in 2024, and continue to decrease slowly until finally stopping altogether in 2044; exact values are found in Golder (1997j);
- total volume of MFT to be transferred into the end pit lake is 66 million m^3 at 30% solids (Golder 1997j);
- total volume of tailings sand and MFT porewater to be transferred into the end pit lake is 43.6 million m^3 (Golder 1997 j);
- MFT and tailings pond water transfer rates must be controlled such that discharge from the end pit lake is non-chronically toxic and less than 1 m^3/s;
- if necessary, Athabasca River water will be added to the end pit lake to ensure that lake outflows are non-chronically toxic (in the final analysis, this did not prove to be necessary);
- precipitation, evaporation and seepage were equal to 1.46, 2.02 and 0.05 million m^3/yr, respectively (Golder 1997 j);
- MFT in the end pit lake continued to consolidate at rates shown in Table V-4; and
- ammonia, organic compounds and their associated acute and chronic toxicity decay at rates specified in Table V-4.

V-1.1.8 Athabasca River

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

Operational flows from existing oil sands operators were simulated based on historical maximum concentrations and long-term average flows reported for each existing release water. Substances included in this analysis were ones that were both detectable (in one or more release waters) and for which an established guideline exists (Table V-3). The quality of future CT reclamation waters were based on existing data from both Suncor and Syncrude.

The following assumptions were used to predict Athabasca water quality:

- complete, instantaneous vertical mixing;
- constant turbulence and dispersion coefficients across the width of the river;
- mass reaching the river banks was reflected back into the river;
- shallow, above-ground flows from the Muskeg River Mine Project area freeze in winter, so muskeg and overburden drainage waters released from this Project only enter the river system during the open water season;
- the end pit lake, present on the Muskeg River Mine Site in 2030 and beyond, only produces a discharge flow in the open water season;
- operational and reclamation seepages from the Muskeg River Mine Project, as well as operational and reclamation releases from existing operators, occurred year round; and,
- chemicals released into the Athabasca River remained in the water column; chemical precipitation, decay, settling and sediment partitioning were ignored.

V-1.2 Water Quality Modelling Results

V-1.2.1 Athabasca River

Tables V-5 and V-8 summarize projected water quality in the Athabasca River during mean open water and annual 7Q10 flows.

V-1.2.2 Muskeg River

Tables V-9 and V-12 summarize projected water quality in the Muskeg River during mean open water and annual 7Q10 flows.

Table V-1 Operational and Reclamation Waters Associated the Muskeg River Mine Project

Parameter / Substance (mg/L)	**Tailings Water[1]**	**CT Seepage[2]**	**Muskeg Dewatering[3]**	**Sand Seepage[4]**
Water Quality Code[5]	**E**	**G**	**N**	**O**
Aluminum - Total	1.2	1.9	0.53	1.2
Ammonia - Total	6.0	6.3	0.91	2.0
Antimony - Total		0.0018	0.0005	ND
Arsenic - Total	0.003	0.007	0.02	0.003
Barium - Total	0.10	0.16	0.2	0.10
Benzo(a)anthracene grp	ND	0.0016	ND	0.00099
Benzo(a)pyrene grp	ND	0.00048	ND	0.00008
Beryllium-Total	0.002	0.006	0.001	0.002
Biological Oxygen Demand	9.6	8	6.7	
Boron - Total	1.9	3.7	0.04	1.9
Cadmium - Total	0.004	0.0066	ND	0.004
Calcium	25	157	106	70
Chloride	17	67	ND	17
Chromium - Total	0.002	0.023	0.023	0.002
Conductivity	1328	2402	614	2500
Copper - Total	0.006	0.022	0.01	0.006
Dissolved Organic Carbon	43	65	10.9	43
Ethylbenzene	0.0015	0.001		0.0015
Fluorene	ND	0.00003	ND	ND
Iron - Total	2.2	1.0	6.12	2.2
Lead - Total	ND	0.02	0.0019	ND
Lithium-Total	0.12	0.20	0.008	0.14
Magnesium	9	28	13	25
Manganese - Total	0.14	0.065	0.801	0.21
Mercury - Total	ND	0.00005	0.00E+00	ND
Molybdenum - Total	0.004	1.4	0.003	0.018
Naphthalene	0.00009	0.00005	ND	0.00005
Naphthenic Acids	55	100	ND	70
Nickel - Total	ND	0.030	ND	ND
Nitrate	0.26	0.05	0.016	0.06
Phenolics - Total	0.004	0.015	ND	0.004
Phosphorus-Total	0.20	0.073	ND	0.4
Pyrene	ND	0.00004	ND	ND
Selenium - Total	0.0002	0.0036	0.012	0.0002
Silver - Total	ND	0.002	ND	ND
Sodium	322	510	5.75	600
Strontium	0.28	2.1	0.168	0.28
Sulphate	32	1270	3.1	200
Total Dissolved Solids	910	1780	334	1007
Total PAH's	0.0023	0.032	ND	0.0011
Toxicity - acute	2.3	2.7		2.3
Toxicity - chronic	6.3	7.2		6.3
Total Suspended Solids	53	17	ND	53
Uranium - Total	ND	ND	0	ND
Vanadium - Total	0.01	0.17	0.005	0.01
Zinc - Total		0.08	0.204	0.058

NOTE: ND = Non-Detect

[1] Assumed identical to Suncor TID drainage water reported in Golder (1996a)

[2] Assumed identical to Suncor CT water reported in Golder (1996a)

[3] Data from Golder (1997d) and unpublished 1997 data from Syncrude

[4] Combination of TID water (Golder 1996a) and Syncrude sand seepage (Golder 1996d)

[5] Refers to codes in Figures V-1 to V-10

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

Parameter (in mg/L)	South Mine Drainage[1]	Mid-Plant Drainage[2]	North Mine Drainage[2]	Future Runoff (max. of South and North)	TID Seepage[2]	Sewage Effluent[4]	CT Seepage[2]	Wastewater[5]	Cooling Pond E[6]	Gypsum (FGD)[2]	Pond 1/1A[2]	Basal Aquifer[3]
Water Quality Code[7]	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**K**	**L**	**M**
Aluminum - Total	0.04	0.1	0.07	0.07	1.2	0.51	1.9	0.72	1.2		0.88	
Ammonia - Total	0.082	19	0.03	0.082	6.0	9	6.3	25	0.22		20	2.8
Antimony - Total							0.0018	0.002			0.0006	
Arsenic - Total	0.0005	0.0007	0.0002	0.0005	0.003	0.004	0.007	0.0018	0.0014		0.0036	
Barium - Total	0.08	0.09	0.12	0.12	0.10	0.06	0.16	0.10	0.082	0.13	0.77	0.25
Benzo(a)anthracene grp	ND	ND	ND	ND	ND		0.0016	0.00029	ND	ND	0.0001	ND
Benzo(a)pyrene grp	ND	ND	ND	ND	ND		0.00048	0.00014	ND			ND
Beryllium-Total	0.003	0.003	0.003	0.003	0.002	0.002	0.006	0.002	0.002			
Biological Oxygen Demand	0.9	1.1	0.7	0.9	9.6	15.9	8	11.2	2.5			
Boron - Total	0.22	0.38	0.19	0.22	1.9	0.50	3.7	0.15	0.07	1.2	2.3	2.2
Cadmium - Total	ND	ND	0.002	0.002	0.004	ND	0.0066	0.006	0.001			
Calcium	82	285	97	97	25	50	157	69	55		43	37
Chloride	40	190	36	40	17	106	67	354	18		33	318
Chromium - Total	0.005	0.01	0.002	0.005	0.002	0.006	0.023	0.009	0.004		0.028	
Conductivity	602	1332	747	747	1328	937	2402	825	245	1374		3040
Copper - Total	0.004	0.027	0.009	0.009	0.006	0.005	0.022	0.055	0.029	0.01		0.003
Dissolved Organic Carbon	11	112	15	15	43	48	65	35	15			
Ethylbenzene	0.001	ND	ND	0.0012	0.002	ND	0.001	0.001	0.0015	ND	ND	
Fluorene	ND	ND	ND	ND	ND		0.00003	ND	ND	ND	0.00014	
Iron - Total	0.11	0.45	0.30	0.30	2.2	1.1	1.0	1.8	2.3	0.35	23	
Lead - Total	ND	ND	ND	ND	ND	ND	0.02	0.015	ND			
Lithium-Total	0.018	0.034	0.016	0.018	0.12	0.01	0.20	0.013	0.006		0.23	0.46
Magnesium	21	79	30	30	9	16	28	18	16	18		20
Manganese - Total	0.068	2.2	0.11	0.11	0.14	0.43	0.065	0.12	0.069	1.4	1.8	0.032
Mercury - Total	0.0003	0.00011	0.00008	0.0003	ND	ND	0.00005	0.0003	0.00006	ND	0.0004	
Molybdenum - Total	ND	0.10	ND	ND	0.004	0.045	1.4	0.55	ND	2.2	0.071	0.0025

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

Parameter (in mg/L)	South Mine Drainage[1]	Mid-Plant Drainage[2]	North Mine Drainage[2]	Future Runoff (max. of South and North)	TID Seepage[2]	Sewage Effluent[4]	CT Seepage[2]	Wastewater[5]	Cooling Pond E[6]	Gypsum (FGD)[2]	Pond 1/1A[2]	Basal Aquifer[3]
Water Quality Code[7]	A	B	C	D	E	F	G	H	I	K	L	M
Naphthalene	ND	ND	ND	ND	0.00009		0.00005	ND	ND	ND	0.00056	0.0013
Naphthenic Acids	4	11	4	4	55	ND	100	ND	ND		95	4.2
Nickel - Total	0.005	0.60	ND	0.005	ND	0.008	0.030	0.15	0.005	0.50	0.055	
Nitrate	ND	0.53	0.014	ND	0.26	8	0.05	1.09	0.12			0.1
Phenolics - Total	0.008	0.04	0.078	0.078	0.004	0.018	0.015	0.88	0.082			
Phosphorus-Total	0.032	1.2	0.036	0.036	0.20	6.2	0.073	0.29	0.13		0.2	0.21
Pyrene	ND	ND	ND	ND	ND		0.00004	0.00016	ND	ND	0.00009	
Selenium - Total	ND	0.0002	ND	ND	0.0002	ND	0.0036	0.0059	0.0002			
Silver - Total	0.002	0.002	ND	0.002	ND	ND	0.002	0.002	ND			
Sodium	33	340	30	33	322	57	510	246	23	16600		705
Strontium	0.17	0.49	0.28	0.28	0.28	0.34	2.1	0.29	0.21		0.77	
Sulphate	128	1250	142	142	32	57	1270	116	49		118	5.3
Total Dissolved Solids	383	2390	518	518	910	560	1780	570	190		1250	1940
Total PAH's	ND	ND	ND	ND	0.0023		0.032	0.0037	ND	0.0053	0.003	0.0023
Toxicity - acute	ND	ND	ND	ND	2.3	1.3	2.7	ND	ND			
Toxicity - chronic	ND	1.4	8.3	8.3	6.3	2.8	7.2	4.0	2.9		14	
Total Suspended Solids	2	171	20	20	53	62	17	42	87			
Uranium - Total	ND	ND	ND	ND	ND	ND	ND	ND	ND			
Vanadium - Total	0.005	0.021	0.005	0.005	0.01	0.011	0.17	1.1	0.006	0.13	0.05	
Zinc - Total	0.004	0.063	0.016	0.016		0.021	0.08	0.12	0.024	0.12	0.007	0.022

NOTE: ND = non-detect

[1] Golder (1996a) and NAQUADAT Station 20AL07DA1014

[2] Golder (1996a)

[3] Golder (1996d)

[4] Golder (1996a) and NAQUADAT Station 20AL07DA1005

[5] Golder (1996a) and NAQUADAT Station 20AL07DA1000/1001

[6] Golder (1996a) and NAQUADAT Station 20AL07DA1013

[7] Water Quality codes correspond to symbols used in Figures V-1 to V-10

Table V-3 Guidelines

Substance (mg/L)	Acute	Chronic	HHC	HHNC	Source(1)
Aluminum - Total		0.1			CCME
Ammonia - Low Winter Flow	16	2.1			USEPA
- Open Water Flow	10	1.9			USEPA
Antimony - Total				0.014	USEPA
Arsenic - Total	0.36	0.01	0.000018		USEPA, ASWQG
Barium - Total		1		1	USEPA, ASWQG
Benzo(a)anthracene group			0.0000028		USEPA
Benzo(a)pyrene group			0.0000028		USEPA
Beryllium-Total	0.13	0.0053			USEPA
Boron - Total		0.5			ASWQG
Cadmium - Total	0.0074	0.0018			USEPA*
Chloride	860	230			USEPA
Chromium (VI)	0.016	0.011			USEPA
Copper - Total	0.027	0.007			ASWQG*
Ethylbenzene		0.7		3.1	CCME, USEPA
Fluorene			1.3		USEPA
Iron - Total		0.3		0.3	ASWQG, USEPA
Lead - Total	0.17	0.007			USEPA*
Lithium-Total		2.5			CCME
Manganese - Total		0.05		0.05	ASWQG, USEPA
Mercury - Total	0.0024	0.000012		0.00014	USEPA
Molybdenum - Total		1			BCMOE
Naphthalene	2.3	0.62			USEPA
Nickel - Total	2.3	0.25		0.61	USEPA*
Nitrate		10		10	CCME, USEPA
Phenolics - Total		0.005			ASWQG
Phosphorus-Total		0.05			ASWQG
Pyrene			0.96		USEPA
Selenium - Total	0.02	0.01			USEPA, ASWQG
Silver - Total	0.01	0.05			USEPA, ASWQG *
Toxicity - acute	0.3				USEPA
Toxicity - chronic		1.0			USEPA
Total Suspended Solids		10			ASWQG
Uranium - Total		0.01			CCME
Vanadium - Total		10			BCMOE
Zinc - Total	0.19	0.05			USEPA*, ASWQG

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

Table V-4 Summary of Decay Rates Used for Water Quality Modelling

Substance	Wetlands		Seepages		EPL and Tailings Ponds	
	(1/year)	Source	(1/year)	Source	(1/year)	Source
Ammonia - Total	8.54	(a)	-		8.54	Suncor 1996
Benzo(a)anthracene group	0.37	(a)	0.0009	(b)	0.37	BOVAR 1996a
Benzo(a)pyrene group	0.48	(a)	0.0012	(b)	0.48	BOVAR 1996a
Naphthenic Acids	2.66	Suncor 1996	0.0065	(d)	1.83	EMA 1993
Toxicity - acute	0.77	(a)	0.0030	(b)	0.77	Syncrude 1995
Toxicity - chronic	1.67	(a)	0.0065	(c)	1.67	Syncrude 1995
MFT consolidation						
Year 1 to 5	-		-		0.0074	EMA 1993
Year 21 to 100	-		-		0.0046	EMA 1993

(a) assumed identical to rates observed in end pit lakes and tailings ponds

(b) calculated using ratio of naphthenic acid degradation rates in anaerobic and aerobic environments and substance degradation in aerobic conditions

(c) assumed identical to naphthenic acids

(d) extrapolation from experiments conducted at Simon Fraser University by M. Moore (1997)

Table V-5 Assessment of Water Quality in the Athabasca River in Mean Open Water Flow Conditions at 10% Right Bank Mixing Zone Boundary

Parameter /	2000		2002		2003		2005		2010	
Substance	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	6.8E-01	C	6.8E-01	C	6.8E-01	C	6.8E-01	C	6.8E-01	C
Ammonia - Total	1.9E-02		1.9E-02		1.9E-02		1.9E-02		1.8E-02	
Antimony - Total	8.1E-07		8.1E-07		8.3E-07		8.4E-07		7.0E-07	
Arsenic - Total	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC
Barium - Total	7.0E-02		7.0E-02		7.0E-02		7.0E-02		7.0E-02	
Benzo(a)anthracene grp	2.7E-07		2.7E-07		2.7E-07		2.7E-07		1.1E-07	
Benzo(a)pyrene grp	6.2E-08		6.2E-08		6.2E-08		6.2E-08		4.3E-08	
Beryllium-Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Boron - Total	4.1E-02		4.1E-02		4.1E-02		4.1E-02		4.1E-02	
Cadmium - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Calcium	3.2E+01	NG	3.2E+01	NG	3.2E+01	NG	3.2E+01	NG	3.2E+01	NG
Chromium - Total	4.0E-03		4.0E-03		4.0E-03		4.0E-03		4.0E-03	
Conductivity	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG
Copper - Total	3.5E-03		3.5E-03		3.5E-03		3.5E-03		3.5E-03	
Dissolved Organic Carbon	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG
Iron - Total	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC
Lead - Total	5.2E-05		5.2E-05		5.2E-05		5.2E-05		5.3E-05	
Magnesium	7.9E+00	NG	7.9E+00	NG	7.9E+00	NG	7.9E+00	NG	7.9E+00	NG
Manganese - Total	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C
Molybdenum - Total	3.1E-04		3.1E-04		3.1E-04		3.1E-04		1.7E-04	
Naphthenic Acids	5.1E-01	NG	5.1E-01	NG	5.0E-01	NG	5.0E-01	NG	5.1E-01	NG
Nickel - Total	5.6E-05		5.6E-05		5.6E-05		5.6E-05		5.2E-05	
Phenolics - Total	2.1E-03		2.1E-03		2.1E-03		2.1E-03		2.1E-03	
Selenium - Total	2.0E-04		2.0E-04		2.0E-04		2.0E-04		2.0E-04	
Silver - Total	7.2E-07		7.2E-07		7.2E-07		7.2E-07		5.0E-07	
Sodium	6.9E+00	NG	6.9E+00	NG	6.9E+00	NG	6.9E+00	NG	7.0E+00	NG
Strontium	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG
Sulphate	1.9E+01	NG	1.9E+01	NG	1.9E+01	NG	1.9E+01	NG	1.9E+01	NG
Total Dissolved Solids	1.5E+02	NG	1.5E+02	NG	1.5E+02	NG	1.5E+02	NG	1.5E+02	NG
Total PAH's	5.0E-06	NG	5.0E-06	NG	5.0E-06	NG	5.0E-06	NG	1.8E-06	NG
Toxicity - acute	4.2E-04		4.2E-04		4.2E-04		4.2E-04		1.7E-04	
Toxicity - chronic	2.8E-03		2.8E-03		2.8E-03		2.8E-03		1.9E-03	
Vanadium - Total	4.1E-03		4.1E-03		4.1E-03		4.1E-03		4.1E-03	
Zinc - Total	1.1E-02		1.1E-02		1.1E-02		1.1E-02		1.1E-02	

C = Chronic
HC = Human Health Carcinogen
HNC = Human Health Non-Carcinogen
NG = no guidelines

Table V-6 Assessment of Water Quality in the Athabasca River in Mean Open Water Flow Conditions at 10% Right Bank Mixing Zone Boundary

Parameter / Substance	2020		2022		2025		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	6.8E-01	C	6.8E-01	C	6.8E-01	C	6.8E-01	C	6.8E-01	C
Ammonia - Total	1.9E-02		1.9E-02		1.8E-02		1.9E-02		1.6E-02	
Antimony - Total	8.5E-07		7.4E-07		7.2E-07		1.6E-05		2.4E-07	
Arsenic - Total	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC	1.4E-03	HC
Barium - Total	7.0E-02		7.0E-02		7.0E-02		7.0E-02		7.0E-02	
Benzo(a)anthracene grp	3.1E-07		3.1E-07		3.1E-07		2.9E-06		4.3E-07	
Benzo(a)pyrene grp	8.5E-08		8.5E-08		8.5E-08		6.0E-07		6.9E-08	
Beryllium-Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Boron - Total	4.1E-02		4.1E-02		4.1E-02		8.7E-02		4.2E-02	
Cadmium - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Calcium	3.2E+01	NG	3.2E+01	NG	3.2E+01	NG	3.3E+01	NG	3.2E+01	NG
Chromium - Total	4.0E-03		4.0E-03		4.0E-03		4.0E-03		4.0E-03	
Conductivity	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.6E+02	NG	2.4E+02	NG
Copper - Total	3.5E-03		3.5E-03		3.5E-03		3.5E-03		3.5E-03	
Dissolved Organic Carbon	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	1.1E+01	NG	1.0E+01	NG
Iron - Total	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC	3.0E+00	C HNC
Lead - Total	5.2E-05		5.2E-05		5.2E-05		2.5E-04		5.7E-05	
Magnesium	7.9E+00	NG	7.9E+00	NG	7.9E+00	NG	8.2E+00	NG	8.0E+00	NG
Manganese - Total	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC	4.0E-01	C HNC
Mercury - Total	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C
Molybdenum - Total	4.2E-04		4.2E-04		4.2E-04		1.3E-02		1.9E-04	
Naphthenic Acids	5.0E-01	NG	5.1E-01	NG	5.1E-01	NG	5.6E-01	NG	5.2E-01	NG
Nickel - Total	7.1E-05		7.1E-05		7.1E-05		3.2E-04		5.5E-05	
Phenolics - Total	2.1E-03		2.1E-03		2.1E-03		2.1E-03		2.0E-03	
Selenium - Total	2.0E-04		2.0E-04		2.0E-04		2.0E-04		2.0E-04	
Silver - Total	9.2E-07		9.2E-07		9.2E-07		1.8E-05		3.8E-07	
Sodium	7.3E+00	NG	7.3E+00	NG	7.3E+00	NG	1.4E+01	NG	7.2E+00	NG
Strontium	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG	2.2E-01	NG
Sulphate	2.0E+01	NG	2.0E+01	NG	2.0E+01	NG	2.9E+01	NG	2.0E+01	NG
Total Dissolved Solids	1.5E+02	NG	1.5E+02	NG	1.5E+02	NG	1.7E+02	NG	1.5E+02	NG
Total PAH's	6.1E-06	NG	6.1E-06	NG	6.1E-06	NG	3.0E-04	NG	4.2E-06	NG
Toxicity - acute	5.4E-04		5.4E-04		5.4E-04		2.6E-03		6.9E-04	
Toxicity - chronic	3.5E-03		3.5E-03		3.5E-03		4.7E-03		1.7E-03	
Vanadium - Total	4.1E-03		4.1E-03		4.1E-03		5.0E-03		4.0E-03	
Zinc - Total	1.1E-02		1.1E-02		1.1E-02		1.2E-02		1.1E-02	

C = Chronic
HC = Human Health Carcinogen
HNC = Human Health Non-Carcinogen
NG = no guidelines

Table V-7 Assessment of Water Quality in the Athabasca River in Annual 7Q10 Flow Conditions at 10% Right Bank Mixing Zone Boundary

Parameter / Substance	2000		2002		2003		2005		2010	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	5.5E-02		5.5E-02		5.5E-02		5.5E-02		5.5E-02	
Ammonia - Total	3.3E-02		3.3E-02		3.3E-02		3.3E-02		3.3E-02	
Antimony - Total	1.6E-07	NG	1.6E-07	NG	2.3E-07	NG	2.5E-07	NG	4.2E-07	NG
Arsenic - Total	4.0E-04		4.0E-04		4.0E-04		4.1E-04		4.1E-04	
Barium - Total	8.6E-02		8.6E-02		8.6E-02		8.6E-02		8.6E-02	
Benzo(a)anthracene grp	9.0E-08	NG	9.0E-08	NG	9.0E-08	NG	9.0E-08	NG	2.2E-07	NG
Benzo(a)pyrene grp	2.4E-08	NG	2.4E-08	NG	2.4E-08	NG	2.4E-08	NG	6.7E-08	NG
Beryllium-Total	4.6E-07		4.6E-07		6.0E-07		6.4E-07		1.1E-06	
Boron - Total	3.0E-02		3.0E-02		3.0E-02		3.0E-02		3.1E-02	
Cadmium - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Calcium	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG
Chromium - Total	3.0E-03		3.0E-03		3.0E-03		3.0E-03		3.0E-03	
Conductivity	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG
Copper - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Dissolved Organic Carbon	8.0E+00	NG	8.0E+00	NG	8.0E+00	NG	8.0E+00	NG	8.0E+00	NG
Iron - Total	1.8E-01		1.8E-01		1.8E-01		1.8E-01		1.8E-01	
Lead - Total	8.3E-06		8.3E-06		8.4E-06		8.4E-06		1.1E-05	
Magnesium	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG
Manganese - Total	1.0E-01	C	1.0E-01	C	1.0E-01	C	1.0E-01	C	1.0E-01	C
Mercury - Total	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C
Molybdenum - Total	9.0E-05		9.0E-05		9.1E-05		9.1E-05		2.0E-04	
Naphthenic Acids	5.8E-03	NG	5.8E-03	NG	5.8E-03	NG	5.8E-03	NG	1.4E-02	NG
Nickel - Total	8.6E-06		8.6E-06		8.5E-06		8.5E-06		9.3E-06	
Phenolics - Total	3.0E-03		3.0E-03		3.0E-03		3.0E-03		3.0E-03	
Selenium - Total	1.0E-04		1.0E-04		1.0E-04		1.0E-04		1.1E-04	
Silver - Total	1.8E-07		1.8E-07		1.8E-07		1.8E-07		2.8E-07	
Sodium	1.6E+01	NG	1.6E+01	NG	1.6E+01	NG	1.6E+01	NG	1.6E+01	NG
Strontium	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG
Sulphate	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG
Total Dissolved Solids	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG
Total PAH's	1.7E-06	NG	1.7E-06	NG	1.7E-06	NG	1.7E-06	NG	4.4E-06	NG
Toxicity - acute	1.6E-04		1.6E-04		1.6E-04		1.6E-04		3.8E-04	
Toxicity - chronic	7.0E-04		7.0E-04		7.0E-04		7.0E-04		1.0E-03	
Vanadium - Total	2.0E-03		2.0E-03		2.0E-03		2.0E-03		2.1E-03	
Zinc - Total	7.0E-03		7.0E-03		7.1E-03		7.1E-03		7.1E-03	

C = Chronic
NG = no guidelines

Table V-8 Assessment of Water Quality in the Athabasca River in Annual 7Q10 Flow Conditions at 10% Right Bank Mixing Zone Boundary

Parameter / Substance	2020		2022		2025		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	5.6E-02		5.6E-02		5.6E-02		5.6E-02		5.7E-02	
Ammonia - Total	3.4E-02		3.4E-02		3.4E-02		3.6E-02		3.6E-02	
Antimony - Total	7.6E-07	NG	7.6E-07	NG	6.0E-07	NG	5.6E-07	NG	5.8E-07	NG
Arsenic - Total	4.1E-04		4.1E-04		4.1E-04		4.1E-04		4.0E-04	
Barium - Total	8.6E-02		8.6E-02		8.6E-02		8.6E-02		8.6E-02	
Benzo(a)anthracene grp	4.7E-07	NG	4.7E-07	NG	4.7E-07	NG	1.0E-06	NG	1.1E-06	NG
Benzo(a)pyrene grp	1.4E-07	NG	1.4E-07	NG	1.4E-07	NG	1.7E-07	NG	1.8E-07	NG
Beryllium-Total	2.1E-06		2.1E-06		1.8E-06		3.3E-06		3.6E-06	
Boron - Total	3.1E-02		3.1E-02		3.1E-02		3.3E-02		3.3E-02	
Cadmium - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Calcium	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG	5.0E+01	NG
Chromium - Total	3.0E-03		3.0E-03		3.0E-03		3.0E-03		3.0E-03	
Conductivity	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG	4.0E+02	NG
Copper - Total	1.0E-03		1.0E-03		1.0E-03		1.0E-03		1.0E-03	
Dissolved Organic Carbon	8.0E+00	NG	8.0E+00	NG	8.0E+00	NG	8.1E+00	NG	8.1E+00	NG
Iron - Total	1.8E-01		1.8E-01		1.8E-01		1.9E-01		1.9E-01	
Lead - Total	1.4E-05		1.4E-05		1.3E-05		2.1E-05		2.1E-05	
Magnesium	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG	1.4E+01	NG
Manganese - Total	1.0E-01	C	1.0E-01	C	1.0E-01	C	1.0E-01	C	1.0E-01	C
Mercury - Total	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C	1.0E-04	C
Molybdenum - Total	4.2E-04		4.2E-04		4.2E-04		4.2E-04		4.5E-04	
Naphthenic Acids	3.0E-02	NG	3.0E-02	NG	3.0E-02	NG	3.2E-02	NG	3.4E-02	NG
Nickel - Total	1.8E-05		1.8E-05		1.8E-05		2.0E-05		1.3E-05	
Phenolics - Total	3.0E-03		3.0E-03		3.0E-03		3.0E-03		3.0E-03	
Selenium - Total	1.1E-04		1.1E-04		1.0E-04		1.0E-04		1.0E-04	
Silver - Total	5.9E-07		5.9E-07		5.9E-07		5.9E-07		6.4E-07	
Sodium	1.6E+01	NG	1.6E+01	NG	1.6E+01	NG	1.7E+01	NG	1.7E+01	NG
Strontium	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG	3.4E-01	NG
Sulphate	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG	4.0E+01	NG
Total Dissolved Solids	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG	2.4E+02	NG
Total PAH's	9.3E-06	NG	9.3E-06	NG	9.3E-06	NG	9.6E-06	NG	1.0E-05	NG
Toxicity - acute	8.0E-04		8.0E-04		8.0E-04		1.6E-03		1.8E-03	
Toxicity - chronic	2.1E-03		2.1E-03		2.1E-03		3.0E-03		3.1E-03	
Vanadium - Total	2.1E-03		2.1E-03		2.1E-03		2.1E-03		2.1E-03	
Zinc - Total	7.2E-03		7.2E-03		7.1E-03		7.2E-03		7.1E-03	

C = Chronic
NG = no guidelines

Table V-9 Assessment of Water Quality in the Muskeg River in Mean Open Water Flow Conditions

Parameter /	2000		2002		2003		2005		2010	
Substance	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	5.5E-02		5.5E-02		5.5E-02		5.5E-02		5.6E-02	
Ammonia - Total	5.5E-02		5.5E-02		5.6E-02		5.6E-02		5.8E-02	
Antimony - Total	3.1E-06		3.1E-06		3.4E-06		3.6E-06		4.6E-06	
Arsenic - Total	3.0E-03	HC	3.0E-03	HC	3.0E-03	HC	3.0E-03	HC	3.0E-03	HC
Barium - Total	2.6E-02		2.6E-02		2.7E-02		2.7E-02		2.7E-02	
Benzo(a)anthracene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Benzo(a)pyrene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Beryllium-Total	6.3E-06		6.3E-06		6.8E-06		7.2E-06		9.2E-06	
Boron - Total	4.5E-02		4.5E-02		4.5E-02		4.5E-02		4.5E-02	
Cadmium - Total	2.0E-04		2.0E-04		2.0E-04		2.0E-04		2.0E-04	
Calcium	3.9E+01	NG	3.9E+01	NG	3.9E+01	NG	3.9E+01	NG	3.9E+01	NG
Chloride	3.1E+00		3.1E+00		3.1E+00		3.1E+00		3.1E+00	
Chromium - Total	5.4E-04		5.4E-04		5.5E-04		5.6E-04		6.1E-04	
Conductivity	2.7E+02	NG	2.7E+02	NG	2.7E+02	NG	2.7E+02	NG	2.7E+02	NG
Copper - Total	8.6E-04		8.6E-04		8.6E-04		8.7E-04		8.8E-04	
Dissolved Organic Carbon	2.2E+01	NG	2.2E+01	NG	2.2E+01	NG	2.2E+01	NG	2.2E+01	NG
Iron - Total	8.2E-01	C HNC	8.2E-01	C HNC	8.3E-01	C HNC	8.3E-01	C HNC	8.4E-01	C HNC
Lead - Total	4.1E-04		4.1E-04		4.1E-04		4.1E-04		4.1E-04	
Magnesium	9.6E+00	NG	9.6E+00	NG	9.6E+00	NG	9.6E+00	NG	9.6E+00	NG
Manganese - Total	4.4E-02		4.4E-02		4.4E-02		4.5E-02		4.6E-02	
Mercury - Total	9.9E-05	C	9.9E-05	C	9.9E-05	C	9.9E-05	C	9.9E-05	C
Molybdenum - Total	2.2E-04		2.2E-04		2.2E-04		2.2E-04		2.3E-04	
Naphthenic Acids	4.0E+00	NG	4.0E+00	NG	4.0E+00	NG	4.0E+00	NG	4.0E+00	NG
Nickel - Total	4.0E-04		4.0E-04		4.0E-04		4.0E-04		4.0E-04	
Phenolics - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Selenium - Total	7.5E-05		7.5E-05		8.2E-05		8.7E-05		1.1E-04	
Silver - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Sodium	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG
Strontium	6.0E-02	NG	6.0E-02	NG	6.0E-02	NG	6.0E-02	NG	6.0E-02	NG
Sulphate	4.5E+00	NG	4.5E+00	NG	4.5E+00	NG	4.5E+00	NG	4.5E+00	NG
Total Dissolved Solids	1.7E+02		1.7E+02		1.7E+02		1.7E+02		1.7E+02	
Total PAH's	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Toxicity - acute	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Toxicity - chronic	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Vanadium - Total	4.3E-04		4.3E-04		4.3E-04		4.3E-04		4.4E-04	
Zinc - Total	1.2E-02		1.2E-02		1.2E-02		1.2E-02		1.3E-02	

C = Chronic
HC = Human Health Carcinogen
HNC = Human Health Non-Carcinogen
NG = no guidelines

Table V-10 Assessment of Water Quality in the Muskeg River in Mean Open Water Flow Conditions

Parameter / Substance	2020		2022		2025		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	5.2E-02		5.2E-02		5.2E-02		2.2E-01	C	5.2E-02	
Ammonia - Total	5.1E-02		5.1E-02		5.0E-02		6.5E-02		5.1E-02	
Antimony - Total	8.1E-07		8.0E-07		1.9E-07		1.1E-04		5.3E-09	
Arsenic - Total	2.9E-03	HC	2.9E-03	HC	2.9E-03	HC	3.2E-03	HC	2.8E-03	HC
Barium - Total	2.6E-02		2.6E-02		2.5E-02		3.9E-02		2.6E-02	
Benzo(a)anthracene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	1.7E-05	HC	3.1E-07	
Benzo(a)pyrene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	3.7E-06	HC	2.3E-08	
Beryllium-Total	1.6E-06		1.6E-06		3.7E-07		4.5E-04		1.6E-06	
Boron - Total	4.5E-02		4.5E-02		4.5E-02		3.5E-01		4.7E-02	
Cadmium - Total	2.0E-04		2.0E-04		2.0E-04		7.8E-04		2.1E-04	
Calcium	3.9E+01	NG	3.9E+01	NG	3.8E+01	NG	4.7E+01	NG	3.9E+01	NG
Chloride	3.1E+00		3.1E+00		3.1E+00		7.8E+00		3.2E+00	
Chromium - Total	4.4E-04		4.4E-04		4.1E-04		2.0E-03		4.4E-04	
Conductivity	2.7E+02	NG	2.7E+02	NG	2.7E+02	NG	4.6E+02	NG	2.7E+02	NG
Copper - Total	8.1E-04		8.1E-04		8.0E-04		2.4E-03		8.1E-04	
Dissolved Organic Carbon	2.2E+01	NG	2.2E+01	NG	2.2E+01	NG	2.6E+01	NG	2.2E+01	NG
Iron - Total	8.0E-01	C HNC	8.0E-01	C HNC	7.9E-01	C HNC	9.7E-01	C HNC	8.1E-01	C HNC
Lead - Total	4.0E-04		4.0E-04		4.0E-04		1.7E-03		4.3E-04	
Magnesium	9.6E+00	NG	9.6E+00	NG	9.6E+00	NG	1.1E+01	NG	9.6E+00	NG
Manganese - Total	4.1E-02		4.1E-02		4.0E-02		6.6E-02	C HNC	4.4E-02	
Mercury - Total	1.0E-04	C	1.0E-04	C	1.0E-04	C	9.5E-05	C	1.0E-04	C
Molybdenum - Total	2.0E-04		2.0E-04		2.0E-04		8.5E-02		2.1E-04	
Naphthenic Acids	4.0E+00	NG	4.0E+00	NG	4.0E+00	NG	3.7E+00	NG	3.9E+00	NG
Nickel - Total	4.0E-04		4.0E-04		4.0E-04		2.1E-03		4.0E-04	
Phenolics - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	1.1E-03		0.0E+00	-
Selenium - Total	1.9E-05		1.9E-05		4.5E-06		2.3E-04		0.0E+00	-
Silver - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	1.2E-04		5.9E-09	
Sodium	1.0E+01	NG	1.0E+01	NG	1.0E+01	NG	5.5E+01	NG	1.1E+01	NG
Strontium	6.0E-02	NG	6.0E-02	NG	5.9E-02	NG	2.0E-01	NG	6.0E-02	NG
Sulphate	4.5E+00	NG	4.5E+00	NG	4.5E+00	NG	8.1E+01	NG	4.6E+00	NG
Total Dissolved Solids	1.7E+02		1.7E+02		1.7E+02		3.1E+02	HNC	1.7E+02	
Total PAH's	0.0E+00	-	0.0E+00	-	0.0E+00	-	2.0E-03	NG	1.5E-06	NG
Toxicity - acute	0.0E+00	-	0.0E+00	-	0.0E+00	-	1.4E-02		5.2E-04	
Toxicity - chronic	0.0E+00	-	0.0E+00	-	0.0E+00	-	2.0E-02		6.1E-04	
Vanadium - Total	4.1E-04		4.1E-04		4.0E-04		1.1E-02		4.1E-04	
Zinc - Total	1.1E-02		1.1E-02		1.1E-02		1.5E-02		1.1E-02	

C = Chronic
HC = Human Health Carcinogen
HNC = Human Health Non-Carcinogen
NG = no guidelines

Table V-11 Assessment of Water Quality in the Muskeg River in Annual 7Q10 Conditions

Parameter / Substance	2000		2002		2003		2005		2010	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	4.0E-02		4.0E-02		7.9E-02		9.2E-02		1.1E-01	C
Ammonia - Total	1.1E+00		1.1E+00		1.1E+00		1.1E+00		1.1E+00	
Antimony - Total	0.0E+00	-	0.0E+00	-	4.0E-05		5.3E-05		7.1E-05	
Arsenic - Total	0.0E+00	-	0.0E+00	-	1.6E-03		2.1E-03		2.9E-03	
Barium - Total	7.1E-02		7.1E-02		8.1E-02		8.5E-02		9.0E-02	
Benzo(a)anthracene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Benzo(a)pyrene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Beryllium-Total	0.0E+00	-	0.0E+00	-	8.0E-05		1.1E-04		1.4E-04	
Boron - Total	5.8E-02		5.8E-02		5.7E-02		5.6E-02		5.5E-02	
Cadmium - Total	6.0E-04		6.0E-04		5.5E-04		5.4E-04		5.1E-04	
Calcium	7.2E+01	NG	7.2E+01	NG	7.4E+01	NG	7.5E+01	NG	7.6E+01	NG
Chloride	5.6E+00		5.6E+00		5.2E+00		5.0E+00		4.8E+00	
Chromium - Total	5.2E-03		5.2E-03		6.6E-03		7.1E-03		7.7E-03	
Conductivity	4.8E+02	NG	4.8E+02	NG	4.9E+02	NG	4.9E+02	NG	5.0E+02	NG
Copper - Total	2.0E-03		2.0E-03		2.6E-03		2.8E-03		3.1E-03	
Dissolved Organic Carbon	2.0E+01	NG	2.0E+01	NG	1.9E+01	NG	1.9E+01	NG	1.9E+01	NG
Iron - Total	2.4E+00	C	2.4E+00	C	2.7E+00	C	2.8E+00	C	2.9E+00	C
Lead - Total	3.8E-03		3.8E-03		3.6E-03		3.6E-03		3.5E-03	
Magnesium	1.7E+01	NG	1.7E+01	NG	1.7E+01	NG	1.7E+01	NG	1.7E+01	NG
Manganese - Total	5.5E-01	C	5.5E-01	C	5.7E-01	C	5.7E-01	C	5.8E-01	C
Mercury - Total	1.0E-04	C	1.0E-04	C	9.2E-05	C	8.9E-05	C	8.6E-05	C
Molybdenum - Total	0.0E+00	-	0.0E+00	-	2.4E-04		3.2E-04		4.3E-04	
Naphthenic Acids	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Nickel - Total	1.3E-03		1.3E-03		1.2E-03		1.2E-03		1.1E-03	
Phenolics - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Selenium - Total	0.0E+00	-	0.0E+00	-	9.6E-04		1.3E-03		1.7E-03	
Silver - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Sodium	1.5E+01	NG	1.5E+01	NG	1.4E+01	NG	1.4E+01	NG	1.3E+01	NG
Strontium	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG
Sulphate	5.1E+00	NG	5.1E+00	NG	4.9E+00	NG	4.9E+00	NG	4.8E+00	NG
Total Dissolved Solids	3.0E+02		3.0E+02		3.1E+02		3.1E+02		3.1E+02	
Total PAH's	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Toxicity - acute	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Toxicity - chronic	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Vanadium - Total	5.0E-04		5.0E-04		8.6E-04		9.8E-04		1.1E-03	
Zinc - Total	2.2E-02		2.2E-02		3.6E-02		4.1E-02		4.8E-02	

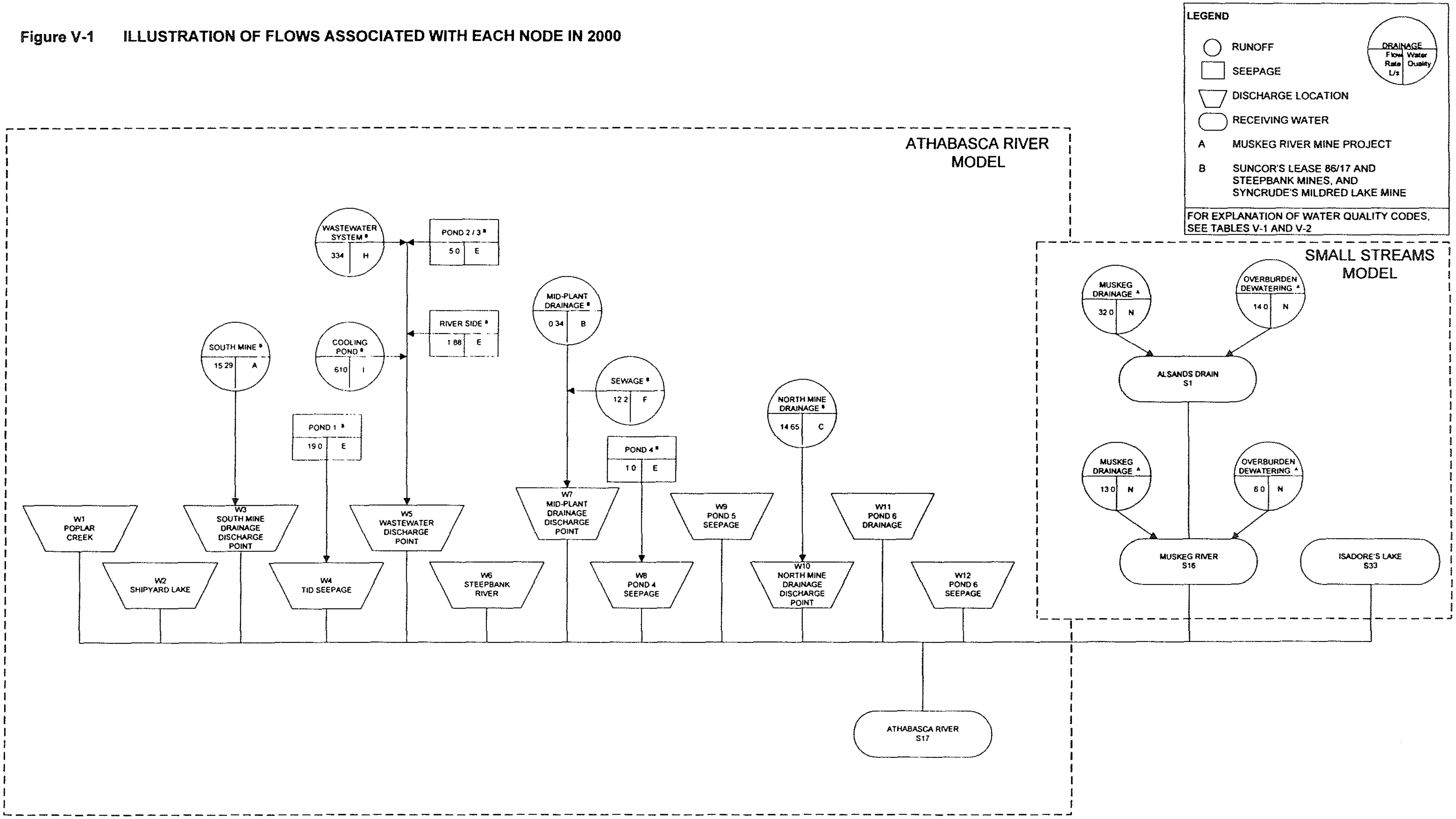
C = Chronic
HC = Human Health Carcinogen
HNC = Human Health Non-Carcinogen
NG = no guidelines

Table V-12 Assessment of Water Quality in the Muskeg River in Annual 7Q10 Conditions

Parameter / Substance	2020		2022		2025		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	1.4E-01	C	1.4E-01	C	6.9E-02		5.5E-02		7.8E-02	
Ammonia - Total	1.1E+00		1.1E+00		1.1E+00		1.1E+00		1.1E+00	
Antimony - Total	1.1E-04		1.1E-04		3.0E-05		1.5E-05		0.0E+00	-
Arsenic - Total	4.3E-03		4.3E-03		1.2E-03		6.1E-04		1.0E-04	
Barium - Total	9.9E-02		9.9E-02		7.9E-02		7.5E-02		7.2E-02	
Benzo(a)anthracene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	2.6E-05	
Benzo(a)pyrene grp	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	2.0E-06	
Beryllium-Total	2.1E-04		2.1E-04		5.9E-05		3.1E-05		6.8E-05	
Boron - Total	5.4E-02		5.4E-02		5.7E-02		5.7E-02		1.2E-01	
Cadmium - Total	4.7E-04		4.7E-04		5.6E-04		5.8E-04		7.2E-04	
Calcium	7.9E+01	NG	7.9E+01	NG	7.4E+01	NG	7.3E+01	NG	7.1E+01	NG
Chloride	4.4E+00		4.4E+00		5.3E+00		5.4E+00		6.0E+00	
Chromium - Total	9.0E-03		9.0E-03		6.3E-03		5.7E-03		5.1E-03	
Conductivity	5.1E+02	NG	5.1E+02	NG	4.9E+02	NG	4.8E+02	NG	5.5E+02	NG
Copper - Total	3.7E-03		3.7E-03		2.5E-03		2.2E-03		2.1E-03	
Dissolved Organic Carbon	1.8E+01	NG	1.8E+01	NG	1.9E+01	NG	2.0E+01	NG	2.1E+01	NG
Iron - Total	3.2E+00	C	3.2E+00	C	2.6E+00	C	2.5E+00	C	2.4E+00	C
Lead - Total	3.4E-03		3.4E-03		3.6E-03		3.7E-03		3.6E-03	
Magnesium	1.6E+01	NG	1.6E+01	NG	1.7E+01	NG	1.7E+01	NG	1.7E+01	NG
Manganese - Total	6.0E-01	C	6.0E-01	C	5.6E-01	C	5.5E-01	C	5.3E-01	C
Mercury - Total	7.9E-05	C	7.9E-05	C	9.4E-05	C	9.7E-05	C	9.7E-05	C
Molybdenum - Total	6.4E-04		6.4E-04		1.8E-04		9.2E-05		6.2E-04	
Naphthenic Acids	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	3.8E-01	NG
Nickel - Total	1.0E-03		1.0E-03		1.2E-03		1.3E-03		1.3E-03	
Phenolics - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	1.4E-04	
Selenium - Total	2.6E-03		2.6E-03		7.1E-04		3.7E-04		0.0E+00	
Silver - Total	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-
Sodium	1.3E+01	NG	1.3E+01	NG	1.4E+01	NG	1.4E+01	NG	3.5E+01	NG
Strontium	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG	1.8E-01	NG
Sulphate	4.7E+00	NG	4.7E+00	NG	5.0E+00	NG	5.0E+00	NG	1.2E+01	NG
Total Dissolved Solids	3.1E+02		3.1E+02		3.0E+02		3.0E+02		3.3E+02	
Total PAH's	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	3.8E-05	NG
Toxicity - acute	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	3.4E-02	
Toxicity - chronic	0.0E+00	-	0.0E+00	-	0.0E+00	-	0.0E+00	-	3.4E-02	
Vanadium - Total	1.5E-03		1.5E-03		7.7E-04		6.4E-04		8.2E-04	
Zinc - Total	6.1E-02		6.1E-02		3.2E-02		2.7E-02		2.3E-02	

C = Chronic
NG = no guidelines

Figure V-1 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2000



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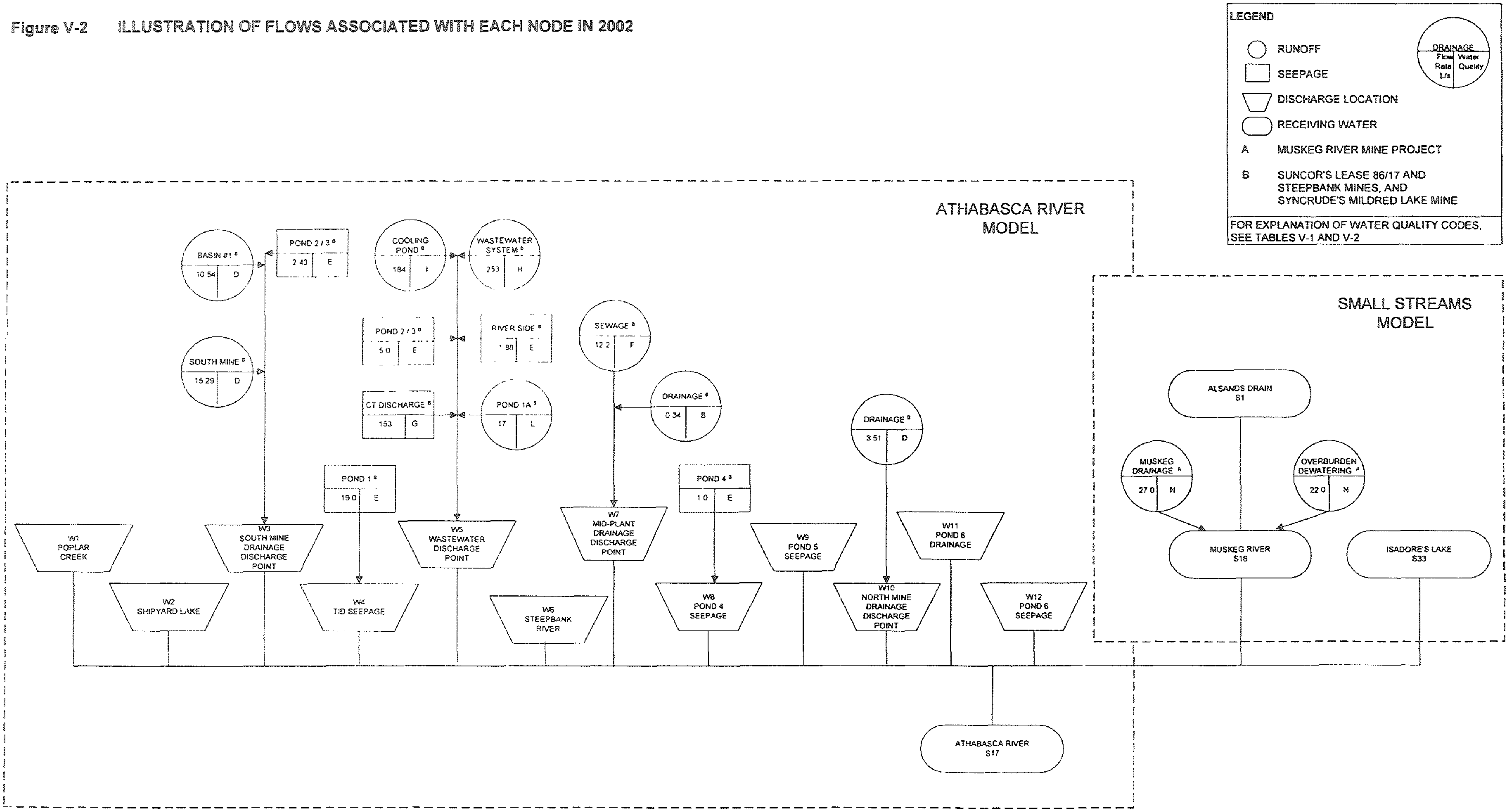
Date Last Revision 4 Dec 97

Figure V-2 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2002



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Date Last Revision 4 Dec 97

Figure V-3 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2003

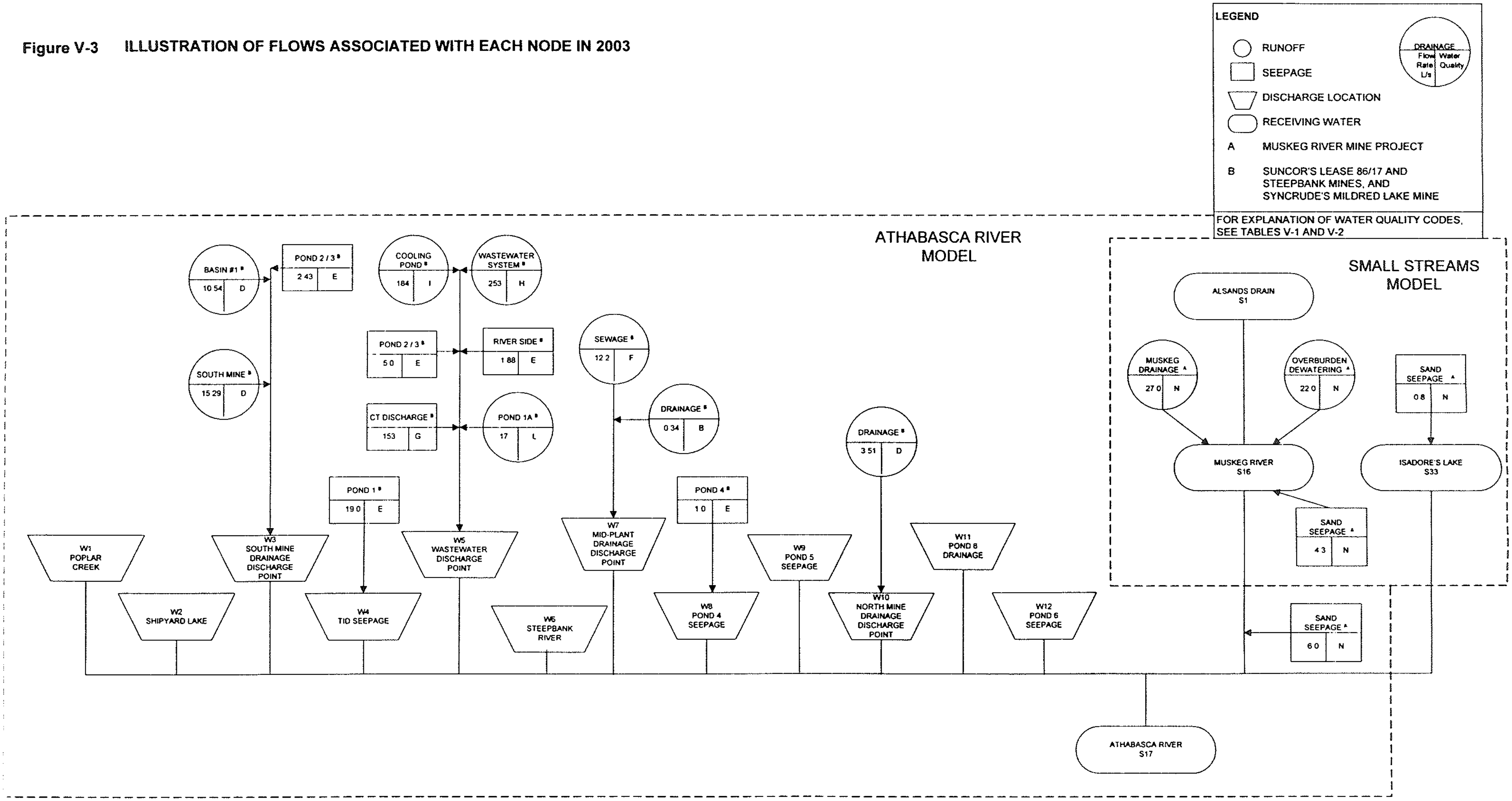

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Figure V-4 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2005

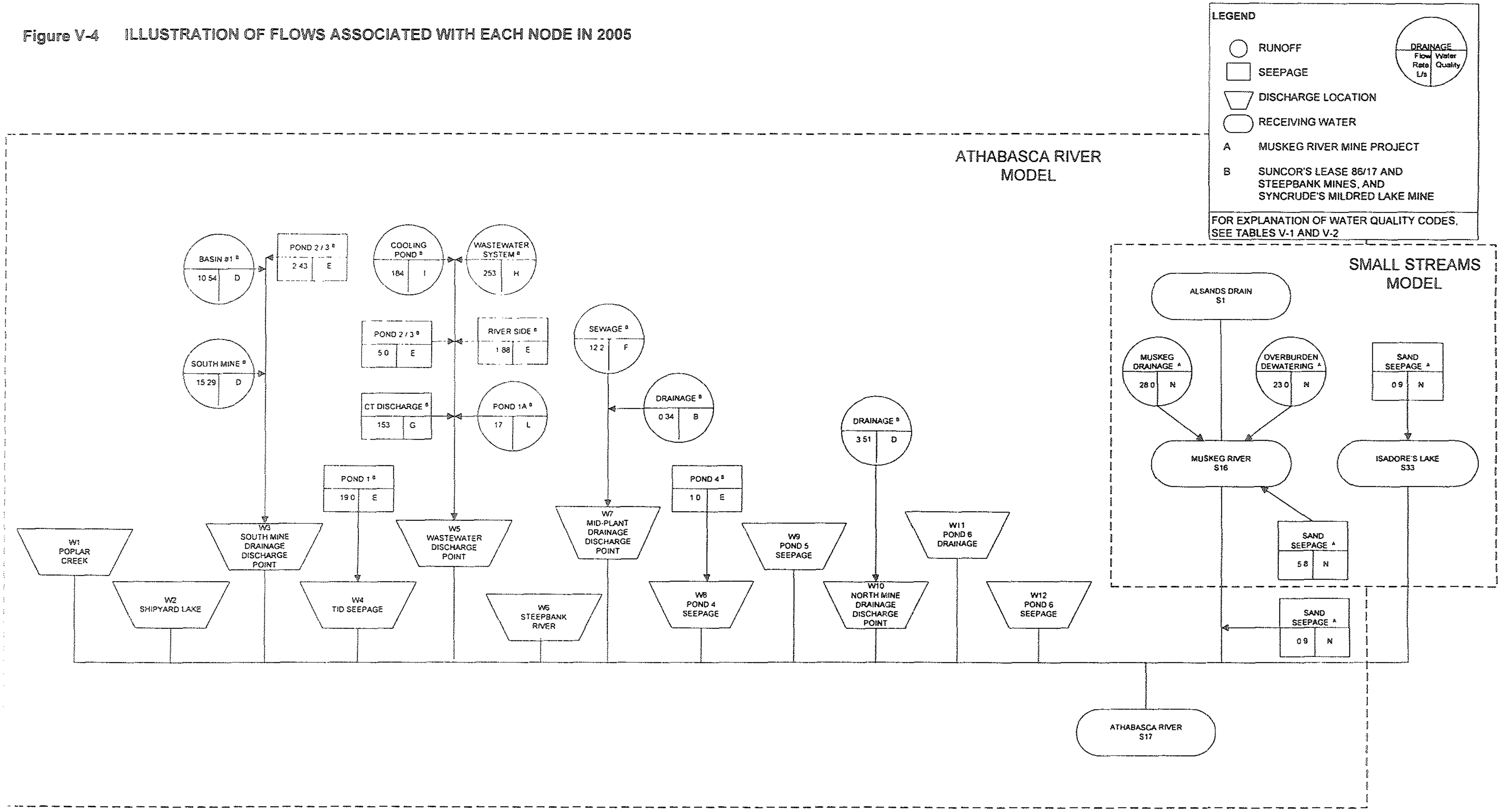

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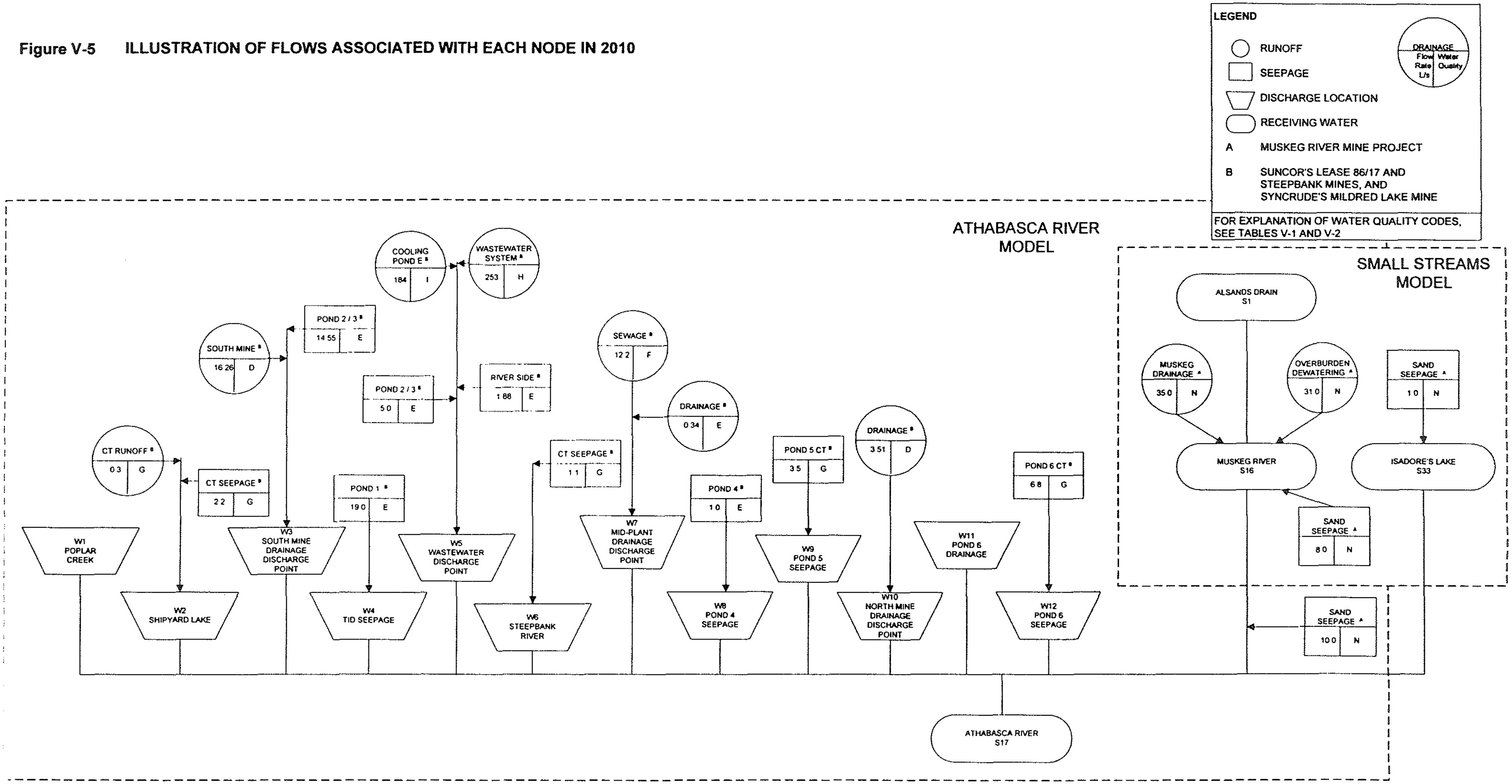
Figure V-5 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2010



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Date Last Revision: 4 Dec 97

Figure V-6 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2020

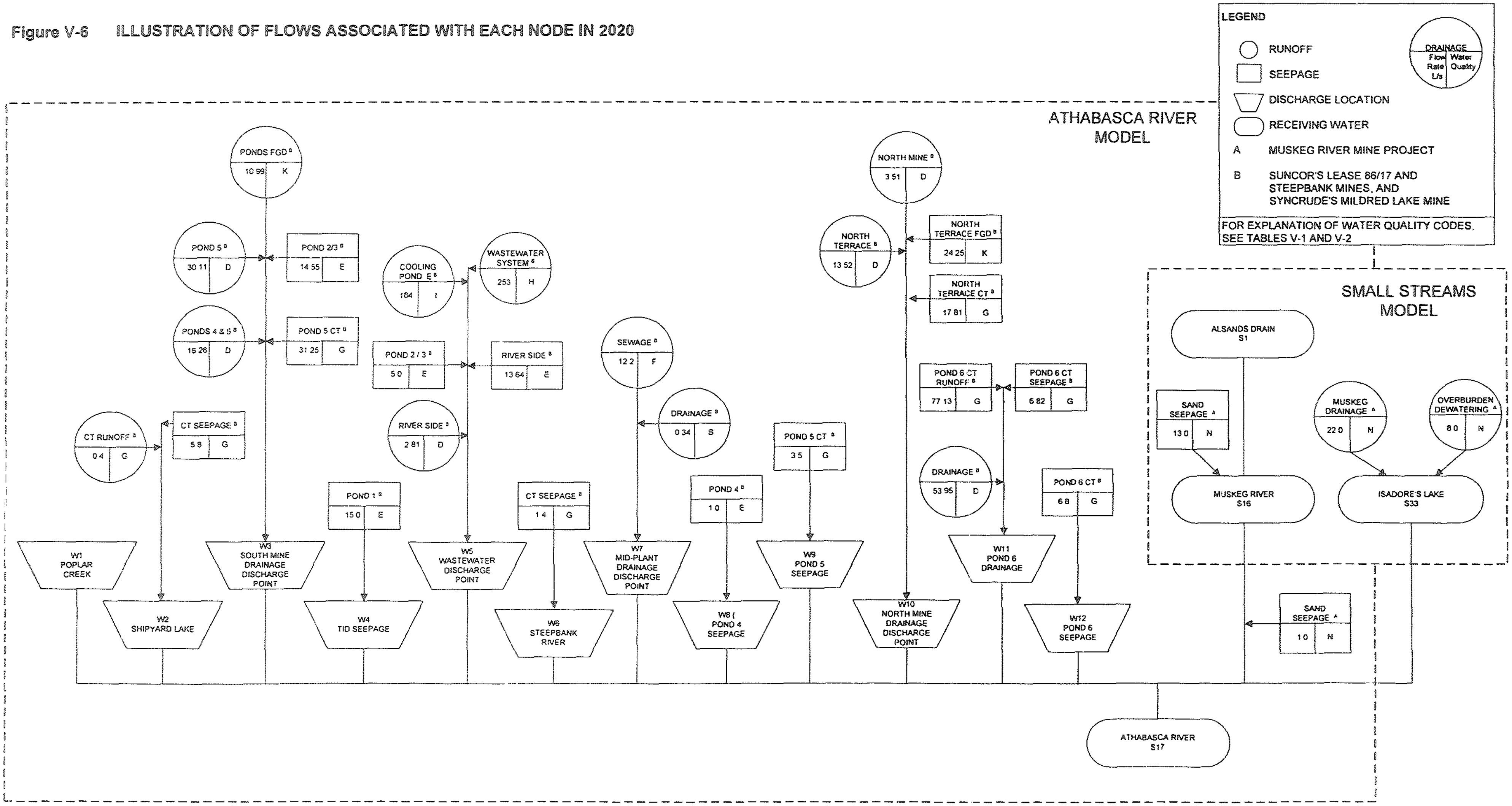

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Figure V-7 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2022

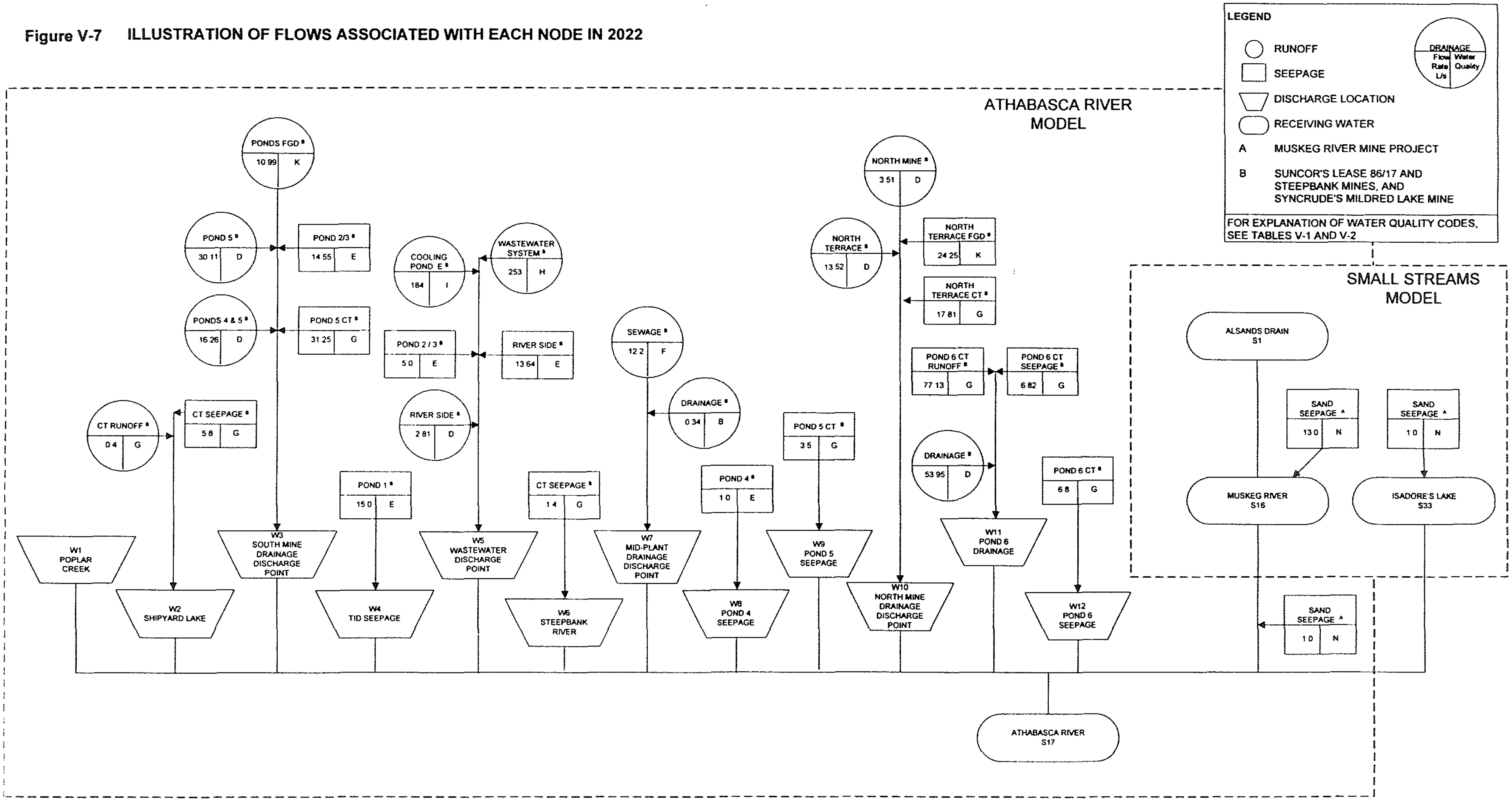

Figure V-8 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2025

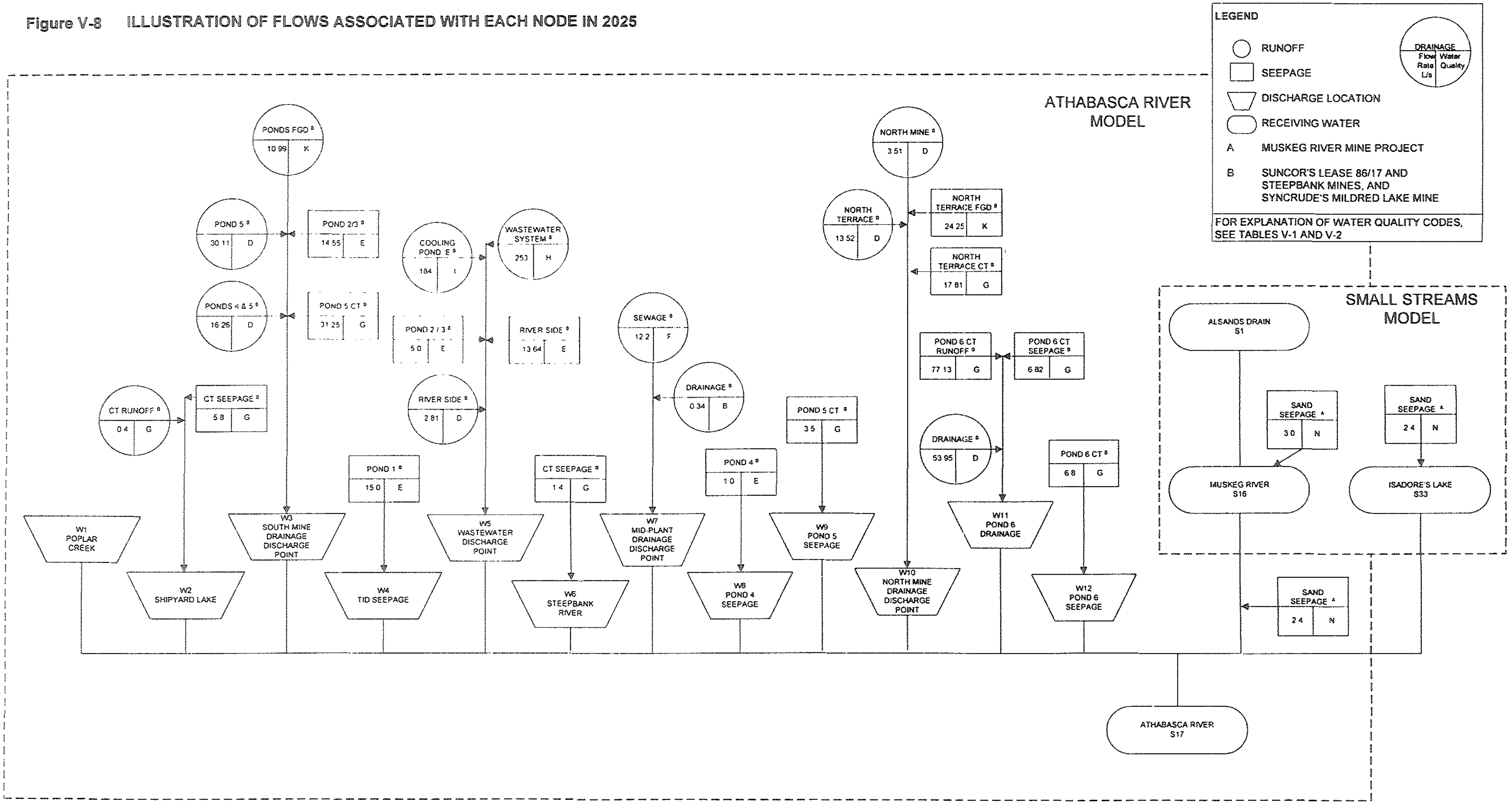

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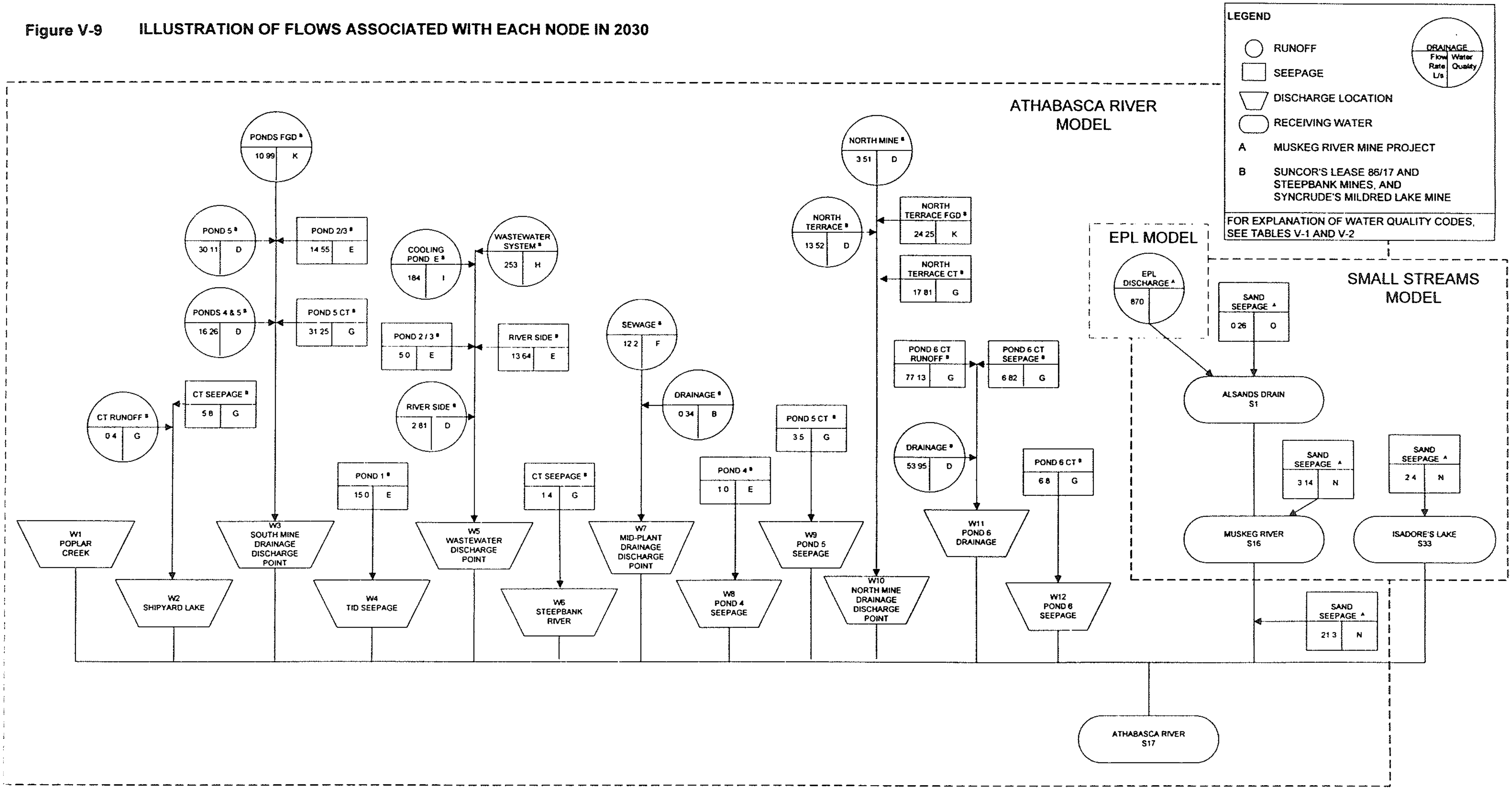
Figure V-9 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN 2030



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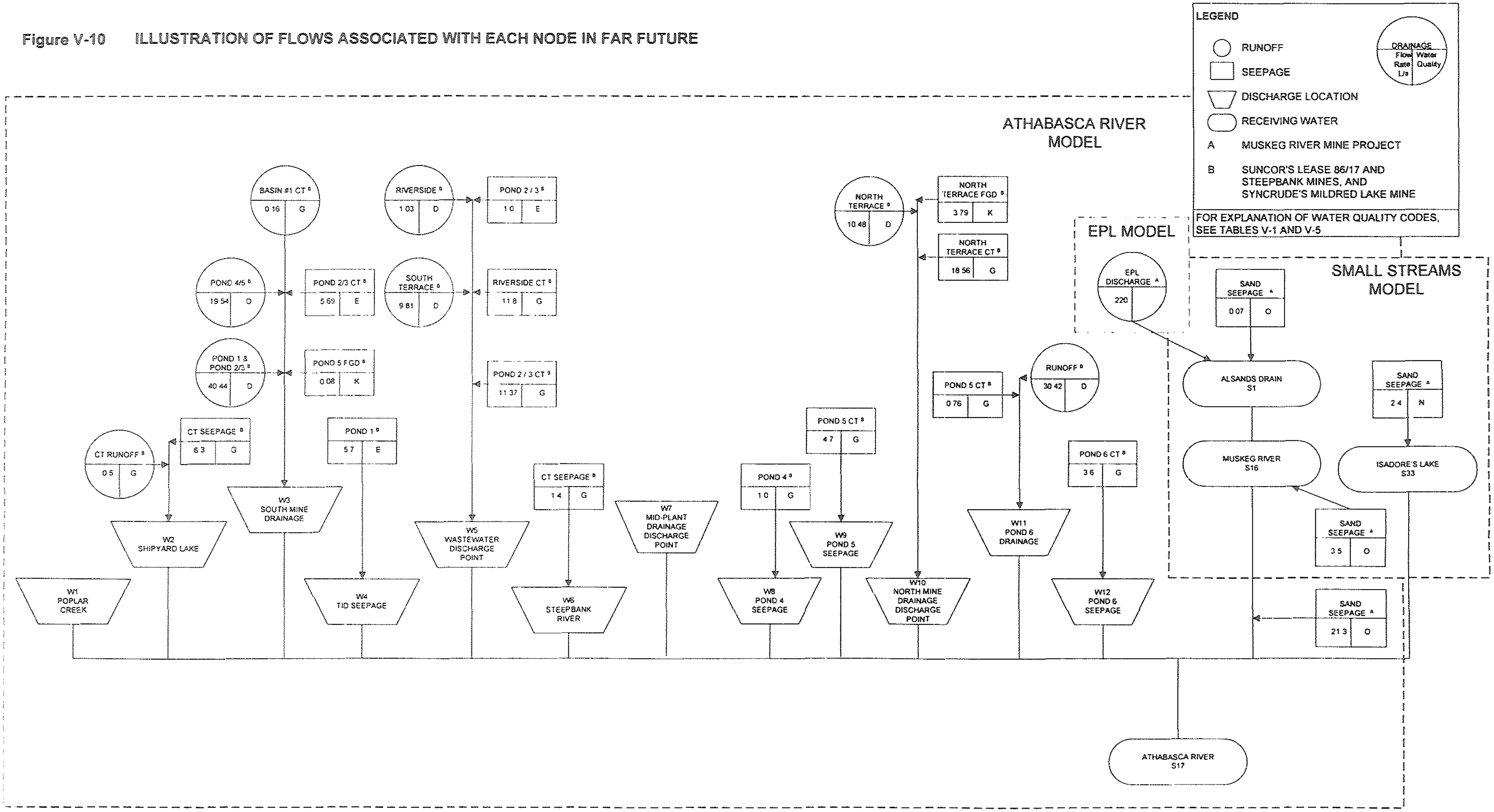
Date Last Revision: 4 Dec 97

Figure V-10 ILLUSTRATION OF FLOWS ASSOCIATED WITH EACH NODE IN FAR FUTURE



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Date Last Revision 4 Dec 97

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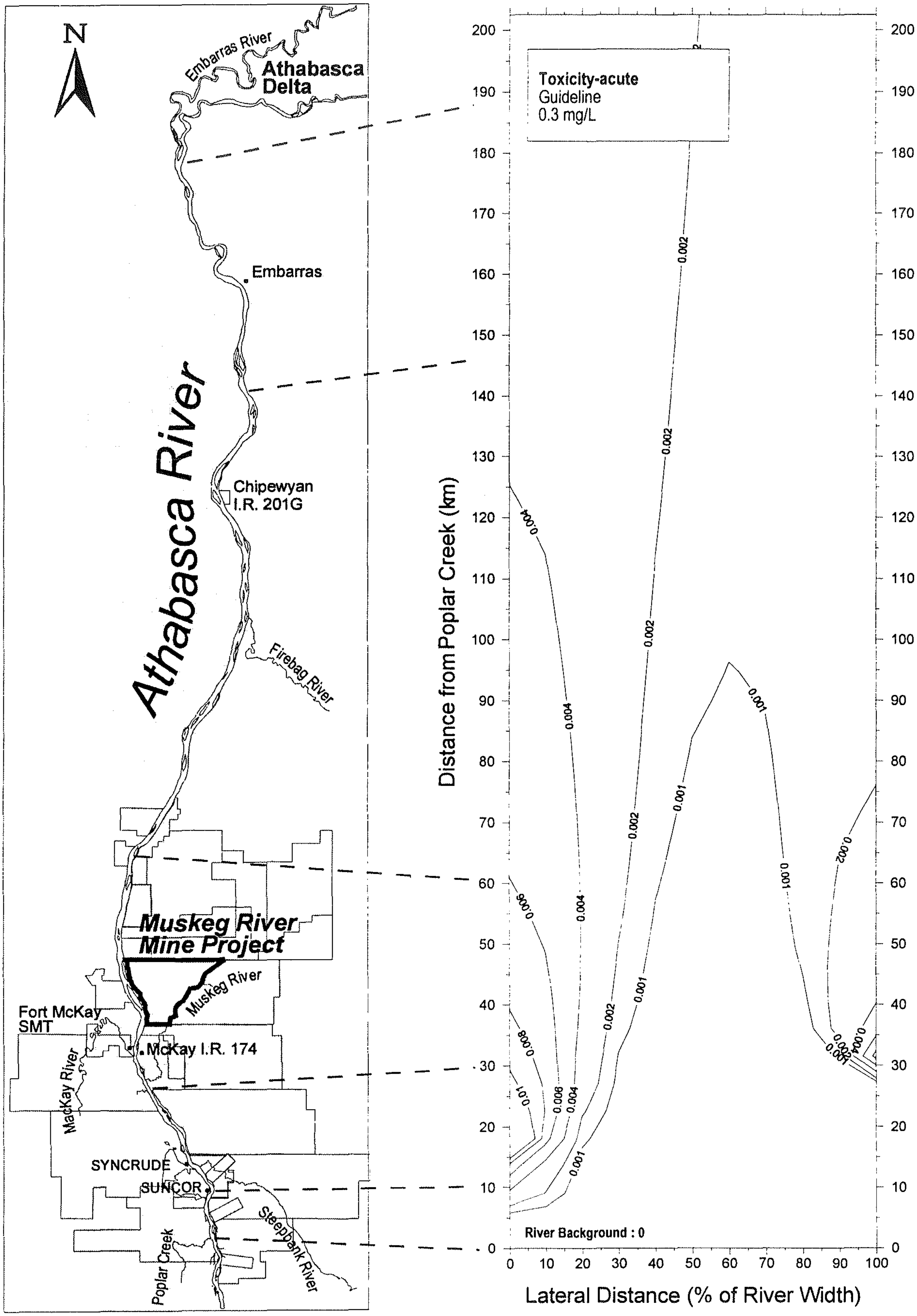

Figure V-11: Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow

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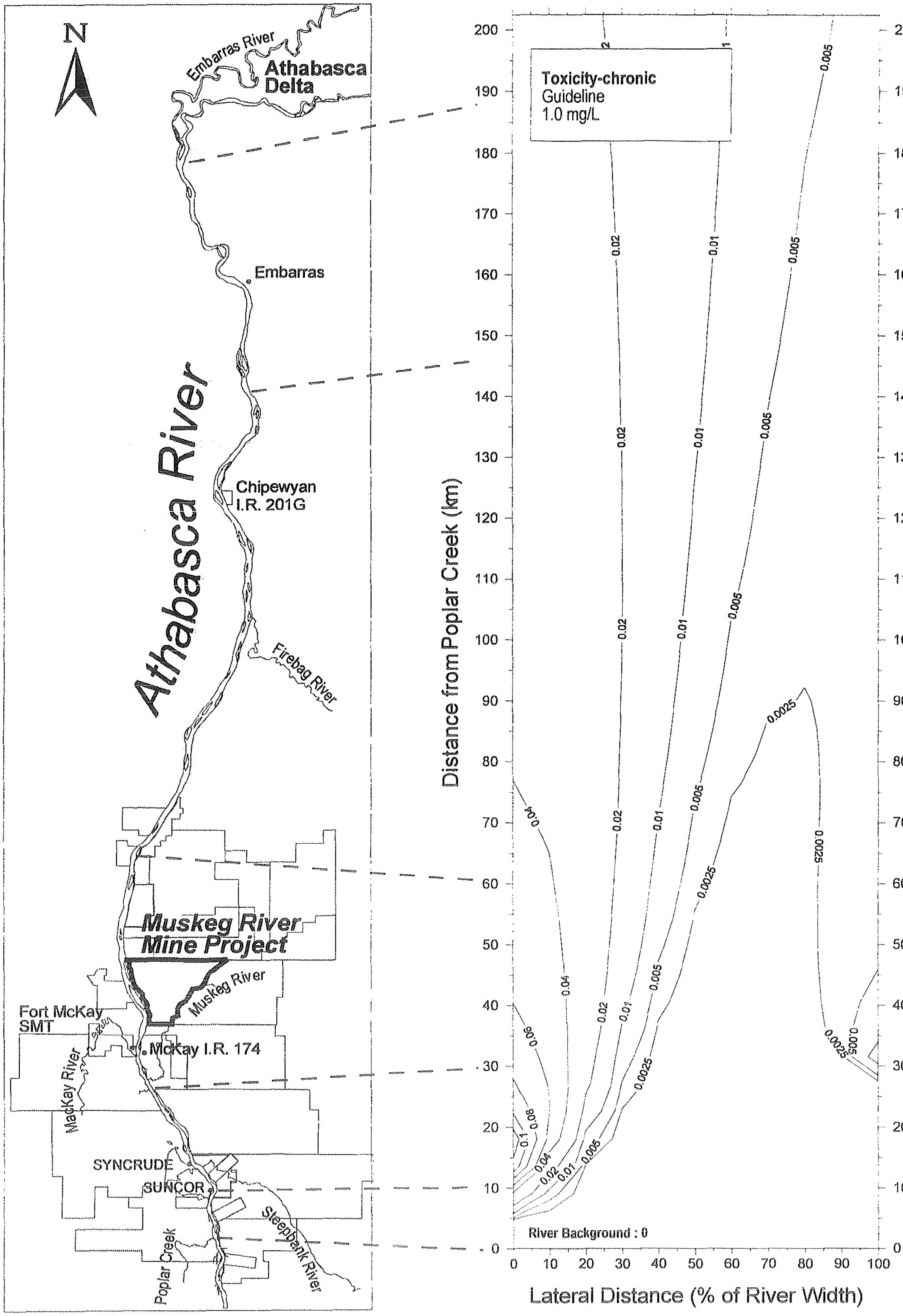


Figure V-12: Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow

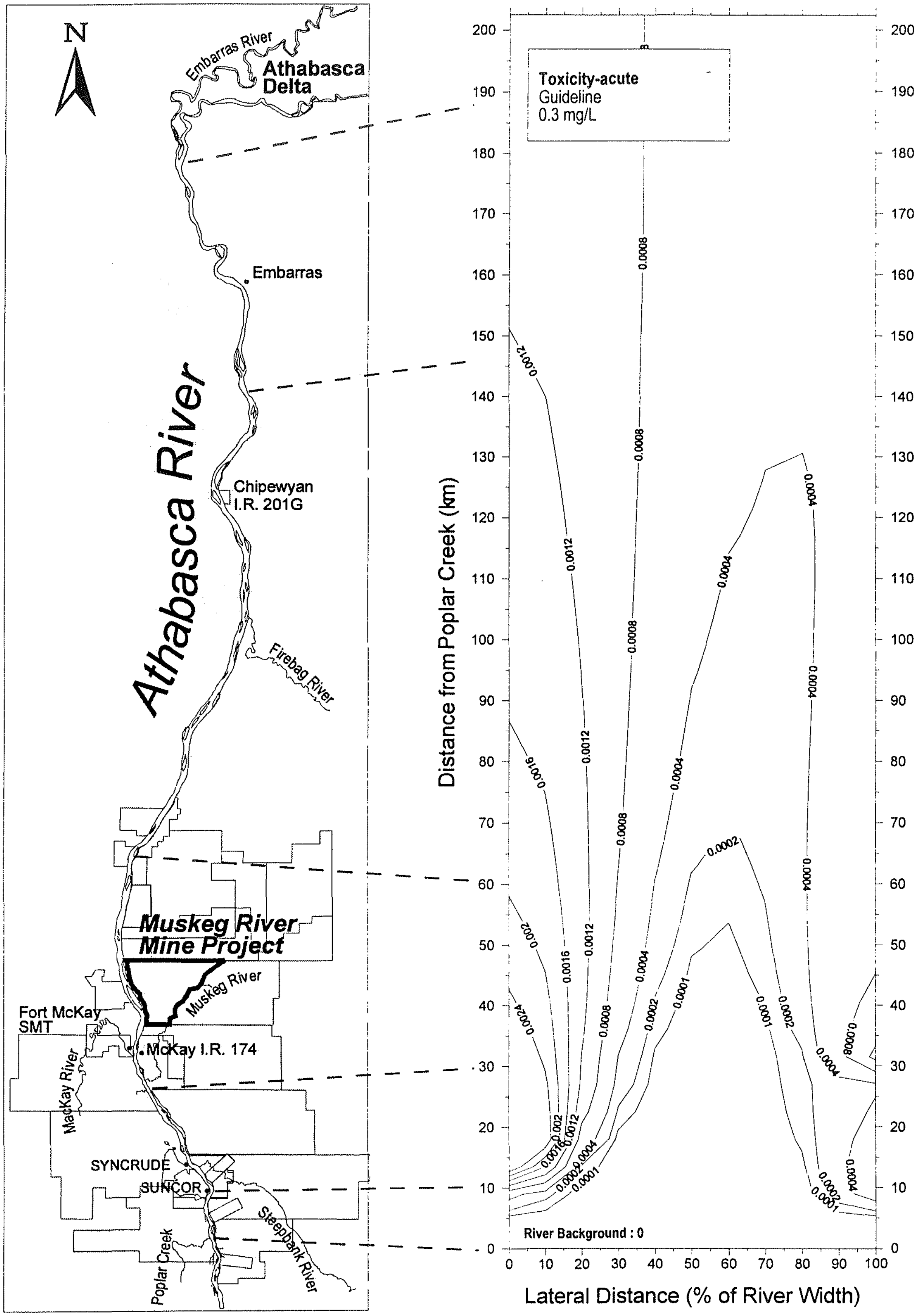


Figure V-13: Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow

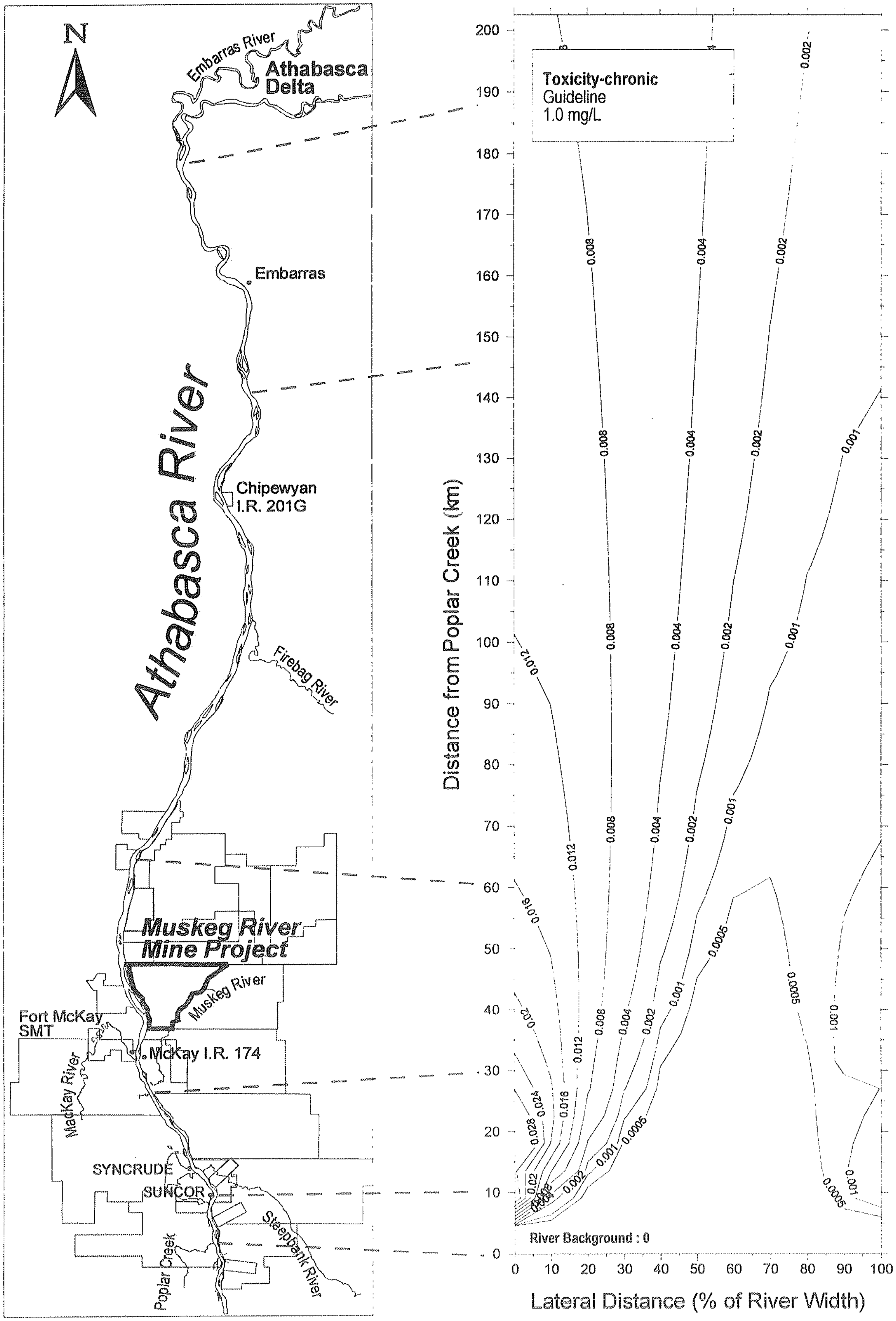


Figure V-14: Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow

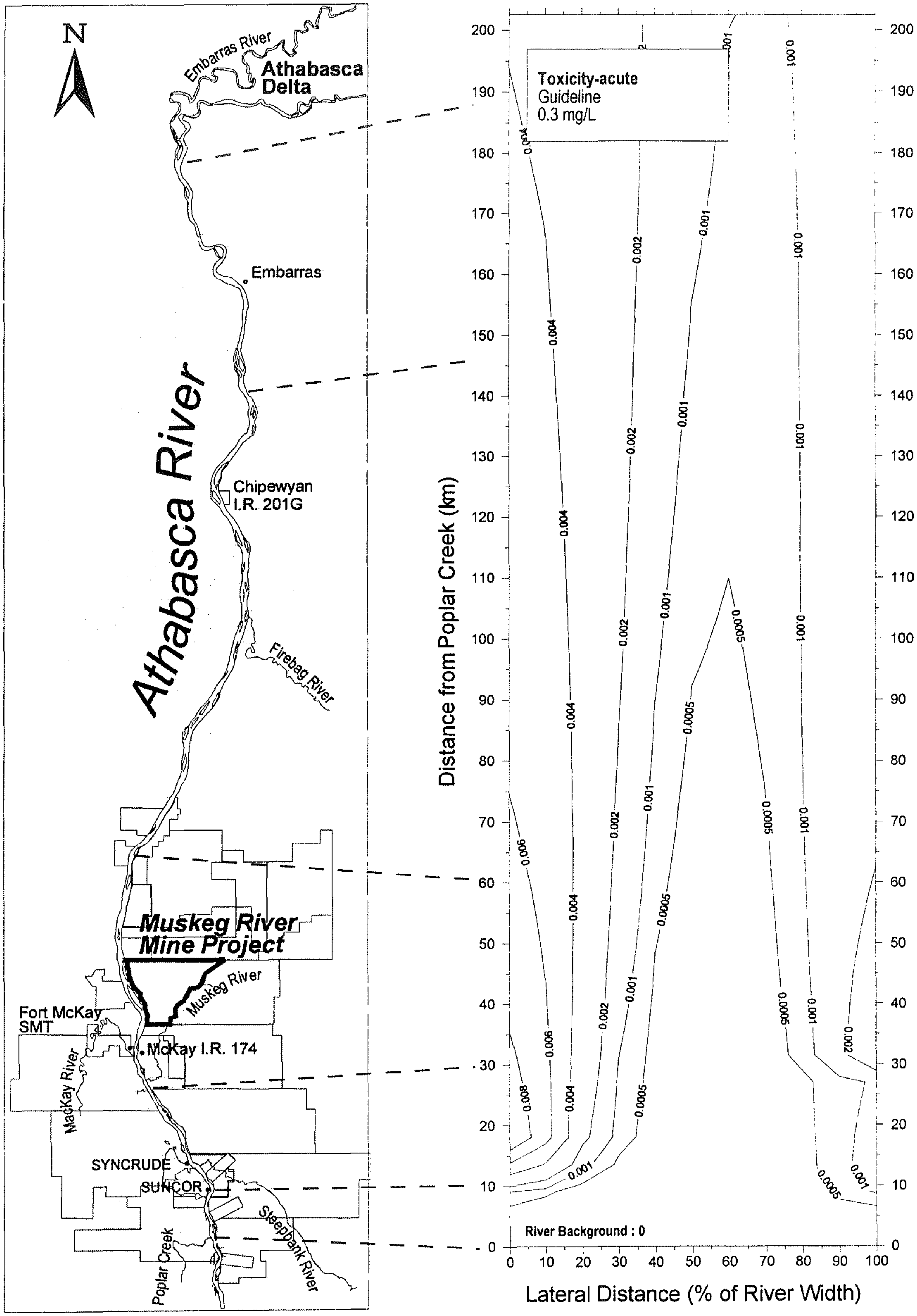


Figure V-15: Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover

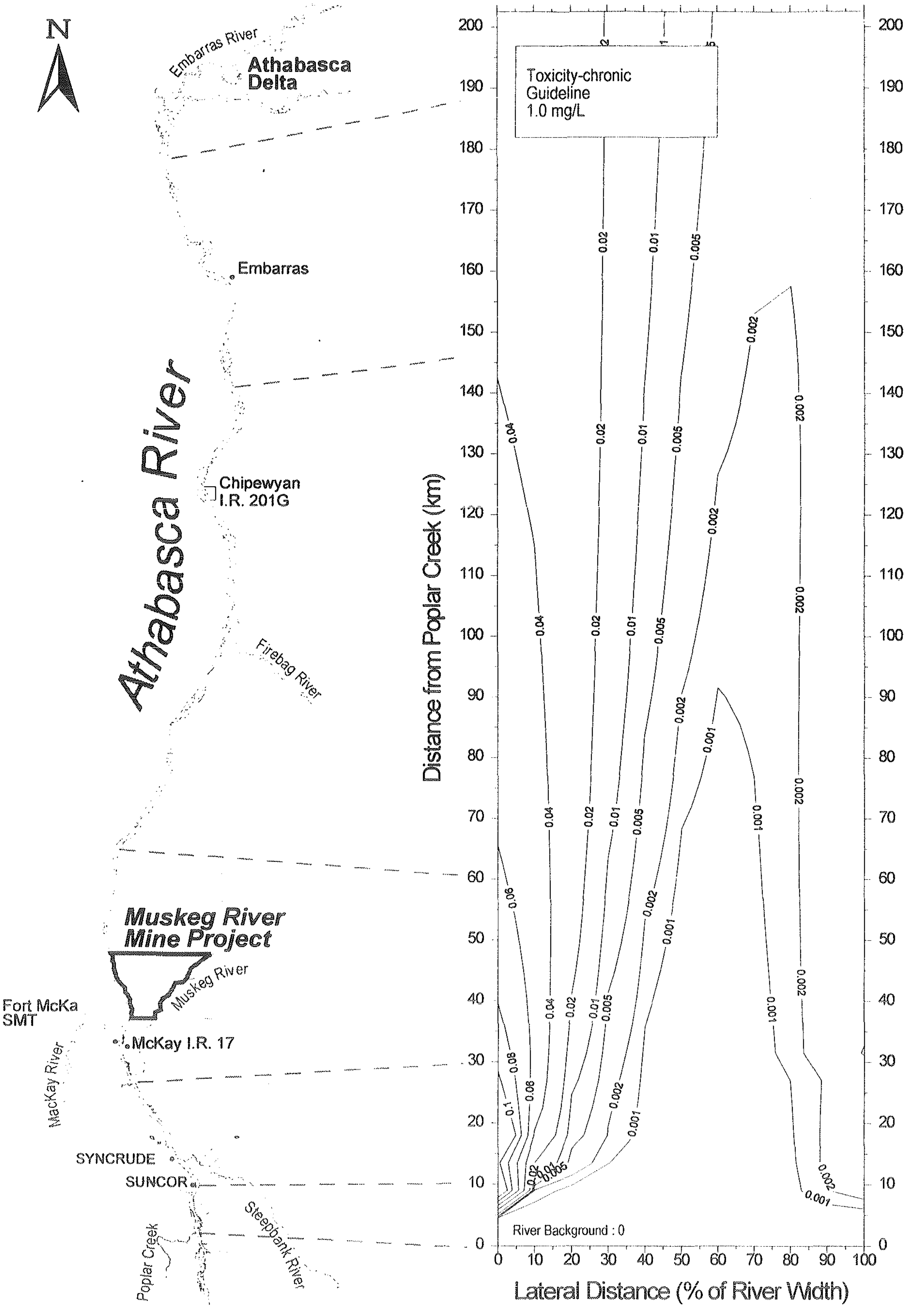
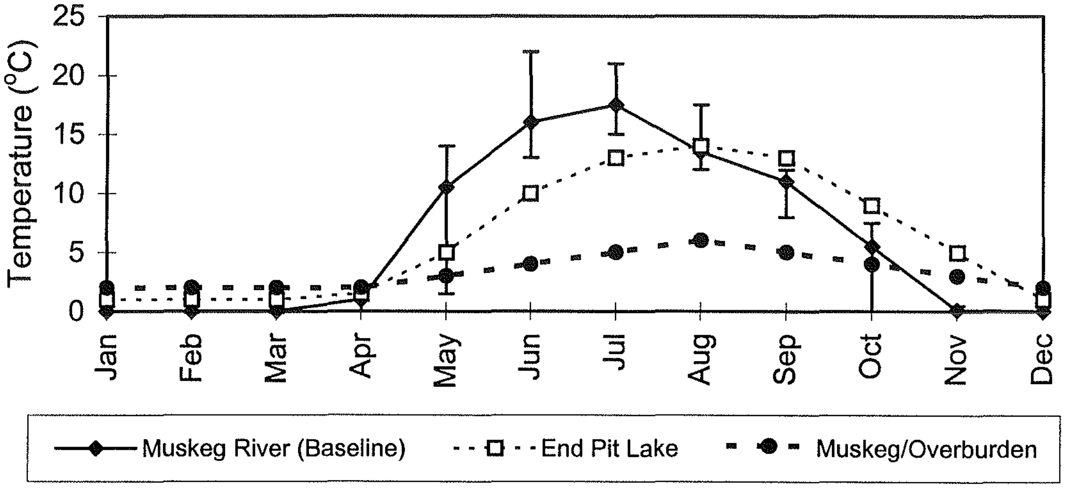


Figure V-16: Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover

Figure V-17 **Monthly Median Temperatures in the Muskeg River, and Assumed Temperatures for End Pit Lake Outflow and Muskeg and Overburden Drainage Waters**



APPENDIX VI

Habitat Requirements for the Muskeg River Mine Project Fish KIRS

VI-1 HABITAT REQUIREMENTS FOR THE MUSKEG RIVER MINE PROJECT FISH KIRS

VI-1.1 Northern Pike

Northern pike in Alberta are widely-distributed and occur almost everywhere except for higher elevation and steeper gradient watercourses in the Rocky Mountains and foothills (Nelson and Paetz 1992). Typical northern pike habitat is characterized by vegetated, nutrient-rich shallow waters. Northern pike are not adapted to survive in strong currents, therefore they predominantly occur in lakes or in slow moving rivers and streams, where they inhabit backwaters and pools (Inskip 1982).

Northern pike are spring-spawners, spawning immediately after ice melt in April to early May when water temperatures range from 4-11°C (Scott and Crossman 1973). They may migrate long distances to reach appropriate spawning areas (Inskip 1982). Both lake and river populations of northern pike tend to migrate up tributaries to find favourable spawning habitat such as wetlands, shallow pools, and the vegetated floodplains of rivers, marshes and bays of lakes (Scott and Crossman 1973; Casselman and Lewis 1996). No nest is built and the semi-adhesive eggs are broadcast over submerged vegetation (Inskip 1982; Casselman and Lewis 1996). The vegetation must provide abundant surface area for eggs and newly hatched fry to attach and allow the circulation of water for oxygenation (Inskip 1982).

Northern pike typically spawn in calm waters less than 0.5 m deep, that contain moderately dense mats of short vegetation (e.g. grasses and sedges). They avoid spawning in channelized reaches and prefer spawning in pools with low velocities and fine substrate. Absence of instream cover and flows greater than 1.5 m/s may inhibit spawning (Inskip 1982). Dissolved oxygen concentrations which fall below 30-35% air saturation usually results in a greatly reduced survival of northern pike eggs and larvae. High water levels at spawning time with stable levels after the incubation period are associated with large year-classes of northern pike. Thus, it is critical that water levels are maintained throughout the egg and fry life stages (Hassler 1970). Water temperature decreases and/or silt deposition have been found to cause significant mortality of incubating eggs (Hassler 1970).

Eggs hatch approximately two weeks after spawning, and the emerging post-hatch larvae attach themselves to aquatic vegetation for 6-10 days as they absorb their yolk reserves. After they detach, the fry remain in the vicinity of the spawning grounds for 2-3 weeks, feeding on zooplankton and aquatic invertebrates (Ford *et al.* 1995). The optimal temperature for northern pike fry is 25.6°C (Casselman and Lewis 1996). The young aggressively defend a territory in shallow areas, seeking cover amongst vegetation as they are photo-sensitive. At 20 mm in length they become free-ranging and move to other parts of the lake or river. Due to their rapid growth and increase in activity, the physical needs of young northern pike expand.

Casselman and Lewis (1996) estimated young northern pike require more than 10 times the area of nursery habitat compared to spawning habitat, and optimally this habitat will contain 40-80% coverage by submergent and emergent aquatic plants. Young northern pike grow rapidly, and shift to piscivory at a length of 50-60 mm. As they grow older, an ambush style of feeding is adopted; therefore, the presence of submerged cover (e.g., aquatic vegetation or logs) is important (Ford *et al.* 1995; Casselman and Lewis 1996). The optimal temperature for northern pike young-of-the-year is 22-23°C (Casselman and Lewis 1996).

Juvenile and adult northern pike prefer shallow, littoral areas (< 4 m deep) with moderate densities of vegetation (> 30% coverage), and usually stay within 100 m of the shore (Inskip 1982; Casselman and Lewis 1996). They are known to move short distances in summer or winter, and rarely make long migrations (Ford *et al.* 1995). However, shallow, heavily vegetated lakes that were favorable for most of the year frequently develop low dissolved oxygen concentrations during winter. Northern pike counter the effects of lowered oxygen concentrations by seeking areas of higher oxygen concentrations higher up in the water column, decreasing their activity levels, and reducing or ceasing to feed. Northern pike generally avoid oxygen concentrations of less than 3-4 mg/L, with the lower incipient lethal oxygen concentration estimated at 0.5-1.5 mg/L. Smaller northern pike are more tolerant of oxygen depression than larger individuals. The optimal temperature for adult northern pike is 19°C, while the incipient lethal water temperature is 30°C for subadults (Casselman and Lewis 1996).

Adult northern pike are a strictly predatory and opportunistic feeder, primarily feeding on fish, but crayfish, waterfowl and even small mammals may contribute to the diet (Scott and Crosman 1973; Ford *et al.* 1995).

VI-1.2 Arctic Grayling

Arctic grayling inhabit cold water streams, rivers and lakes that support aquatic vegetation (Hubert et al. 1985). They are found almost exclusively in pools but can tolerate a current of 0.26 m/s (Kreuger 1981). Arctic grayling overwinter in large streams and rivers or in deep holes (>1.0 m) in smaller streams (Nelson and Wojcik 1953). Spring-fed reaches that do not completely freeze in winter also provide suitable overwintering habitat (Kreuger 1981).

Arctic grayling are spring spawners, and may migrate long distances to reach tributary spawning streams. Once spawning is completed, adult Arctic grayling may move upstream or downstream, or migrate to larger streams for summer feeding (Tack 1980). By late summer or fall, the adults have moved downstream to wintering areas (Kratt and Smith 1977).

Spawning usually occurs over gravel substrate in the transition area between a riffle and a pool (Bishop 1971). Spawning typically occurs in May to early June when water temperatures may range from 4-10°C (Scott and Crossman 1973; Northcote 1995). Current velocities at spawning sites range from 0.34 to 1.46 m/s (Kreuger 1981). Arctic grayling do not typically spawn over silt or clay, as this substrate type does not provide optimal conditions for egg survival (Bishop 1971). Many eggs commonly drift downstream soon after being spawned (Warner 1955).

Newly hatched fry spend a few days buried under 2 to 3 cm of gravel, protected from water currents and wave action (Kratt and Smith 1977). After fry emerge from the gravel they remain in quiet backwaters and sheltered areas of the spawning stream throughout the summer (Craig and Poulin 1975). In contrast, juveniles will use pool and slough habitat in the spawning stream most or all of the growing season, and may feed in riffles (Kreuger 1981). Fry depend on interstitial spaces and shadows of boulders for cover from predators (Kreuger 1981). Juveniles will commonly use overhanging vegetation, logs, boulders and turbulence for instream cover (Kreuger 1981).

Juvenile Arctic grayling have a temperature tolerance of 2-24.5°C and an optimal temperature for growth of 10-12°C. Adult Arctic grayling have a temperature tolerance of 1-20°C and an optimal temperature for growth of 10°C. Juvenile and adult Arctic grayling have a lower lethal oxygen concentration of 1.4 and 2.0 mg/L, respectively (Ford *et al.* 1995).

VI-1.3 Longnose Sucker

Longnose sucker are the most widespread sucker in northern Canada and are found in large numbers in most waterbodies with clear and cool waters (Lee et al. 1980). Longnose sucker spawning normally occurs in tributary streams rather than in lakes or in large rivers (Brown and Graham 1953). Longnose sucker require riffle habitats for spawning, where water velocities range from 0.3 to 1.0 m/s and clean gravel or cobble (1 to 20 cm in diameter) is present. Peak spawning occurs in June when water temperatures range from 10-15°C (Edwards 1983).

The fry of longnose sucker drift downstream following emergence from the gravel. Fry seek shelter from predation and swift flows in shallow areas of reduced velocity and vegetation. Fry have been reported to congregate near the water surface (within 150 mm of surface) and within 2 m of the shore or river bank (Hayes 1956). As young-of-the-year longnose sucker become larger (juveniles), they frequent shallow weedy areas and will seek out areas with some current velocity (Johnson 1971).

Longnose sucker feed on zooplankton and diatoms as fry, and shift to larger organisms such as benthic macroinvertebrates as they become larger (Edwards 1983). Adult longnose suckers in general feed on a wide range of food items based on availability; dominant items in the diet include amphipods, cladocerans, aquatic insect larvae and other invertebrates. The preferred temperature range of adult longnose suckers is 10-15°C with the upper lethel limit estimated at 27°C (Edwards 1983). No specific information exists for dissolved oxygen criteria but concentrations above 5 mg/L is assumed to be adequate (Edwards 1983).

Longnose sucker migrate widely in the Athabasca River system. Most longnose sucker overwinter in Lake Athabasca and migrate into Athabasca River tributaries to spawn. In areas with prolonged and extensive ice cover, overwintering habitats are critical to longnose suckers. The principle habitat requirements for longnose sucker winter habitat are an adequate oxygen supply and sufficient water depth to allow for ice cover and refugia from high water velocities.

VI-1.4 Forage Fish Species

Within the study area, the primary forage fish species of interest are the fathead minnow, pearl dace, lake chub, brook stickleback and slimy sculpin. The general life history of the first four species is generally similar: fathead minnows, brook stickleback, and pearl dace are often found in association with each other, and lake chub and pearl dace are known to hybridize with each other as the two species are closely related (Scott and Crossman 1973; Nelson and Paetz 1992). Therefore, the general life history of these four species will be treated together. The life history of slimy sculpin is somewhat different and will require specific references to these different traits.

The four forage fish species are generally found in a wide range of habitats (small creeks, rivers, ponds and lakes) usually in still waters and in association with aquatic vegetation (Scott and Crossman 1973; Nelson and Paetz 1992; Lane *et al.* 1996). Spawning occurs from April to August when water temperatures range from 8-18°C (Scott and Crossman 1973; Nelson and Paetz 1992). Maturity occurs as early as one year (brook stickleback) to as late as 3-4 years for lake chub. Fathead minnows attach their eggs to the underside of objects and are fractional spawners, spawning several times over a summer (Gale and Buynak 1982). Brook stickleback are unique in that a small nest of detritus and fibres is constructed on aquatic vegetation into which eggs are deposited. Pearl dace deposit their eggs over in shallow water over sand and gravel in weak to moderate current, while lake chub spawn amongst rocks and over silt and detritus (Brown *et al.* 1970). Eggs generally hatch in 5-9 days (Scott and Crossman 1973; Nelson and Paetz 1992).

The diet of these four forage species is typical of other forage fish and consists of aquatic insects (e.g. chironomids), crustaceans (e.g. cladocerans) and algae. Larger lake chub will consume small fish, while brook stickleback will eat fish eggs and larval fish (Scott and Crossman 1973; Nelson and Paetz 1992). These species are short-lived, ranging from three years (fathead minnow) to five years (lake chub). Maximum sizes (length) range from 87 mm (brook stickleback) to 200 mm (lake chub) (Scott and Crossman 1973; Nelson and Paetz 1992). Dissolved oxygen requirements of these four forage species are less critical when compared to salmonid species. They are tolerant to intermediately tolerant to low dissolved oxygen concentrations, with the acute concentrations of dissolved oxygen ranging from < 1 - 2 mg/L (Barton and Taylor 1996). There is little information on temperature tolerances except for fathead minnow which has an upper lethal temperature of 32-33°C (Clayton and Maughan 1978). It is likely the other three species have similar temperature tolerances.

As mentioned earlier, slimy sculpins have different life history traits compared to the previous four species. Slimy sculpins occur in the deeper portions of lakes and in cool, rocky streams. They have been captured in lakes at depths ranging from 6-82 m and most commonly at depths from 37-73 m. They spawn between and under rocks from May to June, when water temperatures range from 5-10°C. Eggs hatch approximately 28 days later (Nelson and Paetz 1992). In an Alaskan stream, Craig and Wells (1976) observed that most slimy sculpins matured at age 3-4. Slimy sculpins feed predominantly on aquatic insect larvae and nymphs, although crustaceans, small fish, and plant material are sometimes eaten (Scott and Crossman 1973; Craig and Wells 1976).

Symons *et al.* (1976) estimated the preferred temperature (acclimated at 20°C) of slimy sculpin was 13°C and the lethal temperature was 25°C. Maximum size from Alberta is 90 mm (Nelson and Paetz 1992) while the largest reported size is 109 mm (Scott and Crossman 1973). The maximum reported lifespan of slimy sculpins is 7 years (Scott and Crossman 1973).

VI-1.5 Lake Whitefish

In Alberta, lake whitefish are most abundant in the eastern portion of the province, in the drainages of the Hay, Slave, Peace, Athabasca, Beaver, North Saskatchewan, and upper Battle rivers. Their presence in southern drainages is the result of introductions. Lake whitefish are characteristically a lake-dwelling species, but in Alberta they do sometimes occur in rivers (Nelson and Paetz 1992).

Lake whitefish are fall-spawners, with spawning occurring in lakes, rivers and streams from October to December when water temperatures are 8°C or less. The longest spawning migrations usually occur when lake whitefish ascend rivers, while shorter migrations occur for lake spawning populations. Age of maturity varies depending on fishing pressure, but 4-9 years is typical. No nest is built and in rivers, the eggs are broadcast over cobble and gravel in shallow running water. In lakes, eggs are broadcast over sand, gravel, cobble and boulders in depths from 0.3 to 30.0 m. Spawning occurs at night. Eggs incubate over the winter for approximately 20-23 weeks, hatching in April or May. Eggs require water temperatures between 0.5-12°C for incubation; 4-6°C has been found to be the optimal water temperature (Scott and Crossman 1973; Ford *et al.* 1995).

After hatching, the young move downstream from spawning areas to river margins. Larval lake whitefish begin feeding on small zooplankton species 1-3 days after hatching. They may also remain in adjacent, backwater areas where they stay for several weeks feeding on planktonic (e.g., cladocerans) and then benthic (e.g., dipteran larvae) organisms (Ford *et al.* 1995). Towards late summer the young move from the warmer epilimnetic waters to the cooler metalimnetic waters, where their diet begins to resemble adult lake whitefish. The upper lethal temperature for young lake whitefish is estimated at 26.6°C with the preferred temperature ranging from 12-16°C (Taylor and Barton 1992; Ford *et al.* 1995).

During the summer months lake whitefish descend into deeper, cooler waters, while in the fall and winter they are found in shallower waters. The preferred temperature range of adult lake whitefish is estimated to be between 8-14°C, while the preferred oxygen concentrations are > 7.0 mg/L. The acute temperature for adults is estimated at > 23°C while the recommended short term exposure for oxygen is estimated at 4.25 mg/L (Taylor and Barton 1992; Ford *et al.* 1995).

Adults are almost entirely benthic feeders and consume aquatic insect larvae (e.g. chironomids and caddisflies), clams, snails and amphipods. Zooplankton, fish and fish eggs are occasionally consumed by adults, in lesser amounts (Nelson and Paetz 1992; Ford *et al.* 1995). The major predators of lake whitefish are lake trout, northern pike, walleye, burbot, and even lake whitefish which will consume their own eggs (Scott and Crossman 1973). Yellow perch and ciscoes will also feed on larval lake whitefish. Lake whitefish on average have a maximum observed age of 16 years.

VI-1.6 Walleye

Walleye are piscivores and feed on a variety of fish species (Scott and Crossman 1973). Adult and juvenile walleye generally feed in turbid waters where forage fish are abundant. In rivers, walleye spawn on rocky shoals downstream of rapids and falls and along shallow shorelines. Lake populations spawn on cobble/boulder shoals. Spawning occurs in spring when water temperatures range from 5.6 - 11.1°C. Walleye fry remain close to the substrate for about 10 days after hatching. They enter the water column to feed on zooplankton until they reach 1.5 to 2.5 cm in length (about six weeks), at which point they begin feeding on fish. Overwintering habitat is similar to summer feeding habitat except that in winter, walleye will avoid strong currents (Scott and Crossman 1973).

Preferred water temperatures are 10 to 18°C in spring and fall and 20 to 24° C in summer (McMahon et al. 1984). Juvenile walleye have a temperature tolerance range of between 15-34°C with 22-28°C providing optimal growth (Ford *et al.* 1995). Adult walleye have a temperature tolerance range of between 0 to 29-34°C, with 20-24°C providing optimal growth (Ford *et al.* 1995). The preferred oxygen concentrations for juvenile and adult walleye is > 5 and > 3 mg/L, respectively. Concentrations below 3 mg/L are likely to physiological impairments and mortality (Ford *et al.* 1995).

VI-1.7 Goldeye

Goldeye are surface feeding fish that occupy warm turbid lakes and rivers. They are opportunistic and survive on a wide variety of food types including invertebrates (terrestrial and aquatic), fish, mammals and fish eggs. Spawning occurs during May and June in firm bottomed pools and backwaters of turbid rivers when water temperatures range from 10-13°C. Since goldeye spawn in turbid water, spawning activity is difficult to observe (Scott and Crossman 1973). In contrast to other freshwater fishes in North America, goldeye eggs are semi-buoyant. Young fry float near the surface and drift downstream.

APPENDIX VII

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

VII-1 THE USE OF AQUATIC TOXICITY TESTS AS THE BASIS FOR IMPACT PREDICTIONS

VII-1.1 Approach

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

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

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

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

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

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

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

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

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

VII-1.2 Aquatic Toxicity Tests

Aquatic toxicity tests are used to detect and evaluate the potential toxicological effects of chemicals on aquatic organisms. Since these effects are not necessarily harmful, a principal function of these tests is to identify chemicals or whole effluents that can have adverse effects at relatively low exposure concentrations. These tests provide a database that can be used to assess the risk associated with a situation in which the chemical agent, the organism and the exposure conditions are defined (Rand 1995). In the case of the Project, the "chemical agents" are reclamation waters; the "organisms" are the KIR fish species; and, the "exposure conditions" are defined by the water quality modelling.

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

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

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

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

VII-1.3 Representative Reclamation Waters

Suncor's reclamation waters were selected to represent reclamation waters associated with the Project. Assumptions specific to the selection of representative reclamation waters include the following:

- results of tests on CT water produced by Suncor are applicable to future CT water produced by the Project;
- tests on Tar Island Dyke (TID) seepage water from Suncor are applicable to future sand seepage water and tailings water produced by the Project; and
- CT water and TID water tests are sufficient to predict overall potential to cause effects in the receiving environment despite the fact that the actual cause of CT or TID toxicity is not yet thoroughly characterized.

VII-1.4 Toxicity Testing of Representative Reclamation Waters

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

- two water flea species (crustaceans): *Daphnia magna* and *Ceriodaphnia dubia* (endpoint is survival); and
- two fish species: rainbow trout (*Oncorhynchus mykiss*) and fathead minnow *(Pimephales promelas)* (endpoint is survival).

Chronic toxicity was determined for:

- the freshwater alga *Selenastrum capricornutum* (endpoint is growth);
- the water flea *Ceriodaphnia dubia* (endpoint is reproduction); and

- fathead minnow (endpoint is growth).

The acute toxicity of CT water varied considerably among the four test species (Table VII-1). The order of sensitivity from least to most sensitive species was *Daphnia magna* << fathead minnow < rainbow trout < *Ceriodaphnia*. The two most sensitive test species, rainbow trout and *Ceriodaphnia*, had LC50s of 35 to 37%. The least sensitive test species, *Daphnia magna*, had no mortality at any test concentration, including 100% CT water.

Chronic toxicity of CT water was greatest in *Ceriodaphnia* (Table VII-1). The order of sensitivity from least to most sensitive species was fathead minnow < *Selenastrum* < *Ceriodaphnia*. The concentration of CT required to produce a 50% reduction in reproduction in *Ceriodaphnia* was 20%. The other two species tested were more tolerant. Growth of the alga *Selenastrum* and the fathead minnow was reduced by 50% at CT concentrations of 41% and 36%, respectively.

The acute toxicity of TID water was somewhat lower than that reported for CT water (Table VII-1). The order of species sensitivity from least to most sensitive was *Daphnia magna* < *Ceriodaphnia* < fathead minnow < rainbow trout. The LC50 for the most sensitive species, rainbow trout, was 35%.

The chronic toxicity of TID water was greatest in *Ceriodaphnia* (Table VII-1), with an IC50 of 22%. The alga *Selenastrum* was barely affected. Growth of the fathead minnow was reduced by 50% at 29% CT water concentration. Thus, the order of species sensitivity from least to most sensitive was *Selenastrum* < fathead minnow < *Ceriodaphnia*.

VII-1.5 Use of Toxicity Data in the Impact Assessment

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

The use of the IC25 as the primary measurement of effect rather than NOECs or LOECs is based upon recommendations by Environment Canada (1996). The reasons for this are: (1) the possible values of NOEC and LOEC are limited to whatever concentrations were chosen by the investigator; i.e., they are not statistically-derived point estimates like the IC25; and, (2) the particular concentrations which emerge as LOEC and NOEC are very much governed by the design and power of the experiment (Environment Canada 1996).

Table VII-1 Toxicity of CT Water and TID Water

Test	Endpoint	CT Water[1]		TID Water[2]	
		Range	n	Range	n
72 h Algal Growth Inhibition Test using the freshwater alga *Selenastrum capricornutum*	IC25 (%)	25 - 50	3	42 - 62	4
	IC50 (%)	41 - 78	3	92 - >100	4
	NOEC (%)	25	3	25 - 50	4
	LOEC (%)	50	3	50 - 100	4
48 h *Daphnia magna* Survival Test	LC25 (%)	>100	3	>100	3
	LC50 (%)	>100	3	>100	4
	NOEC (%)	100	3	100	3
	LOEC (%)	>100	3	>100	3
7 day *Ceriodaphnia dubia* Survival Test	LC25 (%)	27 - 95	4	43.8 - 96	4
	LC50 (%)	35- >100	4	66.7 - >100	4
	NOEC (%)	50 - 100	4	50	4
	LOEC (%)	100– >100	4	100	4
7 day *Ceriodaphnia dubia* Reproduction Test	IC25 (%)	13.9 - 62.5	4	16 - 25	4
	IC50 (%)	19.9 - 75	4	22 - 52	4
	NOEC (%)	12.5 - 25	4	12.5 - 25	4
	LOEC (%)	25 - 50	4	25 - 50	4
96 h Rainbow Trout Survival Test	LC25 (%)	31	1	-	-
	LC50 (%)	37 - >100	11	35 - 55	4
	NOEC (%)	25	1	25	3
	LOEC (%)	50	1	50	3
7 day Fathead Minnow Survival Test	LC25 (%)	33 - 62	2	33 - 61	3
	LC50 (%)	41 - 75	2	64 - 74	3
	NOEC (%)	12.5 - 50	2	50	3
	LOEC (%)	25 - 100	2	100	3
7 day Fathead Minnow Growth Test	IC25 (%)	26 - >50	2	9 - 11	3
	IC50 (%)	36 - >50	2	29 - 52	3
	NOEC (%)	25 - 50	2	<6.25	3
	LOEC (%)	50 - >50	2	6.25 - 12.5	3

NOTES:

[1] CT water data were obtained from the following sources:
EVS (1996)
Golder (1997k)
Golder (1996f)
Suncor's 1995 CT studies
Suncor's 1997 CT studies

[2] TID water data were obtained from HydroQual (1996)

The toxicity data were used in predictive water quality modelling and in subsequent impact prediction as described below:

Concentrations Suncor's reclamation waters representing the LC50 and the IC25 to the most sensitive test organisms were used to assign acute and chronic Toxic Units (TUa and TUc, respectively) to CT water and sand seepage water associated with the Project. The resulting TU values were as shown in Table VII-2:

Table VII-2 **Toxic Unit Values Assigned to Reclamation Waters**

Reclamation Water	TUa	TUc
Sand seepage waer	2.3	6.3
CT water	2.7	7.2

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

The regulatory guidelines used in the impact assessment for toxicity in the receiving environment were $TUa \leq 0.3$ and $TUc \leq 1$ (AEP 1996). These guidelines were developed by the USEPA based on a large set of whole effluent toxicity data. The guideline values correspond to the approximate values of the NOEC for acute and chronic endpoints. Hence, predicted TU values below the guidelines indicate the absence of toxicity. In the event of exceedances of the TU guidelines, the magnitude of the exceedance was used as a guide to assess the severity of the predicted effects.

APPENDIX VIII

Design Criteria for Wildlife Corridors

VIII-1 DESIGN CRITERIA FOR WILDLIFE CORRIDORS

Design criteria applicable to ungulates and carnivores (Soule et al. 1991, Harrison 1992) are summarized as follows: (Soule et al. 1991, Harrison 1992):

- a corridor should be designed with the fewest possible physical or psychological barriers to the target species;
- the corridor should be kept as straight as possible (i.e., it should not include cul-de-sacs or doglegs);
- the edge to interior ratio should be kept as low as possible since edges are where most wildlife-human interactions will take place;
- corridors of constant width are best since funnel-shaped corridors are less effective;
- the nature and extent of human disturbance on either side must be considered; (i.e., the more disturbance, the wider the corridor must be);
- a corridor's width should be proportional to its length; (i.e., the longer the corridor the wider it should be);
- the corridor should be designed for the critical functions in the ecology of the target species; (i.e., is it only used for travelling, or is it also used for bedding, feeding thermal cover, etc.?);
- corridor width is not necessarily the most important factor; other factors such as cover and topography are just as important;
- predators are less at risk of mortality during passage through a corridor, so corridors planned solely for predators can be narrower (Harrison 1992);
- human use of the corridor to ensure corridor should be precluded effectiveness;
- corridors must be designed large enough to withstand natural disturbances (Pace 1991);
- although corridors must be designed for individual species, the needs of other species must not be overlooked (Soule 1991); and
- uncertainty can be addressed by allowing for redundant corridors (Beier and Loe 1992, Smith et al. 1996).

While much has been written on appropriate corridor widths for different target species, none of these recommendations has been derived from empirical evidence (Pace 1991). Suggested widths have ranged from 5 m for small mammals (Lapolla and Barrett 1993) to 6.4 km for large mammals (Csuti 1991). Harris and Aitkins (1991) suggested that corridors of 10 to 30 m were adequate for movement of individuals, while movements of species required 30 to 1000 m and movements of species assemblages required 1000+ m. Pace (1991) also recommended a tiered approach to corridor widths, with three levels of increasing corridor width: 15 to 61 m wide riparian corridors; 400 to 1600 m riparian and ridge corridors; and 1600+ m upland corridors. Within the Bow Valley Corridor, the Three Sisters EIA

(UMA 1991) recommended a minimum width of 350 m for primary corridors and 187 m for secondary corridors, based on elk requirements for secure habitat and hiding cover, respectively (Thomas 1979). Golder (1994) recommended a minimum width of 500 m for the multispecies Sulphur Mountain corridor near the Middle Springs development in Banff National Park.

APPENDIX IX

Wildlife Habitat Effectiveness

IX-1 WILDLIFE HABITAT EFFECTIVENESS

The effectivenesss of a habitat can be decreased through visual, auditory and olfactory disturbance even though the physical characteristics of the habitat may remain unchanged. The end result is that, although the habitat is physically suitable, wildlife do not use it due to its proximity to these disturbances. Such habitat alienation refers to loss of habitat effectiveness when wildlife withdraw from sensory disturbances from human activities, presumably into more marginal habitats (e.g., Morgantini and Hudson 1979). Different species, and individuals within each species, react differently to various stimuli. In general, animals best habituate to stimuli that are predictible in space and time. Mobile species, for example, can adapt their behaviour to avoid roads during the day when traffic is heavy, and use the habitat at night when traffic is light.

Further assesment is required to determine displacement distances of species reacting to different stimuli. This assessment will target vision and hearing responses because of the lack of information about wildlife reactions to industrial tastes and smells.

Numerous studies have shown that some wildlife species are displaced from roads due to sensory stimuli (e.g., Ward 1976, Perry and Overly 1976, Rost and Bailey 1979, Morgantini and Hudson 1979, Lyon et al. 1985, McLellan and Shackleton 1988 and 1989, Leptich and Zager 1991, Reed et al. 1996). Literature reviews pertaining to impacts of oil and gas development on wildlife in Alberta include Sopuck et al. (1979), CAPP (1982) and Jalkotzy et al. (1997). The distance animals are displaced can vary by the amount, type and predictability of the disturbance, the local vegetation and topography, the season, the time of day or night and whether the wildlife population is hunted or not. In general, the degree of displacement is proportional to the amount of disturbance and inversely proportional to the line of sight between the disturbance source and the animals. For example, Ward (1976) determined that disturbance is less in forested than in open habitats.

Hunted wildlife species will also avoid roads to a greater degree than unhunted wildlife species. For example, Schultz and Bailey (1978) found that traffic volumes had little effect on elk displacement for unhunted populations in mountain national parks.

Noise can impact wildlife in several ways. First, it can mask sounds that an animal needs to hear. It can make it impossible for a predator to hear prey thus reducing hunting efficiency. For example, great gray owls hunt by listening for prey. Communication between individuals, for example mothers and offspring, might be masked. Sound may also occur out of the human auditory range. Rock doves can hear sounds as low as 1 Hz and bats use sound as high as 30 Mhz for echo location (typical human hearing is 20 to 20,000 Hz).

As discussed under the effects of habitat loss, the behaviour of humans and development of compensating management programs (mitigation) play a central role in managing the effects of sensory disturbances.

APPENDIX X

HUMAN AND WILDLIFE HEALTH

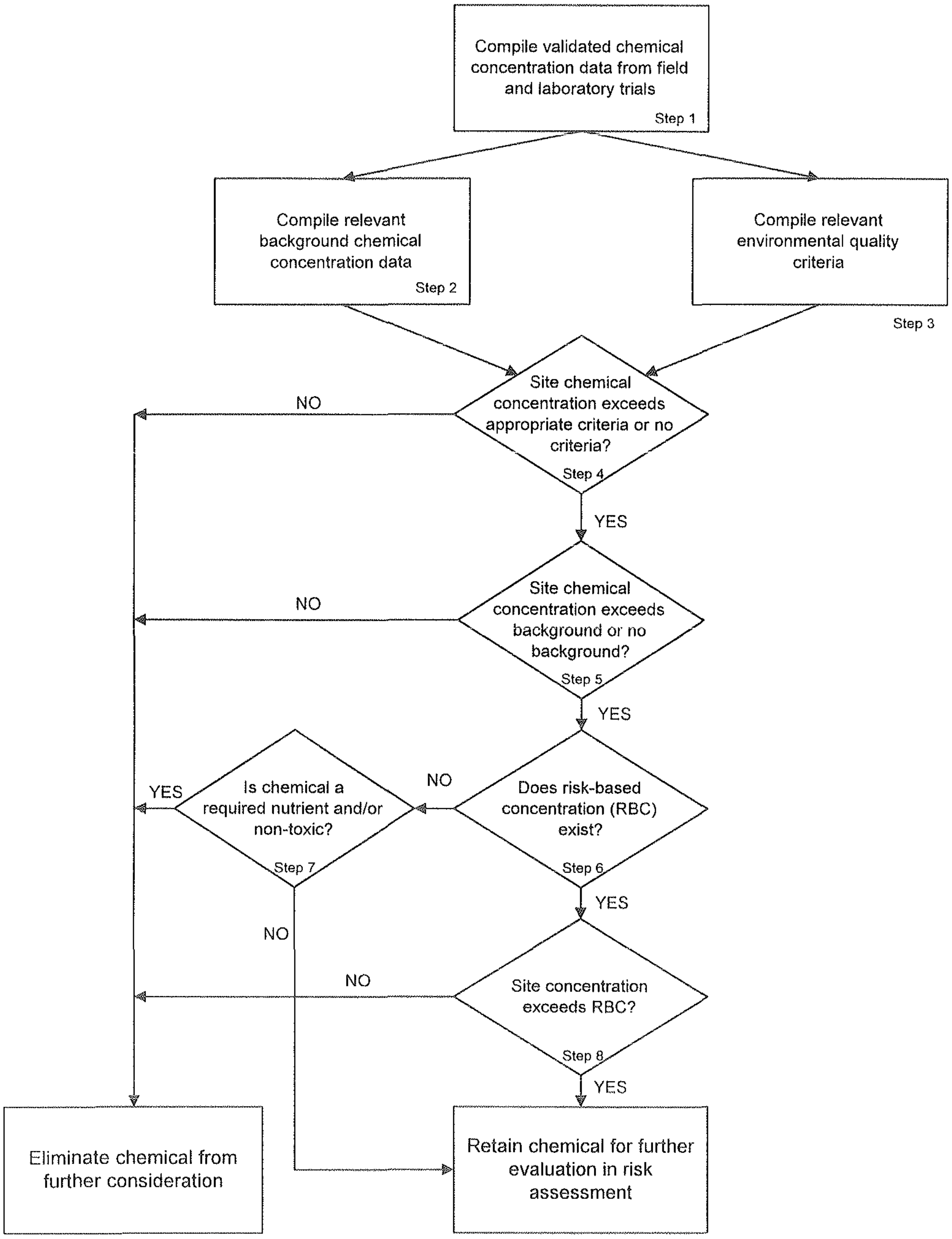
X HUMAN AND WILDLIFE HEALTH APPENDIX

X.1 Chemical Screening

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

The screening process used for both the human and wildlife health risk assessments followed a methodical, step-wise process, as shown schematically in Figure X-1, and outlined in detail below.

Figure X-1 Process for Chemical Screening



X.1.1 GROUPING OF PAHs FOR SCREENING

X.1.1 Grouping of PAHs for Screening

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

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

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

Selection of Surrogate Toxicity Values for Screening Purposes

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

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

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

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

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

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

TABLE X-1 CHEMICAL GROUPINGS AND TOXICITY SURROGATES

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

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

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

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

X.1.2 CHEMICAL SCREENING FOR WILDLIFE HEALTH

X.1.2 Chemical Screening for Wildlife Health

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

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

Site and background data used in chemical screening for wildlife health is listed below under each key question.

W-2: Water-Mediated Exposure (Operation and Closure)

Water - Since operational release waters from Muskeg River Mine Project were not available, water chemistry data from similar oil sands facilities (i.e., Suncor and Syncrude) were used as surrogates for water quality modelling. Predicted concentrations in the Muskeg River were used for chemical screening, since they were more generally more conservative than Athabasca River concentrations. For more details on water quality, refer to Section E5. Maximum predicted concentrations were used for screening purposes.

Background water quality data used in this assessment included water samples that were collected in the Muskeg River from NAQUADAT, Golder and R.L.&L.

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

Background fish tissue data were obtained from laboratory experiments in which walleye and rainbow trout were exposed to Athabasca River water collected upstream of the site (HydroQual 1996). For more details on fish quality, refer to Section E6.

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

W-3: Plant-Mediated Exposure (Operation)

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

Plants - Plant tissue concentrations were predicted for the reclaimed landscape scenario based on measured concentrations in reclamation soils (i.e., overburden, tailings sand and muskeg) and bioconcentration factors for plant uptake. The predicted plant tissue concentrations were used in chemical screening.

W-7: Multi-Media Exposure (Closure)

Terrestrial Plants - Plant tissue concentrations were predicted for the reclaimed landscape scenario based on measured concentrations in reclamation soils (i.e., overburden, tailings sand and muskeg) and bioconcentration factors for plant uptake. The predicted plant tissue concentrations were used in chemical screening.

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

Aquatic Plants - Data from Nix et al. (1994) were used for concentrations in aquatic plants. Nix et al. (1994) studied the uptake of oil sands related inorganic chemicals into cattail and bulrush shoots growing in a constructed wetland. In that study, metal residue concentrations were reported for aquatic plants from two types of constructed wetlands including: (1) experimental control (i.e., surface runoff from a nearby lake), (2) seepage water from tailings ponds dykes. Reference data were also collected from a reference drainage ditch. Residue data from aquatic plants found in the seepage water were used as a basis for chemical screening for wildlife species (e.g., moose, mallard, beaver) that may consume aquatic plants as part of their diet. Residue data from the experimental control, natural wetlands and a reference drainage ditch were used as background data. The maximum residue concentrations were used for screening.

Step 3: Compile Relevant Environmental Criteria and Select SLC

Water - Drinking water criteria included:

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

The lowest available value of the two criteria was chosen as the SLC for drinking water (Table X-2).

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

Steps 4 and 5: Comparison of Maximum Observed Concentration to SLC and Background Concentrations

Maximum observed concentrations were first compared to SLC If the concentration of a chemical did not exceed the SLC, then the chemical was eliminated from further consideration. If the chemical concentration exceeded the SLC or if there was no SLC for a chemical, it was then compared to background concentrations. If the concentration of a chemical was less than or equal to background concentrations, it was eliminated from further consideration since these chemical concentrations were assumed to be natural in origin and not Project-related. If the concentration of a chemical exceeded background concentrations, it was carried forward to Step 6.

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

At this stage, risk-based concentrations (RBCs) were identified for all chemicals for which site concentrations exceeded both SLC and background concentrations. Receptor-specific mammalian wildlife

NOAELS were calculated for water, plants and prey, based on estimated No-Observed-Adverse-Effect-Levels (NOAELs) reported for laboratory animals using appropriate dose-scaling techniques as described in Sample et al. (1996). Dose-scaling from laboratory animals to mammalian wildlife receptors is endorsed by Environment Canada and the U.S. EPA. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among birds is 1. Therefore, NOAELs for avian wildlife species are equivalent to NOAELs reported for avian test species. The receptor-specific wildlife NOAELs are presented in Table X-2, along with details of the laboratory studies used to derive these NOAELs.

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

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

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

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

Aluminum

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

Ammonia

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

Chloride

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

Phosphorus

Phosphorus is a natural element that may be removed from igneous and other types of rock by leaching or weathering (CCREM 1987). Environmental concentrations in western Canada range from 0.003 to 3 mg/L for total phosphorus. Given that phosphorus occurs naturally and that concentrations at the site fall within concentrations reported for western Canada, phosphorus was eliminated from further consideration.

Silicon

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

Sulphate

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

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

In this step, the maximum chemical concentrations measured in water, invertebrates, fish and plants were compared to the RBCs. If the maximum concentration of a chemical exceeded the RBC, then the chemical was retained for further evaluation in the risk assesssment. If the RBC was not exceeded, then the chemical was eliminated from further consideration.

Chemical screening tables are presented in Tables X-4 to X-22. The final chemical list for each key question is presented in Table X-23, indicating the media in which elevated chemical concentrations were identified. For key questions W-4 and W-7, all chemicals that were identified in one or more media were evaluated in all media. This was done to determine the combined exposure to these chemicals from all potentially affected media (i.e., water, invertebrates, fish and plants) during operation (W-4) and following closure (W-7). Detailed screening tables for each media are presented at the end of this section.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Water Shrew							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	0.013	21.6	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	0.013	21.6	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	0.013	123.3	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	0.013	12.3	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	0.013	1.23	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	0.013	123.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	0.013	61.6	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	0.013	9.2	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	0.013	15.4	U.S. EPA 1989c.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes	0.03	0.013	15.4	U.S. EPA 1988
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	0.013	16.4	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	0.013	4.93	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	0.013	9.2	U.S. EPA 1989d.
Acridine	laboratory mice	100	reproduction	0.03	0.013	123.3	Based on anthracene.
Quinoline	laboratory rat	1	increased liver weight	0.35	0.013	2.28	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	0.013	34.2	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	0.013	22.1	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	0.013	32.0	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	0.013	2.54	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	0.013	6.2	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	0.013	640.3	Based on o-cresol.
Aluminum	laboratory mice	1.93	reproduction	0.03	0.013	2.4	Ondreicka et al. 1966
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	0.013	0.154	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	0.013	0.155	Schroeder et al. 1971
Barium	laboratory rat	5.1	growth, hypertension	0.435	0.013	12.2	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	0.013	1.5	Schroeder and Mitchner 1975
Boron	laboratory rat	28.0	reproduction	0.35	0.013	63.8	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	0.013	2.2	Sutou et al. 1980b
Cobalt	cattle	0.24	maximum tolerable level	318	0.013	3.0	NAS 1980.
Copper	mink	11.7	reproduction	1	0.013	34.6	Aulerich et al. 1982
Chromium (III)	laboratory rat	2737.0	reproduction; longevity	0.35	0.013	6234.6	Ivankovic and Preussmann 1975
Cyanide	laboratory rat	6.9	reproduction	1	0.013	20.3	Tewe and Maner 1981
Lead	laboratory rat	8.0	reproduction	0.35	0.013	18.2	Azar et al. 1973
Lithium	laboratory rat	9.4	reproduction	0.35	0.013	21.4	Marathe and Thomas 1986
Manganese	laboratory rat	88	reproduction	0.35	0.013	200.5	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	0.013	3.0	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	0.013	0.32	Schroeder and Mitchener 1971
Nickel	laboratory rat	40.00	reproduction	0.35	0.013	91.12	Ambrose et al. 1976
Selenium	laboratory rat	0.20	reproduction	0.35	0.013	0.46	Rosenfeld and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	0.013	599.1	Skornya 1981.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Tin	laboratory rat	0.6	kidney and liver effects	0.35	0.013	1.4	NTP 1982.
Uranium	laboratory mice	3.1	reproduction	0.028	0.013	3.72	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	0.013	0.44	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	0.013	364.46	Schlicker and Cox 1968
Zirconium	laboratory mice	1.7	lifespan; longevity	0.03	0.013	2.14	Schroeder et al. 1968.
River Otter							
Acenaphthylene	laboratory mice	17.5	hepatoxicity	0.03	7.698	4.4	U.S. EPA 1989a.
Acenaphthene	laboratory mice	17.5	hepatoxicity	0.03	7.698	4.4	U.S. EPA 1989a.
Anthracene	laboratory mice	100	reproduction	0.03	7.698	25.0	U.S. EPA 1989a.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	7.698	2.5	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	7.698	0.25	Mackenzie and Angevine 1981.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	7.698	25.0	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.03	7.698	12.5	Ambrose et al. 1960.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	7.698	1.9	Based on pyrene.
Fluorene	laboratory mice	12.5	hematological effects	0.03	7.698	3.1	U.S. EPA 1989c.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes	0.03	7.698	3.1	U.S. EPA 1988
Naphthalene	laboratory mice	13	mortality, body & organ weights	0.03	7.698	3.3	Shopp et al. 1984.
Phenanthrene	laboratory mice	4.0	mortality, clinical signs	0.03	7.698	1.0	Buening et al. 1979.
Pyrene	laboratory mice	7.5	kidney effects	0.03	7.698	1.9	U.S. EPA 1989d.
Acridine	laboratory mice	100	reproduction	0.03	7.698	25.0	Based on anthracene.
Quinoline	laboratory rat	1.0	increased liver weight	0.35	7.698	0.46	U.S. EPA 1986. Based on pyridine.
Chloroform	laboratory rat	15	liver, kidney, gonads	0.35	7.698	6.9	Palmer et al. 1979.
Ethylbenzene	laboratory rat	9.7	liver and kidney toxicity	0.35	7.698	4.5	Wolf et al. 1956.
Toluene	laboratory mice	26	reproduction	0.03	7.698	6.5	Nawrot and Staples 1979.
Xylene	laboratory mice	2.1	reproduction	0.03	7.698	0.51	Marks et al. 1982.
2,4-Dimethylphenol	laboratory mice	5.0	clinical signs and blood changes	0.03	7.698	1.2	U.S. EPA 1989c.
m-cresol	mink	216	reproduction	1	7.698	129.8	Based on o-cresol.
Aluminum	laboratory mice	1.93	reproduction	0.03	7.698	0.5	Ondreicka et al. 1966
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	7.698	0.031	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	7.698	0.031	Schroeder et al. 1971
Barium	laboratory rat	5.1	growth, hypertension	0.435	7.698	2.5	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	7.698	0.3	Schroeder and Mitchner 1975
Boron	laboratory rat	28.0	reproduction	0.35	7.698	12.9	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	7.698	0.4	Sutou et al. 1980b
Copper	mink	11.7	reproduction	1	7.698	7.0	Aulerich et al. 1982.
Cyanide	laboratory rat	6.9	reproduction	1	7.698	4.1	Tewe and Maner 1981
Lead	laboratory rat	8.0	reproduction	0.35	7.698	3.7	Azar et al. 1973
Lithium	laboratory rat	9.4	reproduction	0.35	7.698	4.3	Marathe and Thomas 1986
Manganese	laboratory rat	88	reproduction	0.35	7.698	40.6	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	7.698	0.6	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	7.698	0.06	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	7.698	18.5	Ambrose et al. 1976.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Selenium	laboratory rat	0.2	reproduction	0.35	7.698	0.1	Rosenfeld and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	7.698	121.4	Skornya 1981.
Tin	laboratory rat	0.60	kidney and liver effects	0.35	7.698	0.3	NTP 1982
Uranium	laboratory mouse	3.1	reproduction	0.028	7.698	0.75	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	7.698	0.09	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	7.698	73.9	Schlicker and Cox 1968.
Zirconium	laboratory mouse	1.7	lifespan; longevity	0.03	7.698	0.43	Schroeder et al. 1968.
Killdeer							
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	22.6	Peakall et al. 1982.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0989	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	0.0989	0.011	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	0.0989	1.1	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	0.0989	22.6	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	0.0989	22.6	Based on anthracene.
Aluminum	ringed dove	109.7	reproduction	0.155	0.0989	109.7	Carriere et al. 1986
Arsenic	mallard ducks	5.1	mortality	1	0.0989	5.1	USFWS 1964
Barium	day-old chicks	21	mortality	0.121	0.0989	21	Johnson et al. 1960.
Cadmium	mallard	1.45	reproduction	1.153	0.0989	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.0989	1	Haseltine et al. 1985.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.0989	0.7	NAS 1980.
Copper	day-old chicks	47	growth, mortality	0.534	0.0989	47	Mehring et al. 1960
Manganese	Japanese quail	977	growth, behaviour	0.072	0.0989	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.0989	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.0989	3.5	Lepore and Miller 1965
Nickel	mallard	77.4	mortality, growth, behaviour	0.782	0.0989	77.4	Cain and Pafford 1981
Selenium	mallard	0.5	reproduction	1	0.0989	0.5	Heinz et al. 1987
Uranium	black duck	16	mortality, body weight, liver/kidney effects	1.25	0.0989	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.4	mortality, body weight	1.17	0.0989	11.4	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.0989	14.5	Stahl et al. 1990
Great Blue Heron							
Acenaphthylene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Peakall et al. 1982.
Acenaphthene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Peakall et al. 1982.
Anthracene	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	22.6	Patton and Dieter 1980.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	2.204	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.011	weight gain; osmoregulation	0.4	2.204	0.011	Peakall et al. 1982.
Benzo(ghi)perylene	herring gull	1.1	weight gain; osmoregulation	0.4	2.204	1.1	Based on benzo(a)pyrene and TEFS.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Dibenzothiophene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Based on pyrene.
Fluoranthene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Based on pyrene.
Fluorene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Phenanthrene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Pyrene	mallard	22.6	liver weights, blood flow	1	2.204	22.6	Patton and Dieter 1980.
Acridine	herring gull	22.6	weight gain; osmoregulation	0.4	2.204	22.6	Based on anthracene.
Aluminum	ringed dove	109.7	reproduction	0.155	2.204	109.7	Carriere et al. 1986
Arsenic	mallard	5.1	mortality	1	2.204	5.1	USFWS 1964
Barium	day-old chicks	21	mortality	0.121	2.204	21	Johnson et al. 1960.
Cadmium	mallard	1.45	reproduction	1.153	2.204	1.45	White and Finley 1978.
Copper	day-old chicks	33.2	growth, mortality	0.534	2.204	33.2	Mehring et al. 1960.
Manganese	Japanese quail	977	growth, behaviour	0.072	2.204	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	2.204	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	2.204	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behaviour	0.782	2.204	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	2.204	0.5	Heinz et al. 1987
Uranium	black duck	16	mortality, body weight, liver/kidney effects	1.25	2.204	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.4	mortality, body weight	1.17	2.204	11.4	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	2.204	14.5	Stahl et al. 1990
Deer Mouse							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	0.0187	19.7	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	0.0187	19.7	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	0.0187	112.5	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	0.0187	11.3	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	0.0187	1.1	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	0.0187	11.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	0.0187	104.0	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	0.0187	584.6	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	0.0187	584.6	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	0.0187	0.23	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	0.0187	8.4	Based on pyrene.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	0.0187	5.6	U.S. EPA 1989c.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	0.0187	20.2	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	0.0187	14.1	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	0.0187	14.1	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	0.0187	15.0	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	0.0187	4.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	0.0187	124.8	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	0.0187	8.4	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	0.0187	2.1	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	0.0187	2.3	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	0.0187	2.2	Ondreicka et al. 1966.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	0.0187	0.14	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	0.0187	0.14	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	0.0187	11.1	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	0.0187	1.4	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	0.0187	58.2	Weir and Fisher 1972
Cadmium	laboratory rat	1	reproduction	0.35	0.0187	2.1	Sutou et al. 1980
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	0.0187	6.8	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	0.0187	5692.9	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	0.0187	2.7	NAS 1980.
Copper	mink	11.71	reproduction	1	0.0187	31.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	0.0187	13.4	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	0.0187	16.6	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	0.0187	25.4	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	0.0187	183.0	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	0.0187	2.7	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	0.0187	0.29	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	0.0187	83.2	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	0.0187	0.4	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	0.0187	547.0	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	0.0187	0.016	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	0.0187	3.4	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	0.0187	0.41	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	0.0187	332.8	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	0.0187	2.0	Schroeder et al. 1968.
Snowshoe hare							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	1.505	6.6	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	1.505	6.6	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	1.505	37.6	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	1.505	3.8	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	1.505	0.38	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	1.505	3.8	Based on benzo(a)pyrene and TEFS.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	1.505	37.6	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	1.505	34.7	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	1.505	195.2	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	1.505	195.2	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	1.505	0.08	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	1.505	1.9	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	1.505	2.8	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	1.505	6.7	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	1.505	4.7	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	1.505	4.7	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	1.505	5.0	Shopp et al. 1984.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	1.505	1.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	1.505	41.7	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	1.505	2.8	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	1.505	0.69	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	1.505	0.77	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	1.505	0.73	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	1.505	0.047	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	1.505	0.047	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	1.505	3.7	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	1.505	0.5	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	1.505	19.4	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	1.505	0.7	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	1.505	2.3	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	1.505	1900.7	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	1.505	0.92	NAS 1980.
Copper	mink	11.71	reproduction	1	1.505	10.6	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	1.505	4.5	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	1.505	5.6	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	1.505	8.5	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	1.505	61.1	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	1.505	0.9	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	1.505	0.10	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	1.505	27.8	Ambrose et al. 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	1.505	0.14	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	1.505	182.6	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	1.505	0.005	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	1.505	1.1	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	1.505	0.14	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	1.505	111.1	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	1.505	0.65	Schroeder et al. 1968.
Beaver							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	18.275	3.5	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	18.275	3.5	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	18.275	20.1	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	18.275	2.0	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	18.275	0.20	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	18.275	2.0	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	18.275	18.6	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	18.275	104.6	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	18.275	104.6	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	18.275	0.040	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	18.275	1.0	U.S. EPA 1989c.

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	18.275	1.5	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	18.275	3.6	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	18.275	2.5	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	18.275	2.5	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	18.275	2.7	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	18.275	0.81	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	18.275	22.3	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	18.275	1.5	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	18.275	0.37	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	18.275	0.41	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	18.275	0.39	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	18.275	0.025	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	18.275	0.025	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	18.275	2.0	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	18.275	0.2	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	18.275	10.4	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	18.275	0.4	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	18.275	1.2	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	18.275	1018.2	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	18.275	0.49	NAS 1980.
Copper	mink	11.71	reproduction	1	18.275	5.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	18.275	2.4	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	18.275	3.0	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	18.275	4.5	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	18.275	32.7	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	18.275	0.5	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	18.275	0.05	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	18.275	14.9	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	18.275	0.07	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	18.275	97.8	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	18.275	0.003	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	18.275	0.61	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	18.275	0.07	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	18.275	59.5	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	1.505	0.65	Schroeder et al. 1968.
Moose							
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	381	1.6	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	381	1.6	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	381	9.4	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	381	0.94	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	381	0.09	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	381	0.94	Based on benzo(a)pyrene and TEFS.

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	381	9.4	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	381	8.7	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	381	48.9	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	381	48.9	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	381	0.019	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	381	0.47	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	381	0.71	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	381	1.7	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	381	1.2	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	381	1.2	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	381	1.3	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	381	0.38	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	381	10.4	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	381	0.71	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	381	0.17	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	381	0.19	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	381	0.18	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	381	0.012	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	381	0.012	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	381	0.93	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	381	0.1	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	381	4.9	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	381	0.2	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	381	0.57	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	381	476.5	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	381	0.23	NAS 1980.
Copper	mink	11.71	reproduction	1	381	2.7	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	381	1.1	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	381	1.4	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	381	2.1	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	381	15.3	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	381	0.2	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	381	0.024	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	381	7.0	Ambrose et. al 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	381	0.035	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	381	45.8	Skornya 1981.
Thallium	laboratory rat	0.0074	reproduction	0.365	381	0.001	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	381	0.28	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	381	0.034	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	381	27.9	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	381	0.16	Schroeder et al. 1968.
Black Bear							

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Acenaphthene	laboratory mice	17.5	hepatotoxicity	0.03	130	2.2	U.S. EPA 1989a.
Acenaphthylene	laboratory mice	17.5	hepatotoxicity	0.03	130	2.2	Based on acenaphthene.
Anthracene	laboratory mice	100	mortality, clinical signs, body weights	0.03	130	12.3	U.S. EPA 1989b.
Benzo(a)anthracene	laboratory mice	10	reproduction	0.03	130	1.2	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	laboratory mice	1	reproduction	0.03	130	0.12	Mackenzie and Angevine 1981.
Benzo(b,k)fluoranthene	laboratory mice	10	reproduction	0.03	130	1.2	Based on benzo(a)pyrene and TEFS.
Benzo(ghi)perylene	laboratory mice	100	reproduction	0.03	130	12.3	Based on benzo(a)pyrene and TEFS.
Biphenyl	laboratory rats	50	reproduction	0.35	130	11.4	Ambrose et al. 1960.
m-cresol	mink	216.2	reproduction	1	130	64.0	Based on o-cresol.
o-cresol	mink	216.2	reproduction	1	130	64.0	Hornshaw et al. 1986.
Dibenzo(a,h)anthracene	laboratory mice	0.2	reproduction	0.03	130	0.02	Based on benzo(a)pyrene and TEFS.
2,4-Dimethylphenol	laboratory mice	5	clinical signs and blood changes	0.03	130	0.6	U.S. EPA 1989c.
Dibenzothiophene	laboratory mice	7.5	kidney effects	0.03	130	0.9	Based on pyrene.
Ethylbenzene	laboratory rats	9.71	liver and kidney toxicity	0.35	130	2.2	Wolf et al. 1956.
Fluoranthene	laboratory mice	12.5	nephropathy, liver changes,	0.03	130	1.5	U.S. EPA 1988.
Fluorene	laboratory mice	12.5	hematological effects	0.03	130	1.5	U.S. EPA 1989d.
Naphthalene	laboratory mice	13.3	mortality, body & organ weights	0.03	130	1.6	Shopp et al. 1984.
Phenanthrene	laboratory mice	4	mortality, clinical signs	0.03	130	0.5	Buening et al. 1979.
Phenol	laboratory rats	60	reproduction	0.35	130	13.7	NTP 1983.
Pyrene	laboratory mice	7.5	kidney effects	0.03	130	0.9	U.S. EPA 1989e.
Quinoline	laboratory rat	1	increased liver weight	0.35	130	0.23	U.S. EPA 1986. Based on pyridine.
Xylene	laboratory mice	2.06	reproduction	0.03	130	0.25	Marks et al. 1982.
Aluminum	laboratory mice	1.93	reproduction	0.03	130	0.24	Ondreicka et. al 1966.
Antimony	laboratory mice	0.125	lifespan, longevity	0.03	130	0.015	Schroeder et al. 1968.
Arsenic	laboratory mice	0.126	reproduction	0.03	130	0.016	Schroeder and Mitchener 1971.
Barium	laboratory rat	5.06	growth, hypertension	0.435	130	1.2	Perry et al. 1983.
Beryllium	laboratory rat	0.7	longevity, weight loss	0.35	130	0.2	Schroeder and Mitchner 1975
Boron	laboratory rat	28	reproduction	0.35	130	6.4	Weir and Fisher 1972
Cadmium	laboratory rat	1.0	reproduction	0.303	130	0.2	Sutou et al. 1980b
Chromium (hexavalent)	laboratory rat	3.28	body weight; food consumption	0.35	130	0.7	Mackenzie et al. 1958.
Chromium (trivalent)	laboratory rat	2737	reproduction, longevity	0.35	130	623.5	Ivankovic and Preussmann 1975.
Cobalt	cattle	0.24	maximum tolerable level	318	130	0.30	NAS 1980.
Copper	mink	11.71	reproduction	1	130	3.5	Aulerich et al. 1982.
Cyanide	laboratory rat	6.87	reproduction	0.273	130	1.5	Tewe and Maner 1981.
Lead	laboratory rat	8	reproduction	0.35	130	1.8	Azar et al. 1973.
Lithium	laboratory rat	9.39	reproduction	1	130	2.8	Marathe and Thomas 1986.
Manganese	laboratory rat	88	reproduction	0.35	130	20.0	Laskey et al. 1982.
Mercury (inorganic)	mink	1	reproduction	1	130	0.3	Aulerich et al. 1974
Molybdenum	laboratory mice	0.26	reproduction	0.03	130	0.03	Schroeder and Mitchener 1971
Nickel	laboratory rat	40	reproduction	0.35	130	9.1	Ambrose et al. 1976.
Selenium	laboratory rat	0.2	reproduction	0.35	130	0.05	Rosenfield and Beath 1954
Strontium	laboratory rat	263	body weight and bone changes	0.35	130	59.9	Skornya 1981.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

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Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Thallium	laboratory rat	0.0074	reproduction	0.365	130	0.002	Formigli et al. 1986.
Uranium	laboratory mice	3.07	reproduction	0.028	130	0.4	Paternain et al. 1989.
Vanadium	laboratory rat	0.21	reproduction	0.26	130	0.04	Domingo et al. 1986.
Zinc	laboratory rat	160	reproduction	0.35	130	36.4	Schlicker and Cox 1968.
Zirconium	laboratory mice	1.738	lifespan; longevity	0.03	130	0.21	Schroeder et al. 1968.
American robin							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0836	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	0.0836	0.0112	Peakall et al. 1982.
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	0.0836	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Phenanthrene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	0.0836	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	0.0836	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	0.0836	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	0.0836	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	0.0836	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	0.0836	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	0.0836	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.0836	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.0836	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	0.0836	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	0.0836	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	0.0836	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.0836	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.0836	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	0.0836	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	0.0836	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	0.0836	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	0.0836	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	0.0836	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.0836	14.5	Stahl et al. 1990
Ruffed grouse							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	0.54285	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	0.54285	0.0112	Peakall et al. 1982.
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	0.54285	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Phenanthrene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	0.54285	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	0.54285	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	0.54285	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	0.54285	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	0.54285	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	0.54285	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	0.54285	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	0.54285	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	0.54285	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	0.54285	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	0.54285	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	0.54285	977	Laskey and Edens 1985
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	0.54285	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	0.54285	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	0.54285	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	0.54285	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	0.54285	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	0.54285	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	0.54285	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	0.54285	14.5	Stahl et al. 1990
Mallard							
Acenaphthene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Acenaphthylene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Based on acenaphthene.
Benzo(a)anthracene	herring gull	0.11	weight gain; osmoregulation	0.4	1.107	0.11	Based on benzo(a)pyrene and TEFS.
Benzo(a)pyrene	herring gull	0.0112	weight gain; osmoregulation	0.4	1.107	0.0112	Peakall et al. 1982.
Benzo(b,k)fluoranthene	herring gull	0.11	weight gain; osmoregulation	0.4	1.107	0.11	Based on benzo(a)pyrene and TEFS.
Dibenzothiophene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Based on pyrene
Fluorene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Phenanthrene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Pyrene	mallard	22.55	liver weights, blood flow	1	1.107	22.55	Patton and Dieter 1980.
Aluminum	ringed dove	111.4	reproduction	0.155	1.107	111.4	Carriere et al. 1986.
Arsenic	cowbird	2.46	mortality	0.049	1.107	2.46	USFWS 1969.
Arsenic	mallard	5.135	mortality	1	1.107	5.135	USFWS 1964.
Barium	day-old chicks	20.826	mortality	0.121	1.107	20.826	Johnson et al. 1960.
Boron	mallard	28.8	reproduction	1	1.107	28.8	Smith and Anders, 1989
Cadmium	mallard	1.45	reproduction	1.153	1.107	1.45	White and Finley 1978.
Chromium	black duck	1	reproduction	1.25	1.107	1	Haseltine et al., unpub. data.
Cobalt	chicken	0.7	maximum tolerable level	1.6	1.107	0.7	NAS 1980.
Copper	day-old chicks	33.21	growth	0.534	1.107	33.21	Mehring et al. 1960.
Lead	american kestrel	3.85	reproduction	0.13	1.107	3.85	Pattee 1984.
Manganese	japanese quail	977	growth, behaviour	0.072	1.107	977	Laskey and Edens 1985

TABLE X-2

SUMMARY OF CHRONIC WILDLIFE NOAELS FOR ECOLOGICAL RECEPTORS

Chemicals	Test Species	Test[1] Species NOAEL (mg/kg-BW/day)	Toxicological Endpoint	Test Species Body Weight (kg)	Endpoint[2] Species Body Weight (kg)	Estimated[3] Chronic Wildlife NOAEL (mg/kg-BW/day)	References
Mercury (inorganic)	Japanese quail	0.45	reproduction	0.15	1.107	0.45	Hill and Schaffner 1976
Molybdenum	chicken	3.5	reproduction	1.5	1.107	3.5	Lepore and Miller 1965
Nickel	mallard duckling	77.4	mortality, growth, behavior	0.782	1.107	77.4	Cain and Pafford 1981.
Selenium	mallard	0.5	reproduction	1	1.107	0.5	Heinz et al. 1987.
Selenium	mallard	0.4	reproduction	1	1.107	0.4	Heinz et al. 1989.
Uranium	black duck	16	mortality, body weight	1.25	1.107	16	Haseltine and Sileo 1983.
Vanadium	mallard	11.38	mortality, body weight	1.17	1.107	11.38	White and Dieter 1978.
Zinc	chicken	14.5	reproduction	1.935	1.107	14.5	Stahl et al. 1990

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

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

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

[4] For avian species, estimated wildlife NOAEL = test NOAEL. Based on method by Sample et al. (1996).

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Water Shrew								
Acenaphthylene	21.6	0.013	-	0.01235	0.001987	-	2.3	14.1
Acenaphthene	21.6	0.013	-	0.01235	0.001987	-	2.3	14.1
Anthracene	123.3	0.013	-	0.01235	0.001987	-	13.0	80.7
Benzo(a)anthracene	12.3	0.013	-	0.01235	0.001987	-	1.3	8.0
Benzo(a)pyrene	1.23	0.013	-	0.01235	0.001987	-	0.1	0.8
Benzo(ghi)perylene	123.3	0.013	-	0.01235	0.001987	-	13.0	80.7
Biphenyl	61.6	0.013	-	0.01235	0.001987	-	6.5	40.3
Dibenzothiophene	9.24	0.013	-	0.01235	0.001987	-	1.0	6.0
Fluorene	15.41	0.013	-	0.01235	0.001987	-	1.6	10.1
Fluoranthene	15.41	0.013	-	0.01235	0.001987	-	1.6	10.1
Naphthalene	16.39	0.013	-	0.01235	0.001987	-	1.7	10.7
Phenanthrene	4.93	0.013	-	0.01235	0.001987	-	0.5	3.2
Pyrene	9.24	0.013	-	0.01235	0.001987	-	1.0	6.0
Acridine	123.25	0.013	-	0.01235	0.001987	-	13.0	80.6
Quinoline	2.28	0.013	-	0.01235	0.001987	-	0.2	1.5
Chloroform	34.17	0.013	-	0.01235	0.001987	-	3.6	22.4
Ethylbenzene	22.12	0.013	-	0.01235	0.001987	-	2.3	14.5
Toluene	32.02	0.013	-	0.01235	0.001987	-	3.4	20.9
Xylenes	2.54	0.013	-	0.01235	0.001987	-	0.3	1.7
2,4-Dimethylphenol	6.16	0.013	-	0.01235	0.001987	-	0.6	4.0
m-cresol	640.28	0.013	-	0.01235	0.001987	-	67.4	418.9
Aluminum	2.4	0.013	-	0.01235	0.001987	-	0.3	1.6
Antimony	0.15	0.013	-	0.01235	0.001987	-	0.0	0.1
Arsenic	0.155	0.013	-	0.01235	0.001987	-	0.0	0.1
Barium	12.17	0.013	-	0.01235	0.001987	-	1.3	8.0
Beryllium	1.5	0.013	-	0.01235	0.001987	-	0.2	1.0
Boron	63.8	0.013	-	0.01235	0.001987	-	6.7	41.7
Cadmium	2.2	0.013	-	0.01235	0.001987	-	0.2	1.4
Chromium (III)	6234.6	0.013	-	0.01235	0.001987	-	656.3	4079.0
Cobalt	3	0.013	-	0.01235	0.001987	-	0.3	2.0
Copper	34.6	0.013	-	0.01235	0.001987	-	3.6	22.6
Cyanide	20.3	0.013	-	0.01235	0.001987	-	2.1	13.3
Lead	18.2	0.013	-	0.01235	0.001987	-	1.9	11.9
Lithium	21.4	0.013	-	0.01235	0.001987	-	2.3	14.0

TABLE X-3

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

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Manganese	200.45	0.013	-	0.01235	0.001987	-	21.1	131.1
Mercury (inorganic)	3	0.013	-	0.01235	0.001987	-	0.3	2.0
Molybdenum	0.32	0.013	-	0.01235	0.001987	-	0.03	0.2
Nickel	91.12	0.013		0.01235	0.001987	-	9.6	59.6
Selenium	0.46	0.013	-	0.01235	0.001987	-	0.0	0.3
Strontium	599.08	0.013	-	0.01235	0.001987	-	63.1	392.0
Tin	1.37	0.013	-	0.01235	0.001987	-	0.1	0.9
Uranium	3.72	0.013	-	0.01235	0.001987	-	0.4	2.4
Vanadium	0.44	0.013	-	0.01235	0.001987	-	0.05	0.3
Zinc	364.46	0.013		0.01235	0.001987	-	38.4	238.4
Zirconium	2.14	0.013	-	0.01235	0.001987	-	0.2	1.4
River Otter								
Acenaphthylene	4.37	7.698	-	0.3678	0.6214	-	9.2	5.4
Acenaphthene	4.37	7.698	-	0.3678	0.6214	-	9.2	5.4
Anthracene	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Benzo(a)anthracene	2.50	7.698	-	0.3678	0.6214	-	5.2	3.1
Benzo(a)pyrene	0.25	7.698	-	0.3678	0.6214	-	0.5	0.3
Benzo(ghi)perylene	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Biphenyl	12.49	7.698	-	0.3678	0.6214	-	26.1	15.5
Dibenzothiophene	1.87	7.698	-	0.3678	0.6214	-	3.9	2.3
Fluorene	3.12	7.698	-	0.3678	0.6214	-	6.5	3.9
Fluoranthene	3.12	7.698	-	0.3678	0.6214	-	6.5	3.9
Naphthalene	3.32	7.698	-	0.3678	0.6214	-	7.0	4.1
Phenanthrene	1.00	7.698	-	0.3678	0.6214	-	2.1	1.2
Pyrene	1.87	7.698	-	0.3678	0.6214	-	3.9	2.3
Acridine	24.99	7.698	-	0.3678	0.6214	-	52.3	31.0
Quinoline	0.46	7.698	-	0.3678	0.6214	-	1.0	0.6
Chloroform	6.93	7.698	-	0.3678	0.6214	-	14.5	8.6
Ethylbenzene	4.48	7.698	-	0.3678	0.6214	-	9.4	5.6
Toluene	6.49	7.698	-	0.3678	0.6214	-	13.6	8.0
Xylenes	0.51	7.698	-	0.3678	0.6214	-	1.1	0.6
2,4-Dimethylphenol	1.25	7.698	-	0.3678	0.6214	-	2.6	1.5
m-cresol	129.80	7.698	-	0.3678	0.6214	-	271.7	160.8
Aluminum	0.50	7.698	-	0.3678	0.6214	-	1.0	0.6
Antimony	0.03	7.698	-	0.3678	0.6214	-	0.1	0.04

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Arsenic	0.03	7.698	-	0.3678	0.6214	-	0.1	0.04
Barium	2.47	7.698	-	0.3678	0.6214	-	5.2	3.1
Beryllium	0.3	7.698	-	0.3678	0.6214	-	0.6	0.4
Boron	12.9	7.698	-	0.3678	0.6214	-	27.0	16.0
Cadmium	0.4	7.698	-	0.3678	0.6214	-	0.8	0.5
Copper	7.03	7.698	-	0.3678	0.6214	-	14.7	8.7
Cyanide	4.1	7.698	-	0.3678	0.6214	-	8.6	5.1
Lead	3.7	7.698	-	0.3678	0.6214	-	7.7	4.6
Lithium	4.34	7.698	-	0.3678	0.6214	-	9.1	5.4
Manganese	40.64	7.698	-	0.3678	0.6214	-	85.0	50.3
Mercury (inorganic)	0.60	7.698	-	0.3678	0.6214	-	1.3	0.7
Molybdenum	0.06	7.698	-	0.3678	0.6214	-	0.1	0.1
Nickel	18.47	7.698	-	0.3678	0.6214	-	38.7	22.9
Selenium	0.09	7.698	-	0.3678	0.6214	-	0.2	0.1
Strontium	121.44	7.698	-	0.3678	0.6214	-	254.2	150.4
Tin	0.28	7.698	-	0.3678	0.6214	-	0.6	0.3
Uranium	0.75	7.698	-	0.3678	0.6214	-	1.6	0.9
Vanadium	0.09	7.698	-	0.3678	0.6214	-	0.2	0.1
Zinc	73.88	7.698	-	0.3678	0.6214	-	154.6	91.5
Zirconium	0.43	7.698	-	0.3678	0.6214	-	0.9	0.5
Killdeer								
Acenaphthylene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Acenaphthene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Benzo(a)anthracene	0.11	0.0989	-	0.0154	0.02179	-	0.1	0.05
Benzo(a)pyrene	0.011	0.0989	-	0.0154	0.02179	-	0.01	0.005
Benzo(ghi)perylene	1.1	0.0989	-	0.0154	0.02179	-	0.71	0.50
Dibenzothiophene	22.6	0.0989	-	0.0154	0.02179	-	14.5	10.3
Fluoranthene	22.6	0.0989	-	0.0154	0.02179	-	14.5	10.3
Fluorene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Phenanthrene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Pyrene	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Acridine	22.55	0.0989	-	0.0154	0.02179	-	14.5	10.2
Aluminum	109.7	0.0989	-	0.0154	0.02179	-	70.5	49.8
Arsenic	5.1	0.0989	-	0.0154	0.02179	-	3.3	2.3
Barium	21	0.0989	-	0.0154	0.02179	-	13.5	9.5

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Cadmium	1.45	0.0989	-	0.0154	0.02179	-	0.9	0.7
Chromium	1	0.0989	-	0.0154	0.02179	-	0.6	0.5
Cobalt	0.7	0.0989	-	0.0154	0.02179	-	0.4	0.3
Copper	47	0.0989	-	0.0154	0.02179	-	30.2	21.3
Lead	3.85	0.0989	-	0.0154	0.02179	-	2.5	1.7
Manganese	977	0.0989	-	0.0154	0.02179	-	627.4	443.4
Mercury (inorganic)	0.45	0.0989	-	0.0154	0.02179	-	0.3	0.2
Molybdenum	3.5	0.0989	-	0.0154	0.02179	-	2.2	1.6
Nickel	77.4	0.0989	-	0.0154	0.02179	-	49.7	35.1
Selenium	0.5	0.0989	-	0.0154	0.02179	-	0.3	0.2
Uranium	16	0.0989	-	0.0154	0.02179	-	10.3	7.3
Vanadium	11.4	0.0989	-	0.0154	0.02179	-	7.3	5.2
Zinc	14.5	0.0989	-	0.0154	0.02179	-	9.3	6.6
Great Blue Heron								
Acenaphthylene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Acenaphthene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Benzo(a)anthracene	0.11	2.204	-	0.09757	0.2223	-	0.2	0.1
Benzo(a)pyrene	0.011	2.204	-	0.09757	0.2223	-	0.0	0.0
Benzo(ghi)perylene	1.1	2.204	-	0.09757	0.2223	-	2.48	1.09
Dibenzothiophene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Fluoranthene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Fluorene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Phenanthrene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Pyrene	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Acridine	22.55	2.204	-	0.09757	0.2223	-	50.9	22.4
Aluminum	109.7	2.204	-	0.09757	0.2223	-	247.8	108.8
Arsenic	5.1	2.204	-	0.09757	0.2223	-	11.5	5.1
Barium	21	2.204	-	0.09757	0.2223	-	47.4	20.8
Cadmium	1.4	2.204	-	0.09757	0.2223	-	3.2	1.4
Copper	47	2.204	-	0.09757	0.2223	-	106.2	46.6
Lead	3.85	2.204	-	0.09757	0.2223	-	8.7	3.8
Manganese	977	2.204	-	0.09757	0.2223	-	2206.9	968.6
Molybdenum	3.5	2.204	-	0.09757	0.2223	-	7.9	3.5
Mercury (inorganic)	0.45	2.204	-	0.09757	0.2223	-	1.0	0.4
Nickel	77.4	2.204	-	0.09757	0.2223	-	174.8	76.7

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

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Selenium	0.5	2.204	-	0.09757	0.2223	-	1.1	0.5
Uranium	16	2.204	-	0.09757	0.2223	-	36.1	15.9
Vanadium	11.4	2.204	-	0.09757	0.2223	-	25.8	11.3
Zinc	14.5	2.204	-	0.09757	0.2223	-	32.8	14.4
Deer Mouse								
Acenaphthene	19.7	0.0187	0.00188	0.00136	0.00276	19.6	27.1	13.3
Acenaphthylene	19.7	0.0187	0.00188	0.00136	0.00276	19.6	27.1	13.3
Anthracene	112.5	0.0187	0.00188	0.00136	0.00276	111.9	154.7	76.2
Benzo(a)anthracene	11.3	0.0187	0.00188	0.00136	0.00276	11.2	15.5	7.7
Benzo(a)pyrene	1.1	0.0187	0.00188	0.00136	0.00276	1.1	1.5	0.7
Benzo(b,k)fluoranthene	11.3	0.0187	0.00188	0.00136	0.00276	11.2	15.5	7.7
Biphenyl	104	0.0187	0.00188	0.00136	0.00276	103.4	143.0	70.5
m-cresol	584.6	0.0187	0.00188	0.00136	0.00276	581.5	803.8	396.1
o-cresol	584.6	0.0187	0.00188	0.00136	0.00276	581.5	803.8	396.1
Dibenzo(a,h)anthracene	0.23	0.0187	0.00188	0.00136	0.00276	0.2	0.3	0.2
Dibenzothiophene	8.4	0.0187	0.00188	0.00136	0.00276	8.4	11.6	5.7
2,4-Dimethylphenol	5.6	0.0187	0.00188	0.00136	0.00276	5.6	7.7	3.8
Ethylbenzene	20.2	0.0187	0.00188	0.00136	0.00276	20.1	27.8	13.7
Fluoranthene	14.1	0.0187	0.00188	0.00136	0.00276	14.0	19.4	9.6
Fluorene	14.1	0.0187	0.00188	0.00136	0.00276	14.0	19.4	9.6
Naphthalene	15	0.0187	0.00188	0.00136	0.00276	14.9	20.6	10.2
Phenanthrene	4.5	0.0187	0.00188	0.00136	0.00276	4.5	6.2	3.0
Phenol	124.8	0.0187	0.00188	0.00136	0.00276	124.1	171.6	84.6
Pyrene	8.4	0.0187	0.00188	0.00136	0.00276	8.4	11.6	5.7
Quinoline	2.1	0.0187	0.00188	0.00136	0.00276	2.1	2.9	1.4
Xylene	2.3	0.0187	0.00188	0.00136	0.00276	2.3	3.2	1.6
Aluminum	2.2	0.0187	0.00188	0.00136	0.00276	2.2	3.0	1.5
Antimony	0.14	0.0187	0.00188	0.00136	0.00276	0.1	0.2	0.1
Arsenic	0.14	0.0187	0.00188	0.00136	0.00276	0.1	0.2	0.1
Barium	11.1	0.0187	0.00188	0.00136	0.00276	11.0	15.3	7.5
Beryllium	1.4	0.0187	0.00188	0.00136	0.00276	1.4	1.9	0.9
Boron	58.2	0.0187	0.00188	0.00136	0.00276	57.9	80.0	39.4
Cadmium	2.1	0.0187	0.00188	0.00136	0.00276	2.1	2.9	1.4
Chromium (hexavalent)	6.8	0.0187	0.00188	0.00136	0.00276	6.8	9.4	4.6
Chromium (trivalent)	5692.9	0.0187	0.00188	0.00136	0.00276	5662.6	7827.7	3857.1

TABLE X-3

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

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Chemicals	Estimated^{1} Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint^{2} Species Body Weight (kg)	Plant^{2} Ingestion Rate (kg/day)	Prey^{2} Ingestion Rate (kg/day)	Water^{2} Ingestion Rate (L/day)	Risk-Based^{3} Concentration (mg/kg plant)	Risk-Based^{3} Concentration (mg/kg prey)	Risk-Based^{3} Concentration (mg/L water)
Cobalt	2.7	0.0187	0.00188	0.00136	0.00276	2.7	3.7	1.8
Copper	31.7	0.0187	0.00188	0.00136	0.00276	31.5	43.6	21.5
Cyanide	13.4	0.0187	0.00188	0.00136	0.00276	13.3	18.4	9.1
Lead	16.6	0.0187	0.00188	0.00136	0.00276	16.5	22.8	11.2
Lithium	25.4	0.0187	0.00188	0.00136	0.00276	25.3	34.9	17.2
Manganese	183	0.0187	0.00188	0.00136	0.00276	182.0	251.6	124.0
Mercury	2.7	0.0187	0.7236	0.00136	0.00276	0.0070	3.7	1.83
Molybdenum	0.29	0.0187	0.7236	0.00136	0.00276	0.001	0.4	0.2
Nickel	83.2	0.0187	0.7236	0.00136	0.00276	0.2	114.4	56.4
Selenium	0.4	0.0187	0.7236	0.00136	0.00276	0.001	0.6	0.3
Strontium	547	0.0187	0.7236	0.00136	0.00276	1.4	752.1	370.6
Thallium	0.016	0.0187	0.7236	0.00136	0.00276	0.00004	0.0	0.01
Uranium	3.4	0.0187	0.7236	0.00136	0.00276	0.009	4.7	2.3
Vanadium	0.41	0.0187	0.7236	0.00136	0.00276	0.001	0.6	0.3
Zinc	332.8	0.0187	0.7236	0.00136	0.00276	0.9	457.6	225.5
Zirconium	2	0.0187	0.7236	0.00136	0.00276	0.01	2.8	1.4
Snowshoe hare								
Acenaphthene	6.6	1.505	0.1178	-	0.143	8.4	-	6.9
Acenaphthylene	6.6	1.505	0.1178	-	0.143	8.4	-	6.9
Anthracene	37.6	1.505	0.1178	-	0.143	48.0	-	39.6
Benzo(a)anthracene	3.8	1.505	0.1178	-	0.143	4.9	-	4.0
Benzo(a)pyrene	0.38	1.505	0.1178	-	0.143	0.5	-	0.4
Benzo(b,k)fluoranthene	3.8	1.505	0.1178	-	0.143	4.9	-	4.0
Benzo(ghi)perylene	37.6	1.505	0.1178	-	0.143	48.0	-	39.6
Biphenyl	34.7	1.505	0.1178	-	0.143	44.3	-	36.5
m-cresol	195.2	1.505	0.1178	-	0.143	249.4	-	205.4
n-cresol	195.2	1.505	0.1178	-	0.143	249.4	-	205.4
Dibenzo(a,h)anthracene	0.08	1.505	0.1178	-	0.143	0.1	-	0.1
Dibenzothiophene	2.8	1.505	0.1178	-	0.143	3.6	-	2.9
2,4-Dimethylphenol	1.9	1.505	0.1178	-	0.143	2.4	-	2.0
Ethylbenzene	6.7	1.505	0.1178	-	0.143	8.6	-	7.1
Fluoranthene	4.7	1.505	0.1178	-	0.143	6.0	-	4.9
Fluorene	4.7	1.505	0.1178	-	0.143	6.0	-	4.9
Naphthalene	5	1.505	0.1178	-	0.143	6.4	-	5.3
Phenanthrene	1.5	1.505	0.1178	-	0.143	1.9	-	1.6

TABLE X-3

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

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Phenol	41.7	1.505	0.1178	-	0.143	53.3	-	43.9
Pyrene	2.8	1.505	0.1178	-	0.143	3.6	-	2.9
Quinoline	0.69	1.505	0.1178	-	0.143	0.9	-	0.7
Xylene	0.77	1.505	0.1178	-	0.143	1.0	-	0.8
Aluminum	0.73	1.505	0.1178	-	0.143	0.9	-	0.8
Antimony	0.047	1.505	0.1178	-	0.143	0.1	-	0.05
Arsenic	0.047	1.505	0.1178	-	0.143	0.1	-	0.05
Barium	3.7	1.505	0.1178	-	0.143	4.7	-	3.9
Beryllium	0.5	1.505	0.1178	-	0.143	0.6	-	0.5
Boron	19.4	1.505	0.1178	-	0.143	24.8	-	20.4
Cadmium	0.7	1.505	0.1178	-	0.143	0.9	-	0.7
Chromium (hexavalent)	2.3	1.505	0.1178	-	0.143	2.9	-	2.4
Chromium (trivalent)	1900	1.505	0.1178	-	0.143	2427.4	-	1999.7
Cobalt	0.92	1.505	0.1178	-	0.143	1.2	-	1.0
Copper	10.6	1.505	0.1178	-	0.143	13.5	-	11.2
Cyanide	4.5	1.505	0.1178	-	0.143	5.7	-	4.7
Lead	5.6	1.505	0.1178	-	0.143	7.2	-	5.9
Lithium	8.5	1.505	0.1178	-	0.143	10.9	-	8.9
Manganese	61.1	1.505	0.1178	-	0.143	78.1	-	64.3
Mercury	0.9	1.505	0.1178	-	0.143	1.1	-	0.9
Molybdenum	0.1	1.505	0.1178	-	0.143	0.1	-	0.1
Nickel	27.8	1.505	0.1178	-	0.143	35.5	-	29.3
Selenium	0.14	1.505	0.1178	-	0.143	0.2	-	0.1
Strontium	182.6	1.505	0.1178	-	0.143	233.3	-	192.2
Thallium	0.005	1.505	0.1178	-	0.143	0.0	-	0.01
Uranium	1.1	1.505	0.1178	-	0.143	1.4	-	1.2
Vanadium	0.14	1.505	0.1178	-	0.143	0.2	-	0.1
Zinc	111.1	1.505	0.1178	-	0.143	141.9	-	116.9
Zirconium	0.65	1.505	0.1178	-	0.143	0.8	-	0.7
Beaver								
Acenaphthene	3.5	18.275	0.7237	-	1.353	88.4	-	47.3
Acenaphthylene	3.5	18.275	0.7237	-	1.353	88.4	-	47.3
Anthracene	20.1	18.275	0.7237	-	1.353	507.6	-	271.5
Benzo(a)anthracene	2	18.275	0.7237	-	1.353	50.5	-	27.0
Benzo(a)pyrene	0.2	18.275	0.7237	-	1.353	5.1	-	2.7

TABLE X-3

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

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

TABLE X-3

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

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Strontium	97.8	18.275	0.7237	-	1.353	2469.7	-	1321.0
Thallium	0.003	18.275	0.7237	-	1.353	0.1	-	0.04
Uranium	0.61	18.275	0.7237	-	1.353	15.4	-	8.2
Vanadium	0.07	18.275	0.7237	-	1.353	1.8	-	0.9
Zinc	59.5	18.275	0.7237	-	1.353	1502.5	-	803.7
Zirconium	0.65	18.275	0.7237	-	1.353	16.4	-	8.8
Moose								
Acenaphthene	1.6	381	6.586	-	20.83	9.3	-	2.9
Acenaphthylene	1.6	381	6.586	-	20.83	9.3	-	2.9
Anthracene	9.4	381	6.586	-	20.83	54.4	-	17.2
Benzo(a)anthracene	0.94	381	6.586	-	20.83	5.4	-	1.7
Benzo(a)pyrene	0.09	381	6.586	-	20.83	0.5	-	0.2
Benzo(b,k)fluoranthene	0.94	381	6.586	-	20.83	5.4	-	1.7
Benzo(ghi)perylene	9.4	381	6.586	-	20.83	54.4	-	17.2
Biphenyl	8.7	381	6.586	-	20.83	50.3	-	15.9
m-cresol	48.9	381	6.586	-	20.83	282.9	-	89.4
n-cresol	48.9	381	6.586	-	20.83	282.9	-	89.4
Dibenzo(a,h)anthracene	0.019	381	6.586	-	20.83	0.1	-	0.03
Dibenzothiophene	0.71	381	6.586	-	20.83	4.1	-	1.3
2,4-Dimethylphenol	0.47	381	6.586	-	20.83	2.7	-	0.9
Ethylbenzene	1.7	381	6.586	-	20.83	9.8	-	3.1
Fluoranthene	1.2	381	6.586	-	20.83	6.9	-	2.2
Fluorene	1.2	381	6.586	-	20.83	6.9	-	2.2
Naphthalene	1.3	381	6.586	-	20.83	7.5	-	2.4
Phenanthrene	0.38	381	6.586	-	20.83	2.2	-	0.7
Phenol	10.4	381	6.586	-	20.83	60.2	-	19.0
Pyrene	0.71	381	6.586	-	20.83	4.1	-	1.3
Quinoline	0.17	381	6.586	-	20.83	1.0	-	0.3
Xylene	0.19	381	6.586	-	20.83	1.1	-	0.3
Aluminum	0.18	381	6.586	-	20.83	1.0	-	0.3
Antimony	0.012	381	6.586	-	20.83	0.1	-	0.02
Arsenic	0.012	381	6.586	-	20.83	0.1	-	0.02
Barium	0.93	381	6.586	-	20.83	5.4	-	1.7
Beryllium	0.1	381	6.586	-	20.83	0.6	-	0.2
Boron	4.9	381	6.586	-	20.83	28.3	-	9.0

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Cadmium	0.2	381	6.586	-	20.83	1.2	-	0.37
Chromium (hexavalent)	0.57	381	6.586	-	20.83	3.3	-	1.0
Chromium (trivalent)	476.5	381	6.586	-	20.83	2756.6	-	871.6
Cobalt	0.23	381	6.586	-	20.83	1.3	-	0.4
Copper	2.7	381	6.586	-	20.83	15.6	-	4.9
Cyanide	1.1	381	6.586	-	20.83	6.4	-	2.0
Lead	1.4	381	6.586	-	20.83	8.1	-	2.6
Lithium	2.1	381	6.586	-	20.83	12.1	-	3.8
Manganese	15.3	381	6.586	-	20.83	88.5	-	28.0
Mercury	0.2	381	6.586	-	20.83	1.2	-	0.4
Molybdenum	0.024	381	6.586	-	20.83	0.1	-	0.04
Nickel	7	381	6.586	-	20.83	40.5	-	12.8
Selenium	0.035	381	6.586	-	20.83	0.2	-	0.1
Strontium	45.8	381	6.586	-	20.83	265.0	-	83.8
Thallium	0.001	381	6.586	-	20.83	0.01	-	0.002
Uranium	0.28	381	6.586	-	20.83	1.6	-	0.5
Vanadium	0.034	381	6.586	-	20.83	0.2	-	0.1
Zinc	27.9	381	6.586	-	20.83	161.4	-	51.0
Zirconium	0.16	381	6.586	-	20.83	0.9	-	0.3
Black Bear								
Acenaphthene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Acenaphthylene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Anthracene	12.3	130	2.26	0.75	7.89	70.8	213.2	20.3
Benzo(a)anthracene	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Benzo(a)pyrene	0.12	130	2.26	0.75	7.89	0.7	2.1	0.2
Benzo(b,k)fluoranthene	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Benzo(ghi)perylene	12.3	130	2.26	0.75	7.89	70.8	213.2	20.3
Biphenyl	11.4	130	2.26	0.75	7.89	65.6	197.6	18.8
m-cresol	64	130	2.26	0.75	7.89	368.1	1109.3	105.4
n-cresol	64	130	2.26	0.75	7.89	368.1	1109.3	105.4
Dibenzo(a,h)anthracene	0.02	130	2.26	0.75	7.89	0.1	0.3	0.03
Dibenzothiophene	0.6	130	2.26	0.75	7.89	3.5	10.4	1.0
2,4-Dimethylphenol	0.9	130	2.26	0.75	7.89	5.2	15.6	1.5
Ethylbenzene	2.2	130	2.26	0.75	7.89	12.7	38.1	3.6
Fluoranthene	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Fluorene	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5
Naphthalene	1.6	130	2.26	0.75	7.89	9.2	27.7	2.6
Phenanthrene	0.5	130	2.26	0.75	7.89	2.9	8.7	0.8
Phenol	13.7	130	2.26	0.75	7.89	78.8	237.5	22.6
Pyrene	0.9	130	2.26	0.75	7.89	5.2	15.6	1.5
Quinoline	0.23	130	2.26	0.75	7.89	1.3	4.0	0.4
Xylene	0.25	130	2.26	0.75	7.89	1.4	4.3	0.4
Aluminum	0.24	130	2.26	0.75	7.89	1.4	4.2	0.4
Antimony	0.015	130	2.26	0.75	7.89	0.1	0.3	0.02
Arsenic	0.016	130	2.26	0.75	7.89	0.1	0.3	0.03
Barium	1.2	130	2.26	0.75	7.89	6.9	20.8	2.0
Beryllium	0.2	130	2.26	0.75	7.89	1.2	3.5	0.3
Boron	6.4	130	2.26	0.75	7.89	36.8	110.9	10.5
Cadmium	0.2	130	2.26	0.75	7.89	1.2	3.5	0.33
Chromium (hexavalent)	0.7	130	2.26	0.75	7.89	4.0	12.1	1.2
Chromium (trivalent)	623.5	130	2.26	0.75	7.89	3586.5	10807.3	1027.3
Cobalt	0.3	130	2.26	0.75	7.89	1.7	5.2	0.5
Copper	3.5	130	2.26	0.75	7.89	20.1	60.7	5.8
Cyanide	1.5	130	2.26	0.75	7.89	8.6	26.0	2.5
Lead	1.8	130	2.26	0.75	7.89	10.4	31.2	3.0
Lithium	2.8	130	2.26	0.75	7.89	16.1	48.5	4.6
Manganese	20	130	2.26	0.75	7.89	115.0	346.7	33.0
Mercury	0.3	130	2.26	0.75	7.89	1.7	5.2	0.5
Molybdenum	0.03	130	2.26	0.75	7.89	0.2	0.5	0.05
Nickel	9.1	130	2.26	0.75	7.89	52.3	157.7	15.0
Selenium	0.05	130	2.26	0.75	7.89	0.3	0.9	0.1
Strontium	59.9	130	2.26	0.75	7.89	344.6	1038.3	98.7
Thallium	0.002	130	2.26	0.75	7.89	0.012	0.035	0.003
Uranium	0.4	130	2.26	0.75	7.89	2.3	6.9	0.7
Vanadium	0.04	130	2.26	0.75	7.89	0.2	0.7	0.1
Zinc	36.4	130	2.26	0.75	7.89	209.4	630.9	60.0
Zirconium	0.21	130	2.26	0.75	7.89	1.2	3.6	0.3
American robin								
Acenaphthene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Acenaphthylene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Benzo(a)anthracene	0.11	0.0836	0.004884	0.01256	0.019227	0.2	0.1	0.05
Benzo(a)pyrene	0.0112	0.0836	0.004884	0.01256	0.019227	0.019	0.007	0.005
Benzo(b,k)fluoranthene	0.11	0.0836	0.004884	0.01256	0.019227	0.2	0.1	0.05
Dibenzothiophene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Fluorene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Phenanthrene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Pyrene	22.55	0.0836	0.004884	0.01256	0.019227	38.6	15.0	9.8
Aluminum	109.7	0.0836	0.004884	0.01256	0.019227	187.8	73.0	47.7
Antimony	2.46	0.0836	0.004884	0.01256	0.019227	4.2	1.6	1.1
Arsenic	5.135	0.0836	0.004884	0.01256	0.019227	8.8	3.4	2.2
Barium	20.826	0.0836	0.004884	0.01256	0.019227	35.6	13.9	9.1
Boron	28.8	0.0836	0.004884	0.01256	0.019227	49.3	19.2	12.5
Cadmium	1.45	0.0836	0.004884	0.01256	0.019227	2.5	1.0	0.6
Chromium	1	0.0836	0.004884	0.01256	0.019227	1.7	0.7	0.4
Cobalt	0.7	0.0836	0.004884	0.01256	0.019227	1.2	0.5	0.3
Copper	47	0.0836	0.004884	0.01256	0.019227	80.5	31.3	20.4
Lead	3.85	0.0836	0.004884	0.01256	0.019227	6.6	2.6	1.7
Manganese	977	0.0836	0.004884	0.01256	0.019227	1672.3	650.3	424.8
Mercury	0.45	0.0836	0.004884	0.01256	0.019227	0.770	0.300	0.196
Molybdenum	3.5	0.0836	0.004884	0.01256	0.019227	6.0	2.3	1.5
Nickel	77.4	0.0836	0.004884	0.01256	0.019227	132.5	51.5	33.7
Selenium	0.5	0.0836	0.004884	0.01256	0.019227	0.9	0.3	0.2
Selenium	0.4	0.0836	0.004884	0.01256	0.019227	0.7	0.3	0.2
Uranium	16	0.0836	0.004884	0.01256	0.019227	27.4	10.6	7.0
Vanadium	11.38	0.0836	0.004884	0.01256	0.019227	19.5	7.6	4.9
Zinc	14.5	0.0836	0.004884	0.01256	0.019227	24.8	9.7	6.3
Ruffed Grouse								
Acenaphthene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Acenaphthylene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Benzo(a)anthracene	0.11	0.54285	0.0391	-	0.07776	0.2	-	0.1
Benzo(a)pyrene	0.0112	0.54285	0.0391	-	0.07776	0.016	-	0.008
Benzo(b,k)fluoranthene	0.11	0.54285	0.0391	-	0.07776	0.2	-	0.1
Dibenzothiophene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Fluorene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Phenanthrene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7

TABLE X-3

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

Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Pyrene	22.55	0.54285	0.0391	-	0.07776	31.3	-	15.7
Aluminum	109.7	0.54285	0.0391	-	0.07776	152.3	-	76.6
Antimony	2.46	0.54285	0.0391	-	0.07776	3.4	-	1.7
Arsenic	5.135	0.54285	0.0391	-	0.07776	7.1	-	3.6
Barium	20.826	0.54285	0.0391	-	0.07776	28.9	-	14.5
Boron	28.8	0.54285	0.0391	-	0.07776	40.0	-	20.1
Cadmium	1.45	0.54285	0.0391	-	0.07776	2.0	-	1.0
Chromium	1	0.54285	0.0391	-	0.07776	1.4	-	0.7
Cobalt	0.7	0.54285	0.0391	-	0.07776	1.0	-	0.5
Copper	47	0.54285	0.0391	-	0.07776	65.3	-	32.8
Lead	3.85	0.54285	0.0391	-	0.07776	5.3	-	2.7
Manganese	977	0.54285	0.0391	-	0.07776	1356.4	-	682.1
Mercury	0.45	0.54285	0.0391	-	0.07776	0.625	-	0.314
Molybdenum	3.5	0.54285	0.0391	-	0.07776	4.9	-	2.4
Nickel	77.4	0.54285	0.0391	-	0.07776	107.5	-	54.0
Selenium	0.5	0.54285	0.0391	-	0.07776	0.7	-	0.3
Selenium	0.4	0.54285	0.0391	-	0.07776	0.6	-	0.3
Uranium	16	0.54285	0.0391	-	0.07776	22.2	-	11.2
Vanadium	11.38	0.54285	0.0391	-	0.07776	15.8	-	7.9
Zinc	14.5	0.54285	0.0391	-	0.07776	20.1	-	10.1
Mallard								
Acenaphthene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Acenaphthylene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Benzo(a)anthracene	0.11	1.107	0.01574	0.0464	0.13277	0.8	0.3	0.1
Benzo(a)pyrene	0.0112	1.107	0.01574	0.0464	0.13277	0.1	0.03	0.01
Benzo(b,k)fluoranthene	0.11	1.107	0.01574	0.0464	0.13277	0.8	0.3	0.1
Dibenzothiophene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Fluorene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Phenanthrene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Pyrene	22.55	1.107	0.01574	0.0464	0.13277	158.6	53.8	18.8
Aluminum	109.7	1.107	0.01574	0.0464	0.13277	771.5	261.7	91.5
Antimony	2.46	1.107	0.01574	0.0464	0.13277	17.3	5.9	2.1
Arsenic	5.135	1.107	0.01574	0.0464	0.13277	36.1	12.3	4.3
Barium	20.826	1.107	0.01574	0.0464	0.13277	146.5	49.7	17.4
Boron	28.8	1.107	0.01574	0.0464	0.13277	202.6	68.7	24.0

TABLE X-3

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

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Chemicals	Estimated[1] Chronic Wildlife NOAEL (mg/kg-BW/day)	Endpoint[2] Species Body Weight (kg)	Plant[2] Ingestion Rate (kg/day)	Prey[2] Ingestion Rate (kg/day)	Water[2] Ingestion Rate (L/day)	Risk-Based[3] Concentration (mg/kg plant)	Risk-Based[3] Concentration (mg/kg prey)	Risk-Based[3] Concentration (mg/L water)
Cadmium	1.45	1.107	0.01574	0.0464	0.13277	10.2	3.5	1.2
Chromium	1	1.107	0.01574	0.0464	0.13277	7.0	2.4	0.8
Cobalt	0.7	1.107	0.01574	0.0464	0.13277	4.9	1.7	0.6
Copper	47	1.107	0.01574	0.0464	0.13277	330.6	112.1	39.2
Lead	3.85	1.107	0.01574	0.0464	0.13277	27.1	9.2	3.2
Manganese	977	1.107	0.01574	0.0464	0.13277	6871.3	2330.9	814.6
Mercury	0.45	1.107	0.01574	0.0464	0.13277	3.16	1.07	0.38
Molybdenum	3.5	1.107	0.01574	0.0464	0.13277	24.6	8.4	2.9
Nickel	77.4	1.107	0.01574	0.0464	0.13277	544.4	184.7	64.5
Selenium	0.5	1.107	0.01574	0.0464	0.13277	3.5	1.2	0.4
Selenium	0.4	1.107	0.01574	0.0464	0.13277	2.8	1.0	0.3
Uranium	16	1.107	0.01574	0.0464	0.13277	112.5	38.2	13.3
Vanadium	11.38	1.107	0.01574	0.0464	0.13277	80.0	27.2	9.5
Zinc	14.5	1.107	0.01574	0.0464	0.13277	102.0	34.6	12.1

[1] No-Observed Adverse Effect Level (NOAEL) based on the toxicological literature and the method by Opresko *et. al.* 1994. See Table III-1.

[2] Based on literature derived values. See Appendix V for derivation and summary.

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

TABLE X-4

WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Page 1 of 3

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

TABLE X-4

WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Page 2 of 3

Chemicals	CCREM[1] (mg/L) (livestock)	BC MOE[2] (mg/L) (livestock/ wildlife)	Screening[3] Level Criteria (mg/L)
PHENOLS			
Phenol	-[4]	-[4]	-[4]
2,4-Dimethylphenol	-[4]	-[4]	-[4]
m-cresol	-[4]	-[4]	-[4]
o-cresol	-[4]	-[4]	-[4]
INORGANICS			
Aluminum	5	5	5
Ammonia	-[4]	-[4]	-[4]
Antimony	-[4]	-[4]	-[4]
Arsenic	0.5	0.5	0.5
Barium	-[4]	-[4]	-[4]
Beryllium	0.1	0.1	0.1
Boron	5	5	5
Cadmium	0.02	0.02	0.02
Calcium	1000	1000	1000
Chloride	-[4]	-[4]	-[4]
Chromium	1	1	1
Cobalt	1	1	1
Copper	0.5	0.3	0.3
Cyanide	-[4]	-[4]	-[4]
Iron	-[4]	-[4]	-[4]
Lead	0.1	0.1	0.1
Lithium	-[4]	5	5
Magnesium	-[4]	-[4]	-[4]
Manganese	-[4]	-[4]	-[4]
Mercury	0.003	0.002	0.002

TABLE X-4

WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Page 3 of 3

Chemicals	CCREM[1] (mg/L) (livestock)	BC MOE[2] (mg/L) (livestock/ wildlife)	Screening[3] Level Criteria (mg/L)
Molybdenum	0.5	0.05	0.05
Nickel	1	1	1
Phosphorus	-[4]	-[4]	-[4]
Potassium	-[4]	-[4]	-[4]
Selenium	0.05	0.05	0.05
Silicon	-[4]	-[4]	-[4]
Silver	-[4]	-[4]	-[4]
Sodium	-[4]	-[4]	-[4]
Strontium	-[4]	-[4]	-[4]
Sulphate	1000	1000	1000
Tin	-[4]	-[4]	-[4]
Titanium	-[4]	-[4]	-[4]
Vanadium	0.1	0.1	0.1
Uranium	0.2	0.2	0.2
Zinc	50	50	50
Zirconium	-[4]	-[4]	-[4]

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

[2] British Columbia Ministry of Environment Water Quality Criteria for the protection of livestock and/or wildlife (BC Contam Sites Regulation, 1997).

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

[4] No criterion

[5] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

TABLE X-5

COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 1 of 2

Chemical	Future Muskeg River Concentrations			Screening Level Criteria[4]	Background Muskeg River (median)[5]	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHS AND SUBSTITUTED PAHS						
Benzo(a)anthracene group[7]	0	1.70E-05	3.10E-07	-[6]	nd	No criterion; EXCEEDS BACKGROUND
Benzo(a)pyrene group[7]	0	3.70E-06	2.30E-08	-[6]	nd	No criterion; EXCEEDS BACKGROUND
NAPHTHENIC ACIDS						
Naphthenic acids	4	3.74	3.95	-[6]	4	No criterion; Does not exceed background
INORGANICS						
Aluminum	0.06	0.22	0.05	5	0.05	EXCEEDS
Ammonia	0.06	0.06	0.05	-[6]	0.05	No criterion; EXCEEDS BACKGROUND[8]
Antimony	4.60E-06	0.00011	5.30E-09	-[6]	nd	No criterion; EXCEEDS BACKGROUND
Arsenic	0.003	0.0032	0.0028	0.5	0.0029	EXCEEDS
Barium	0.03	0.04	0.03	-[6]	0.03	EXCEEDS
Beryllium	9.20E-06	4.50E-04	1.60E-06	0.1	nd	Does not exceed.
Boron	0.04	0.35	0.05	5	0.05	Does not exceed.
Cadmium	0.0002	0.0008	0.0002	0.02	0.0002	Does not exceed.
Calcium	39	46.6	38.5	1000	38.4	Does not exceed.
Chloride	3.1	7.8	3.2	-[6]	3.1	No criterion; EXCEEDS BACKGROUND[8]
Chromium	0.001	0.002	0.001	1	nd	Does not exceed.
Copper	0.001	0.002	0.001	0.3	0.001	Does not exceed.
Iron	0.83	0.97	0.81	-[6]	0.79	No criterion; EXCEEDS BACKGROUND[8]
Lead	0.0004	0.0017	0.0004	0.1	0.0004	Does not exceed
Magnesium	9.6	11.1	9.6	-[6]	9.6	No criterion; EXCEEDS BACKGROUND[8]
Manganese	0.05	0.07	0.04	-[6]	0.04	No criterion; EXCEEDS BACKGROUND
Mercury	0.0001	0.0001	0.0001	0.002	0.0001	Does not exceed.
Molybdenum	0.0002	0.0847	0.0002	0.05	0.0002	EXCEEDS
Nickel	0.0004	0.0021	0.0004	1	0.0004	Does not exceed.
Selenium	0.0001	0.0002	0.0001	0.05	nd	Does not exceed.
Silver	0	0.00012	5.90E-09	-[6]	5.90E-09	No criterion; EXCEEDS BACKGROUND
Sodium	10.4	54.8	10.6	-[6]	10.4	No criterion; EXCEEDS BACKGROUND[8]

TABLE X-5

COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO WILDLIFE HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 2 of 2

Chemical	Future Muskeg River Concentrations			Screening Level Criteria[4]	Background Muskeg River (median)[5]	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Strontium	0.06	0.2	0.06	-[6]	0.06	No criterion; EXCEEDS BACKGROUND
Sulphate	4.52	81.17	4.61	1000	4.52	Does not exceed.
Vanadium	0.0004	0.011	0.0004	0.1	0.0004	Does not exceed.
Zinc	0.013	0.015	0.011	50	0.011	Does not exceed.

[1] Maximum predicted concentration during construction and operation phases (2000-2025)

[2] Predicted concentration for second year after closure (2030).

[3] Predicted concentration for equilibrium post-closure conditions in the far future.

[4] Screening level criteria were based on the lowest water quality criteria for livestock drinking water.

[5] Median concentrations in Muskeg River in 1997.

[6] No data or criterion.

[7] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[8] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

nd not detected

TABLE X-6

COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Page 1 of 1

Chemical	Release Water Concentrations			RBC for[4] Water Shrew	RBC for[4] River Otter	RBC for[4] Killdeer	RBC for[4] Great Blue Heron	RBC for[4] Moose	RBC for[4] Snowshoe Hare	RBC for[4] Black Bear	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]								
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHS AND SUBSTITUTED PAHS											
Benzo(a)anthracene group[6]	0	1.70E-05	3.10E-07	8	3.1	10.2	22.4	1.7	4	2	Does not exceed.
Benzo(a)pyrene group[6]	0	3.70E-06	2.30E-08	0.8	0.3	0.05	0.1	0.2	0.4	0.2	Does not exceed.
NAPHTHENIC ACIDS											
Naphthenic acids	4	3.74	3.95	-[5]	-[5]	-[5]	-[5]	-[5]	-[5]	-[5]	No criterion
INORGANICS											
Aluminum	0.06	0.22	0.05	1.6	0.6	49.8	108.8	0.3	0.8	0.4	Does not exceed.
Antimony	4.60E-06	0.00011	5.30E-09	0.1	0.04	-[5]	-[5]	0.02	0.05	0.02	Does not exceed.
Arsenic	0.003	0.0032	0.0028	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.03	0.04	0.03	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	9.20E-06	4.50E-04	1.60E-06	1	0.4	-[5]	-[5]	0.2	0.5	0.3	Does not exceed.
Boron	0.04	0.35	0.05	41.7	16	-[5]	-[5]	9	20.4	10.5	Does not exceed.
Cadmium	0.0002	0.0008	0.0002	1.4	0.5	0.7	1.4	1.2	0.9	1.2	Does not exceed.
Chromium	0.001	0.002	0.001	-[5]	-[5]	0.5	-[5]	1	2.4	1.2	Does not exceed.
Copper	0.001	0.002	0.001	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.0004	0.0017	0.0004	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Manganese	0.05	0.07	0.04	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	0.0001	0.0001	0.0001	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.0002	0.0847	0.0002	0.2	0.1	1.6	968.6	0.04	0.1	0.05	EXCEEDS (Moose and Black Bear)
Nickel	0.0004	0.00021	0.0004	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0001	0.0002	0.0001	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Silver	0	0.00012	5.90E-09	-[5]	-[5]	-[5]	-[5]	-[5]	-[5]	-[5]	No criterion
Strontium	0.06	0.2	0.06	392	150.4	-[5]	-[5]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.0004	0.011	0.0004	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.013	0.015	0.011	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[1] Maximum predicted concentration during construction and operation phases (2000-2025)

[2] Predicted concentration for second year after closure (2030).

[3] Predicted concentration for equilibrium post-closure conditions in the far future.

[4] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[5] No data or criterion.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

TABLE X-7

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

Chemical	Site Concentrations	Background Concentrations	Comments
	Athabasca River Downstream (1995)[1] (ug/g) Max	Athabasca River Upstream (1983)[2] (ug/g) Max	
PAHS AND SUBSTITUTED PAHS			
Naphthalene group[3]	0.08	-[4]	No background
INORGANICS			
Aluminum	1070	1260	Does not exceed
Barium	29	13.4	EXCEEDS
Calcium	3030	3610	Does not exceed
Chromium	10.5	10	EXCEEDS
Cobalt	1.4	-[4]	No background
Copper	45	5.5	EXCEEDS
Iron	2400	972	EXCEEDS[5]
Lithium	1.3	-[4]	No Background
Magnesium	1530	426	EXCEEDS[5]
Manganese	314	51.2	EXCEEDS
Mercury	0.055	0.12	Does not exceed
Molybdenum	0.9	2.3	Does not exceed
Nickel	8.8	5.3	EXCEEDS
Phosphorus	5620	3850	EXCEEDS[5]
Potassium	6640	621	EXCEEDS[5]
Silicon	546	-[4]	No background[5]
Silver	0.4	-[4]	No background
Sodium	5140	405	EXCEEDS[5]
Strontium	16.4	10.3	EXCEEDS
Titanium	16.4	26.6	Does not exceed
Vanadium	3.6	3.2	EXCEEDS
Zinc	133	30.1	EXCEEDS

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

[2] Data from benthic invertebrates sampled by Beak during 1983 upstream of Suncor and Syncrude (Beak 1988).

[3] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[4] No data

[5] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE X-8

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

Chemical	Athabasca River[1] (ug/g) Max	RBC for Water Shrew Invertebrate Ingestion[2] (ug/g)	RBC for Killdeer Invertebrate Ingestion[2] (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS				
Naphthalene group[3]	0.08	1.7	-[4]	Does not exceed
INORGANICS				
Barium	29	1.3	13.5	EXCEEDS (shrew, killdeer)
Chromium	10.5	656.3	0.6	EXCEEDS (killdeer)
Cobalt	1.4	0.3	0.4	EXCEEDS (shrew, killdeer)
Copper	45	3.6	30.2	EXCEEDS (shrew, killdeer)
Lithium	1.3	2.3	-[4]	Does not exceed
Manganese	314	21.1	627.4	EXCEEDS (shrew)
Nickel	8.8	9.6	49.7	Does not exceed
Silver	0.4	-[4]	-[4]	No RBC
Strontium	16.4	63.1	-[4]	Does not exceed
Vanadium	3.6	0.0467	7.3	Does not exceed
Zinc	133	38.4	9.3	EXCEEDS (shrew, killdeer)

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

[2] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).
Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors

[3] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[4] No data

TABLE X-9

COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO BACKGROUND CONCENTRATIONS

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

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

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

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

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[5] No data

[6] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These chemicals were not detected above detection limits

TABLE X-10

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

Chemical	Muskeg River[1] Longnose Sucker (ug/g) Max	Athabasca River[1] Walleye (ug/g) Max	Athabasca River[1] Goldeye (ug/g) Max	10%TID[2] Walleye (ug/g) Max - Lab	RBC for[3] River Otter Fish Ingestion (ug/g)	RBC for[3] Great Blue Heron Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS							
Naphthalene group[4]	0.09	<0.02	<0.02	<0.02	7	-[5]	Does not exceed
INORGANICS							
Copper	<1	1	2	<1	14.7	106.2	Does not exceed
Manganese	0.9	1.2	<0.5	6.1	85	2206.9	Does not exceed
Nickel	<1	<1	2	<2	38.7	174.2	Does not exceed
Zinc	6	9	6	17.5	154.6	32.8	Does not exceed

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

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

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer toTable X-1.

[5] No data.

< These chemicals were not detected above detection limits

TABLE X-11

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

Chemical	Site Concentrations		Background Concentrations	Comments
	Baseline On-Site (ug/g) Max	Potential Future[2] (ug/g) Max	Mariana Lakes Region[3] (ug/g) Max	
INORGANICS				
Aluminum	<0.2	40	88	Does not exceed
Antimony	<0.04	<0.04	<0.04	Does not exceed
Arsenic	<0.2	<0.2	<0.2	Does not exceed
Barium	15.5	7.4	18	Does not exceed
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	7	6	6	EXCEEDS
Cadmium	0.09	<0.08	<0.08	EXCEEDS
Calcium	1140	973	1170	Does not exceed
Chromium	<0.5	<0.2	<0.2	Does not exceed
Cobalt	<0.08	<0.08	<0.08	Does not exceed
Copper	4.18	4.6	2.2	EXCEEDS
Iron	20	13	24	Does not exceed
Lead	<0.4	0.3	<0.1	EXCEEDS
Magnesium	488	363	500	Does not exceed
Manganese	576	292	374	EXCEEDS
Mercury	0.02	0.02	0.02	Does not exceed
Molybdenum	<0.4	0.11	0.36	Does not exceed
Nickel	0.99	0.66	0.56	EXCEEDS
Phosphorus	851	750	1070	Does not exceed
Potassium	4590	2930	4830	Does not exceed
Selenium	<0.2	<0.2	<0.2	Does not exceed
Silver	<0.08	<1	<1	Does not exceed
Sodium	17	6	<2	EXCEEDS[4]
Strontium	1.48	1.3	1.4	EXCEEDS
Sulphur	654	707	708	Does not exceed
Thallium	<0.04	<0.04	<0.04	Does not exceed
Tin	<0.08	<0.1	0.3	Does not exceed
Vanadium	<0.08	<0.08	<0.08	Does not exceed
Zinc	1	11	5	EXCEEDS

[1] Blueberries collected on Muskeg River Mine Project Site by Golder during 1997.

[2] Blueberries collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] Blueberries collected near Mariana Lakes, approximately 40 km south of Fort McMurray. These are considered to be background samples.

[4] Sodium was not evaluated in the risk assessment since it is a required nutrient.

< These compounds were not detected above detection limits.

TABLE X-11

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

Chemical	Site Concentrations		Background Concentrations	Comments
	Baseline On-Site (ug/g) Max	Potential Future[2] (ug/g) Max	Mariana Lakes Region[3] (ug/g) Max	
INORGANICS				
Aluminum	<0.2	40	88	Does not exceed
Antimony	<0.04	<0.04	<0.04	Does not exceed
Arsenic	<0.2	<0.2	<0.2	Does not exceed
Barium	15.5	7.4	18	Does not exceed
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	7	6	6	EXCEEDS
Cadmium	0.09	<0.08	<0.08	EXCEEDS
Calcium	1140	973	1170	Does not exceed
Chromium	<0.5	<0.2	<0.2	Does not exceed
Cobalt	<0.08	<0.08	<0.08	Does not exceed
Copper	4.18	4.6	2.2	EXCEEDS
Iron	20	13	24	Does not exceed
Lead	<0.4	0.3	<0.1	EXCEEDS
Magnesium	488	363	500	Does not exceed
Manganese	576	292	374	EXCEEDS
Mercury	0.02	0.02	0.02	Does not exceed
Molybdenum	<0.4	0.11	0.36	Does not exceed
Nickel	0.99	0.66	0.56	EXCEEDS
Phosphorus	851	750	1070	Does not exceed
Potassium	4590	2930	4830	Does not exceed
Selenium	<0.2	<0.2	<0.2	Does not exceed
Silver	<0.08	<1	<1	Does not exceed
Sodium	17	6	<2	EXCEEDS[4]
Strontium	1.48	1.3	1.4	EXCEEDS
Sulphur	654	707	708	Does not exceed
Thallium	<0.04	<0.04	<0.04	Does not exceed
Tin	<0.08	<0.1	0.3	Does not exceed
Vanadium	<0.08	<0.08	<0.08	Does not exceed
Zinc	1	11	5	EXCEEDS

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[1] Blueberries collected on Muskeg River Mine Project Site by Golder during 1997.

[2] Blueberries collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] Blueberries collected near Mariana Lakes, approximately 40 km south of Fort McMurray. These are considered to be background samples.

[4] Sodium was not evaluated in the risk assessment since it is a required nutrient.

< These compounds were not detected above detection limits.

TABLE X-12

COMPARISON OF CHEMICAL CONCENTRATIONS IN LABRADOR TEA TO BACKGROUND CONCENTRATIONS

Chemical	Site Concentrations		Background Concentrations	Comments
	Baseline On-Site (ug/g) Max	Potential Future[2] (ug/g) Max	Mariana Lakes Region and West of Syncrude [3] (ug/g) Max	
PAHS AND SUBSTITUTED PAHS				
Naphthalene group[4]	0.2	0.25	0.1	EXCEEDS
INORGANICS				
Aluminum	14.7	35	43	Does not exceed
Antimony	<0.04	0.68	0.53	EXCEEDS
Arsenic	<0.2	<0.2	<0.2	Does not exceed
Barium	120	112	80.1	EXCEEDS
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	21	25	22	EXCEEDS
Cadmium	0.08	0.09	<0.08	EXCEEDS
Calcium	5710	5890	5870	EXCEEDS[5]
Chromium	<0.5	0.4	<0.2	EXCEEDS
Cobalt	0.31	0.13	0.11	EXCEEDS
Copper	74	23.2	13.7	EXCEEDS
Iron	104	313	49	EXCEEDS[5]
Lead	2.9	0.8	0.3	EXCEEDS
Magnesium	1250	1530	1420	EXCEEDS[5]
Manganese	1070	1010	864	EXCEEDS
Mercury	0.03	0.05	0.04	EXCEEDS
Molybdenum	<0.4	0.12	0.12	Does not exceed
Nickel	6.92	4.67	3.36	EXCEEDS
Phosphorus	1060	1120	1280	Does not exceed
Potassium	5401	5500	5310	EXCEEDS[5]
Selenium	<0.2	<0.2	<0.2	Does not exceed
Silver	<0.08	<0.08	<0.08	Does not exceed
Sodium	12	43	33	EXCEEDS[5]
Strontium	8.58	19.9	13.9	EXCEEDS
Sulphur	1090	1210	1250	Does not exceed
Thallium	<0.04	<0.04	<0.04	Does not exceed
Tin	0.18	0.3	0.3	Does not exceed
Vanadium	<0.08	0.15	<0.08	EXCEEDS
Zinc	54.5	34	27	EXCEEDS

[1] Labrador tea leaves collected on Muskeg River Mine Project by Golder during 1997.

[2] Labrador tea leaves collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] Labrador tea leaves collected near Mariana Lakes, approximately 40 km south of Fort McMurray and west of Syncrude, outside the zone of influence of air emissions. These are considered to be background samples.

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[5] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These compounds were not detected above detection limits.

TABLE X-13

COMPARISON OF CHEMICAL CONCENTRATIONS IN CATTAIL ROOT TO BACKGROUND CONCENTRATIONS

Chemical	Site Concentrations		Background Concentrations	Comments
	Baseline [1] On-Site (ug/g) Max	Potential [2] Future (ug/g) Max	Mariana Lakes Region and West of Syncrude [3] (ug/g) Max	
INORGANICS				
Aluminum	693	611	245	EXCEEDS
Antimony	<0.04	<0.04	<0.04	Does not exceed
Arsenic	0.9	1.1	1.9	Does not exceed
Barium	46.9	47.3	20.7	EXCEEDS
Beryllium	<0.2	<0.2	<0.2	Does not exceed
Boron	29	13	12	EXCEEDS
Cadmium	0.17	0.09	<0.08	EXCEEDS
Calcium	40000	10700	4490	EXCEEDS[4]
Chromium	1	1.2	0.7	EXCEEDS
Cobalt	5.24	1.37	1.04	EXCEEDS
Copper	3.36	14.4	11.2	EXCEEDS
Iron	8340	5160	4160	EXCEEDS[4]
Lead	1.4	2.5	2.1	EXCEEDS
Magnesium	4060	2180	1910	EXCEEDS[4]
Manganese	225	541	717	Does not exceed
Mercury	0.04	0.07	0.06	EXCEEDS
Molybdenum	<0.4	1.7	1.53	EXCEEDS
Nickel	6.43	3.98	3.19	EXCEEDS
Phosphorus	893	2040	3190	Does not exceed
Potassium	15600	26300	34100	Does not exceed
Selenium	0.2	0.7	0.4	EXCEEDS
Silver	<0.08	<1	<1	Does not exceed
Sodium	1330	3340	3670	Does not exceed
Strontium	36.4	38.5	16.6	EXCEEDS
Sulphur	4100	2830	1350	EXCEEDS[4]
Thallium	0.04	<0.04	0.14	Does not exceed
Tin	<0.08	<0.08	0.3	Does not exceed
Vanadium	7.16	6.07	0.82	EXCEEDS
Zinc	59.2	26	45	EXCEEDS

[1] Cattail root collected on Muskeg River Mine Project by Golder during 1997.

[2] Cattail root collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] Cattail root collected near Mariana Lakes, approximately 40 km south of Fort McMurray and west of Syncrude, outside the zone of influence of air emissions. These are considered to be background samples.

[4] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

< These compounds were not detected above detection limits.

TABLE X-14

COMPARISON OF CHEMICAL CONCENTRATIONS IN BLUEBERRIES AND LABRADOR TEA TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Baseline On-site[1] (ug/g) Max	Potential Future[2] (ug/g) Max	Moose RBC for[3] Plant Ingestion (ug/g)	Hare RBC for[3] Plant Ingestion (ug/g)	Bear RBC for[3] Plant Ingestion (ug/g)	Grouse RBC for[3] Plant Ingestion (ug/g)	Comments
Blueberries							
Cadmium	0.09	<0.08	0.104	0.089	0.115	2	Does not exceed
Copper	4.15	3.14	15.6	13.5	20.1	65.3	Does not exceed
Lead	<0.4	0.3	8.1	7.2	10.4	5.3	Does not exceed
Manganese	194	315	88.5	78.1	115	1356.4	EXCEEDS (moose, hare, bear)
Nickel	0.99	0.66	40.5	35.5	52.3	107.5	Does not exceed
Strontium	1.48	1.3	265	233.3	345	-[4]	Does not exceed
Zinc	1	11	161.4	141.9	209	20.1	Does not exceed
Labrador Tea							
Naphthalene group	0.2	0.25	7.5	6.4	9.2	-[4]	Does not exceed
Antimony	<0.04	0.68	0.069	0.01	0.09	3.4	EXCEEDS (moose, hare, bear)
Barium	120	112	5.4	4.7	6.9	28.9	EXCEEDS (moose, hare, bear, grouse)
Boron	21	25	28	25	37	40	Does not exceed
Cadmium	0.08	0.09	0.10	0.09	0.12	2	Does not exceed
Chromium	<0.5	0.4	2757	2427	3587	1.4	Does not exceed
Cobalt	0.31	0.13	1.3	1.2	1.7	1	Does not exceed
Copper	74	23.2	15.6	13.5	20.1	65.3	EXCEEDS (moose, hare, bear, grouse)
Lead	2.9	0.8	8.1	7.2	10.4	5.3	Does not exceed
Manganese	1070	1010	88.5	78.1	115	1356.4	EXCEEDS (moose, hare, bear)
Mercury	0.03	0.05	1.2	1.1	1.7	0.625	Does not exceed
Nickel	6.92	4.67	40.5	35.5	52.3	107.5	Does not exceed
Strontium	8.58	19.9	265	233.3	345	-[4]	Does not exceed
Vanadium	<0.08	0.15	0.2	0.18	0.23	15.8	Does not exceed
Zinc	54.5	34	161.4	141.9	209	20.1	Does not exceed

[1] Samples collected on Muskeg River Mine Project by Golder during 1997.

[2] Samples collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).
Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[4] No data

TABLE X-15

COMPARISON OF CHEMICAL CONCENTRATIONS IN CATTAILS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Baseline On-site (ug/g) Max[1]	Potential Future (ug/g) Max[2]	Moose RBC for[3] Plant Ingestion (ug/g)	Mallard RBC for[3] Plant Ingestion (ug/g)	Comments
Cattail Root					
Aluminum	693	611	1	771.5	EXCEEDS (moose)
Barium	46.9	47.3	5.4	147	EXCEEDS (moose)
Boron	29	13	28	203	EXCEEDS (moose)
Cadmium	0.17	0.09	0.1	10	EXCEEDS (moose)
Chromium	1	1.2	2757	7	Does not exceed
Cobalt	5	1.37	1.3	5	EXCEEDS (moose)
Copper	3.36	14.4	15.6	330.6	Does not exceed
Lead	1.4	2.5	8.1	27	Does not exceed
Mercury	0.04	0.07	1.2	3.2	Does not exceed
Molybdenum	<0.4	1.7	0.1	24.6	EXCEEDS (moose)
Selenium	0.2	0.7	0.2	3.5	EXCEEDS (moose)
Strontium	36.4	38.5	265	-[4]	Does not exceed
Vanadium	7.16	6.07	0.2	80	EXCEEDS (moose)
Zinc	59.2	26	161	102	Does not exceed

[1] Samples collected on Muskeg River Mine Project by Golder during 1997.

[2] Samples collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[4] No data

TABLE X-16

COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC PLANTS GROWN IN TREATED WETLANDS TO BACKGROUND WETLANDS

Page 1 of 2

Chemicals	TREATMENT			BACKGROUND		Comments
	Dyke Drainage[1] Wetlands (mg/kg plant)	Pond 1A [2] Wetlands (mg/kg plant)	Syncrude[3] Pit 7 (mg/kg plant)	Syncrude[4] Reference Wetlands (mg/kg plant)	Control[5] Wetlands (mg/kg plant)	
PAHS AND SUBSTITUTED PAHS						
Acenaphthene group[6]	-[7]	-[7]	0.013	<0.001	-[7]	EXCEEDS
Benzo(a)anthracene group[6]	-[7]	-[7]	0.118	<0.001	-[7]	EXCEEDS
Benzo(a)pyrene group[6]	-[7]	-[7]	0.019	<0.001	-[7]	EXCEEDS
Biphenyl	-[7]	-[7]	0.002	0.001	-[7]	EXCEEDS
Dibenzo(a,h)anthracene	-[7]	-[7]	0.001	<0.001	-[7]	EXCEEDS
Dibenzothiophene group[6]	-[7]	-[7]	0.774	0.001	-[7]	EXCEEDS
Fluoranthene group[6]	-[7]	-[7]	0.035	<0.001	-[7]	EXCEEDS
Fluorene group[6]	-[7]	-[7]	0.141	0.018	-[7]	EXCEEDS
Naphthalene group[6]	-[7]	-[7]	0.299	0.013	-[7]	EXCEEDS
Phenanthrene group[6]	-[7]	-[7]	1.762	<0.001	-[7]	EXCEEDS
Pyrene	-[7]	-[7]	0.001	<0.001	-[7]	EXCEEDS
INORGANICS						
Aluminum	367	701.86	1610	1440	358.67	EXCEEDS
Arsenic	-[7]	-[7]	1.6	2.5	-[7]	Does not exceed
Barium	-[7]	-[7]	28.7	21.5	-[7]	EXCEEDS
Beryllium	-[7]	-[7]	0.14	0.15	-[7]	Does not exceed
Boron	-[7]	-[7]	44	15	-[7]	EXCEEDS
Cadmium	0.06	0.07	0.29	0.34	0.07	Does not exceed
Calcium	-[7]	-[7]	6150	8490	-[7]	Does not exceed
Copper	2.29	2.82	6.2	9.74	3.66	Does not exceed
Lead	-[7]	-[7]	0.6	1.2	-[7]	Does not exceed
Lithium	-[7]	-[7]	5	<4	-[7]	EXCEEDS
Iron	642.67	363.43	2300	4400	936.78	Does not exceed

TABLE X-16

COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC PLANTS GROWN IN TREATED WETLANDS TO BACKGROUND WETLANDS

Page 2 of 2

Chemicals	TREATMENT			BACKGROUND		Comments
	Dyke Drainage[1] Wetlands (mg/kg plant)	Pond 1A [2] Wetlands (mg/kg plant)	Syncrude[3] Pit 7 (mg/kg plant)	Syncrude[4] Reference Wetlands (mg/kg plant)	Control[5] Wetlands (mg/kg plant)	
Magnesium	-[7]	-[7]	2130	2600	-[7]	Does not exceed
Manganese	266.88	303	217	828	741.5	Does not exceed
Mercury	0.07	0.11	-[7]	-[7]	0.02	EXCEEDS
Nickel	2.22	2.27	3.5	2.7	2.66	EXCEEDS
Phosphorus	-[7]	-[7]	1350	1060	-[7]	EXCEEDS[8]
Potassium	-[7]	-[7]	6730	12200	-[7]	Does not exceed
Silicon	-[7]	-[7]	283	302	-[7]	Does not exceed
Sodium	-[7]	-[7]	11100	3750	-[7]	EXCEEDS[8]
Strontium	-[7]	-[7]	60.3	34.1	-[7]	EXCEEDS
Titanium	-[7]	-[7]	9.48	16.3	-[7]	Does not exceed
Vanadium	-[7]	-[7]	4.7	5.1	-[7]	Does not exceed
Zinc	33.75	20.78	22.1	34.1	41.35	Does not exceed
Zirconium	-[7]	-[7]	2	1.5	41.35	Does not exceed

[1] Data from dyke drainage water constructed wetland (Nix 1995).

[2] Data from Pond 1A constructed wetland (Nix 1995).

[3] Data from Syncrude, Pit 7 (unpublished data). Plants grown in fine tails.

[4] Data from Syncrude reference wetlands (unpublished data). This sample was considered to be representative of background values.

[5] Data from control constructed wetlands (Nix 1995). This sample was considered to be representative of background values.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[7] Not analyzed or no data available.

[8] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE X-17

COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC PLANTS GROWN IN TREATED WETLANDS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Page 1 of 1

Chemicals	Dyke Drainage[1] Wetlands	Pond 1A [2] Wetlands (mg/kg plant)	Syncrude[3] (mg/kg plant)	RBC for Mallard[4] (mg/kg plant)	RBC for Beaver[4] (mg/kg plant)	RBC for for Moose[4] (mg/kg plant)	Comments
PAHS AND SUBSTITUTED PAHS							
Acenaphthene group[6]	-[5]	-[5]	0.013	158.6	88.4	9.3	Does not exceed
Benzo(a)anthracene group[6]	-[5]	-[5]	0.118	0.8	50.5	5.4	Does not exceed
Benzo(a)pyrene	-[5]	-[5]	0.019	0.1	5.1	0.5	Does not exceed
Biphenyl	-[5]	-[5]	0.002	-[5]	469.7	50.3	Does not exceed
Dibenzo(a,h)anthracene	-[5]	-[5]	0.001	-[5]	1	0.1	Does not exceed
Dibenzothiophene group[6]	-[5]	-[5]	0.774	158.6	37.9	4.1	Does not exceed
Fluoranthene group[6]	-[5]	-[5]	0.035	158.6	63.1	6.9	Does not exceed
Fluorene group[6]	-[5]	-[5]	0.141	158.6	63.1	6.9	Does not exceed
Naphthalene group[6]	-[5]	-[5]	0.299	158.6	68.2	7.5	Does not exceed
Phenanthrene group[6]	-[5]	-[5]	1.47	158.6	20.5	2.2	Does not exceed
INORGANICS							
Aluminum	367	701.86	1610	771.5	9.8	1	EXCEEDS (mallard; beaver; moose)[7]
Barium	-[5]	-[5]	28.70	146.5	50.5	5.4	EXCEEDS (moose)
Boron	-[5]	-[5]	36.5	202.6	262.6	28.3	EXCEEDS (moose)
Lithium	-[5]	-[5]	5	-[5]	113.6	12.1	Does not exceed
Mercury	0.07	0.07	-[5]	3.16	12.6	1.2	Does not exceed
Nickel	2.22	-[5]	3.5	544.4	376.3	40.5	Does not exceed
Strontium	-[5]	-[5]	60.3	-[5]	2470	265	Does not exceed

[1] Data from dyke drainage water constructed wetland (Nix 1995).

[2] Data from Pond 1A constructed wetland (Nix et al. 1995).

[3] Data from Syncrude, Pit 7 (unpublished data). Plants grown in fine tails.

[4] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set to 1.0.

[5] Not analyzed or no data available.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[7] Although aluminum theoretically exceeds the RBCs for some species, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route.

Therefore, aluminum was excluded from further consideration.

TABLE X-18

COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC INVERTEBRATES FROM TREATED WETLANDS TO BACKGROUND CONCENTRATIONS

Page 1 of 1

Chemical	Dyke Drainage[1] (ug/g)	Split Dyke[1] Drainage (ug/g)	Control[2] (ug/g)	Comments
Benthic Invertebrates				
Aluminum	450	1800	220	Does not exceed
Barium	71.5	29	52.6	Does not exceed
Cadmium	<[3]	<[3]	<[3]	Does not exceed
Copper	40	20	20	EXCEEDS
Iron	2650	2970	2100	Does not exceed
Lead	<[3]	<[3]	<[3]	Does not exceed
Manganese	77	110	46	Does not exceed
Mercury	<[3]	<[3]	<[3]	Does not exceed
Titanium	20	30	9	Does not exceed
Total Extractable Hydrocarbons	74.1	66.8	99.8	Does not exceed
Zinc	110	94	94	EXCEEDS
Emergent Insects				
Aluminum	70	-[4]	40	Does not exceed
Barium	84.4	-[4]	41	EXCEEDS
Cadmium	<[3]	-[4]	<[3]	Does not exceed
Copper	70	-[4]	70	Does not exceed
Iron	650	-[4]	1800	Does not exceed
Lead	<[3]	-[4]	<[3]	Does not exceed
Manganese	190	-[4]	80	Does not exceed
Mercury	<[3]	-[4]	<[3]	Does not exceed
Titanium	10	-[4]	<30	EXCEEDS
Zinc	220	-[4]	200	Does not exceed
Chironomid Larvae				
Aluminum	18.38	-[4]	71	Do not exceed
Cadmium	0.57	-[4]	0.34	EXCEEDS
Iron	6590.6	-[4]	3394	EXCEEDS[5]
Lead	5.73	-[4]	2.4	EXCEEDS
Mercury	5.39	-[4]	8.5	Do not exceed
Zinc	145.11	-[4]	234.07	Do not exceed

[1] Data from dyke drainage water constructed wetland (Nix 1995).

[2] Data from control constructed wetlands (Nix 1995) considered to be representative of background values.

[3] Not detected. Detection limit not specified.

[4] Not analyzed.

[5] Iron was not evaluated in the risk assessment since it is a required nutrient.

TABLE X-19

COMPARISON OF CHEMICAL CONCENTRATIONS IN AQUATIC INVERTEBRATES FROM TREATED WETLANDS TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Chemical	Dyke Drainage[1] (mg/kg)	Dyke Drainage[1] (split trench) (mg/kg)	RBC for[2] Mallard (mg/kg prey)	Comments
Benthic Invertebrates				
Copper	40	20	112	Does not exceed
Zinc	110	94	34.6	EXCEEDS
Emergent Insects				
Barium	84.4	-[3]	50	EXCEEDS
Titanium	10	-[3]	-[3]	No RBC
Chironomid Larvae				
Cadmium	0.57	-[3]	3.5	Does not exceed
Lead	5.73	-[3]	9.2	Does not exceed

[1] Data from dyke drainage water constructed wetland (Nix 1995).

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set to 1.0.

[3] Not analyzed, or no data available.

TABLE X-20

ESTIMATION OF CHEMICAL CONCENTRATIONS IN TERRESTRIAL PLANT TISSUES GROWING ON RECLAMATION SOILS

Page 1 of 1

Chemicals	Overburden[1] (mg/kg soil)	Tailings Sand[2] (mg/kg soil)	Background Muskeg[3] (mg/kg soil)	Plant Uptake Factor[4] (unitless)	Plants Growing on Overburden[5] (mg/kg plant)	Plants Growing on Tailings Sand[5] (mg/kg plant)	Plants Growing on Muskeg[5] (mg/kg plant)
PAHS AND SUBSTITUTED PAHS							
Benzo(a)anthracene group[7]	<0.01	0.65	0.03	0.015	-[6]	0.00975	0.00045
Benzo(a)pyrene group[7]	<0.01	0.2	<0.01	0.01	-[6]	0.002	-[6]
Benzo(b&k)fluoranthene	<0.01	0.03	<0.01	0.01	-[6]	0.0003	-[6]
Dibenzothiophene group[7]	0.24	0.8	<0.01	0.11	0.0264	0.088	-[6]
Fluorene group[7]	0.05	<0.01	<0.01	0.15	0.0075	-[6]	-[6]
Fluoranthene group[7]	<0.01	0.01	<0.01	0.037	-[6]	0.00037	-[6]
Naphthalene group[7]	0.49	<0.01	0.05	0.44	0.2156	-[6]	0.022
Phenanthrene group[7]	0.15	0.56	0.03	0.1	0.015	0.056	0.003
Pyrene	<0.01	0.04	<0.01	0.038	-[6]	0.00152	-[6]

[1] Overburden (KCa; CP3) data as reported by ETL (1993; n=1).

[2] Tailings Sand (Suncor Beach; CP5) data as reported by ETL (1993; n=1).

[3] Muskeg soil analyzed by CHEMEX Labs Alberta Inc. Oct. 30, 1995. This sample is considered to be representative of background soils (n=1).

[4] Plant uptake factors estimating plant tissue concentrations of PAHs from soil concentrations (Travis and Arms 1988).

[5] Plant tissue concentration = soil concentration x plant uptake factor

[6] Not analyzed, no data available or unable to calculate plant concentration due to non-detect soil concentration.

[7] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

TABLE X-21

COMPARISON OF OBSERVED AND ESTIMATED CHEMICAL CONCENTRATIONS IN TERRESTRIAL PLANTS GROWING ON RECLAMATION SOILS TO RISK-BASED CONCENTRATIONS (RBCs) FOR WILDLIFE HEALTH

Chemicals	Plants Growing on Overburden[1] (mg/kg plant)	Plants Growing on Tailings Sand[2] (mg/kg plant)	RBC for[3] Moose (mg/kg plant)	RBC for[3] Hare (mg/kg plant)	RBC for[3] Beaver (mg/kg plant)	RBC for[3] Mouse (mg/kg plant)	RBC for[3] Grouse (mg/kg plant)	RBC for[3] Robin (mg/kg plant)	Comments
PAHS AND SUBSTITUTED PAHS									
Benzo(a)anthracene group[4]	-[5]	0.00975	5.4	4.9	50.5	11.2	0.2	0.2	Does not exceed
Benzo(a)pyrene group[4]	-[5]	0.002	0.5	0.5	5.1	1.1	0.016	0.019	Does not exceed
Benzo(b&k)fluoranthene group[4]	-[5]	0.0003	5.4	4.9	50.5	11.2	0.2	0.2	Does not exceed
Dibenzothiophene group[4]	0.0264	0.088	4.1	3.6	37.9	8.4	31.3	38.6	Does not exceed
Fluorene group[4]	0.0075	-[5]	6.9	6	63.1	14	31.3	38.6	Does not exceed
Fluroanthene group[4]	-[5]	0.00037	6.9	6	63.1	14	31.3	38.6	Does not exceed
Naphthalene group[4]	0.2156	-[5]	7.5	6.4	68.2	14.9	31.3	38.6	Does not exceed
Phenanthrene group[4]	0.015	0.056	2.2	1.9	20.5	4.5	31.3	38.6	Does not exceed
Pyrene	-[5]	0.00152	4.1	3.6	37.9	8.4	31.3	38.6	Does not exceed
INORGANICS									
Aluminum	-[5]	80.4	1	0.9	9.8	2.2	152.3	187.8	EXCEEDS (all mammals)[6]
Arsenic	-[5]	0.062	0.1	0.1	0.6	0.1	7.1	8.8	Does not exceed
Barium	-[5]	19.1	5.4	4.7	50.5	11	28.9	35.6	EXCEEDS (moose, hare, bear, mouse)
Beryllium	0.015[1]	-[5]	0.6	0.6	5.1	1.4	-[5]	-[5]	Does not exceed
Boron	-[5]	35.9	28.3	263	263	57.9	40	49.3	EXCEEDS (moose)
Cadmium	-[5]	0.3	1.2	0.9	10.11	2.1	2	2.5	Does not exceed
Cobalt	-[5]	0.1	1.3	1.2	12.4	2.7	1	1.2	Does not exceed
Chromium	-[5]	0.9	2757	25712	25712	5663	1.4	1.7	Does not exceed
Copper	-[5]	3.8	15.6	13.5	143.9	31.5	65.3	80.5	Does not exceed
Lead	-[5]	0.22	8.1	7.2	75.8	16.5	5.3	6.6	Does not exceed
Mercury	-[5]	0.013	1.2	1.1	12.6	0.007	0.625	0.77	EXCEEDS (mouse)
Molybdenum	-[5]	0.65	0.1	1.3	1.3	0.001	4.9	6	EXCEEDS (moose, bear, mouse)
Nickel	-[5]	0.96	40.5	35.5	376.3	0.2	107.5	132.5	EXCEEDS (mouse)
Selenium	-[5]	0.44	0.2	1.8	1.8	0.001	0.7	0.9	EXCEEDS (moose, bear, mouse)
Strontium	-[5]	48.2	265	2470	2470	1.4	-[5]	-[5]	EXCEEDS (mouse)
Vanadium	-[5]	0.43	0.2	0.2	1.8	0.001	15.8	19.5	EXCEEDS (moose, hare, bear, mouse)
Zinc	-[5]	45.3	161.4	142	1503	0.9	20.1	24.8	EXCEEDS (mouse, grouse, robin)[7]

[1] Estimated plant concentrations based on overburden (KCa; CP3) data as reported by ETL (1993; n=1).

[2] Estimated plant concentrations based on tailings sand (Suncor Beach; CP5) data as reported by ETL (1993; n=1).

[3] RBC = THQ x (NOAEL x body weight)/(ingestion rate x exposure frequency x bioavailability factor).Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[5] No data or criterion available

[6] Although aluminum theoretically exceeds the RBC, aluminum as aluminum silicate in clay soils is not bioavailable. Therefore aluminum was excluded from further consideration.

[7] The only chemical that was identified for the robin was zinc. Zinc is a required nutrient and concentrations measured in these plants are not atypical, when compared to plants growing control areas. For these reason, the robin was not evaluated in the wildlife population exposure model.

TABLE X-22

COMPARISON OF ESTIMATED WATER CONCENTRATIONS ON THE RECLAIMED LANDSCAPE TO RISK-BASED CONCENTRATIONS FOR WILDLIFE

Page 1 of 1

Chemical	Far Future On-Site Water Quality[1] (mg/L)	RBC for[2] Moose (mg/L)	RBC for[2] Mallard (mg/L)	RBC for[2] Grouse (mg/L)	RBC for[2] Robin (mg/L)	RBC for[2] Beaver (mg/L)	RBC for[2] Snowshoe Hare (mg/L)	Comments
PAHS AND SUBSTITUTED PAHS								
Benzo(a)anthracene group[4]	0.00099	1.7	0.1	0.1	0.05	27	4	Does not exceed.
Benzo(a)pyrene group[4]	0.00008	0.2	0.01	0.008	0.005	2.7	0.4	Does not exceed.
NAPHTHENIC ACIDS								
Naphthenic acids	70	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	No criterion
INORGANICS								
Aluminum	1.15	0.3	91.5	76.6	47.7	5.3	0.8	EXCEEDS (hare)[5]
Antimony	nd	0.02	2.1	1.7	1.1	0.3	0.05	Does not exceed.
Arsenic	0.003	0.02	4.3	3.6	2.2	0.3	0.05	Does not exceed.
Barium	0.1	1.7	17.4	14.5	9.1	27	3.9	Does not exceed.
Beryllium	0.002	0.2	-[3]	-[3]	-[3]	2.7	0.5	Does not exceed.
Boron	1.88	9	24	20.1	12.5	140.5	20.4	Does not exceed.
Cadmium	0.004	1.2	1.2	1	0.6	5.4	0.9	Does not exceed.
Chromium	0.002	1	0.8	0.7	0.4	13753	2.4	Does not exceed.
Copper	0.006	4.9	39.2	32.8	20.4	77	11.2	Does not exceed.
Lead	nd	2.6	3.2	2.7	1.7	40.5	5.9	Does not exceed.
Manganese	0.213	28	814.6	682	424.8	441.7	64.3	Does not exceed.
Mercury	nd	0.4	0.38	0.314	0.196	6.8	0.9	Does not exceed.
Molybdenum	0.018	0.04	2.9	2.4	1.5	0.7	0.1	Does not exceed.
Nickel	nd	12.8	64.5	54	33.7	201.3	29.3	Does not exceed.
Selenium	0.0002	0.1	0.4	0.3	0.2	0.9	0.1	Does not exceed.
Silver	nd	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	No criterion
Strontium	0.278	83.8	-[3]	-[3]	-[3]	1321	192.2	Does not exceed.
Vanadium	0.01	0.1	9.5	7.9	4.9	0.9	0.1	Does not exceed.
Zinc	0.058	51	12.1	10.1	6.3	803.7	116.9	Does not exceed.

[1] Estimated based on sand seepage release waters predicted for the Shell reclaimed landscape.

[2] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

[3] No data or criterion

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[5] Although aluminum theoretically exceeds the RBC, the amount of dissolved aluminum in water is a minor component of the total aluminum concentration reported here and would be less than the RBC for snowshoe hare.

Therefore aluminum was excluded from further consideration

TABLE X-23

LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR WILDLIFE

Chemical	Water Shrew	Killdeer	Moose	Snowshoe Hare	Black Bear	Ruffed Grouse	Mallard	Deer Mouse
W-2: Exposure to Water and/or Aquatic Invertebrates (Operations and Closure)								
Barium	x	x						
Chromium		x						
Cobalt	x	x						
Copper	x	x						
Manganese	x							
Molybdenum			x		x			
Zinc	x	x						
W-3 Exposure to Terrestrial Plants (Operations)								
Antimony			x	x	x			
Barium			x	x	x	x		
Boron			x					
Cadmium			x					
Cobalt			x					
Copper			x	x	x	x		
Manganese			x	x	x			
Molybdenum			x					
Selenium			x					
Vanadium			x					
W-4 Multi-Media Exposure (Operations)								
Antimony			x	x	x			
Barium	x	x	x	x	x	x		
Boron			x					
Cadmium			x					
Chromium		x						
Cobalt	x	x	x					
Copper	x	x	x	x	x	x		
Manganese	x		x	x	x			
Molybdenum			x		x			
Selenium			x					
Vanadium			x					
Zinc	x	x						
W-7 Multi-Media Exposure (Closure)								
Barium			x	x			x	x
Boron			x					
Mercury								x
Molybdenum			x					x
Nickel								x
Selenium			x					x
Strontium								x
Vanadium			x	x				x
Zinc						x	x	x

X.1.3 CHEMICAL SCREENING FOR HUMAN HEALTH

X.1.3 Chemical Screening for Human Health

A similar methodical step-wise screening process was applied to identify chemicals of potential concern that might affect human health.

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

HH-1: Water-Mediated Exposure (Operation and Closure)

Water - Since operational release waters from Muskeg River Mine Project were not available, water chemistry data from similar oil sands facilities (i.e., Suncor and Syncrude) were used as surrogates for water quality modelling. Predicted concentrations in the Muskeg River were used for chemical screening, since they were more generally more conservative than Athabasca River concentrations. For more details on water quality, refer to Section E5. Maximum predicted concentrations were used for screening purposes.

Background water quality data used in this assessment included water samples that were collected in the Athabasca River upstream of the present oil sands operations (Syncrude and Suncor) and water samples collected in several tributaries of the Athabasca River (*i.e.,* Steepbank River, Leggett Creek, McLean Creek and Wood Creek).

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

Background fish tissue data were obtained from laboratory experiments in which walleye and rainbow trout were exposed to Athabasca River water collected upstream of the site (HydroQual 1996). For more details on fish quality, refer to Section E6.

HH-2: Air-Mediated Exposure (Operation)

Air - Air quality data were modelled based on predicted emissions from extraction and utilities, diesel exhaust emissions and off-gasing from tailings ponds and mine surfaces, as summarized in Section E2. This data was used in the chemical screening for key question HH-2.

HH-3: Plant-Mediated Exposure (Operation)

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

HH-7: Multi-Media Exposure (Closure)

Plants - Plant tissue concentrations were predicted for the reclaimed landscape scenario based on measured concentrations in reclamation soils (i.e., overburden, tailings sand and muskeg) and bioconcentration factors for plant uptake. The predicted plant tissue concentrations were used in chemical screening.

Meat - Game meat data were obtained from two sources for chemical screening: (i) duckling liver concentrations, following exposure to release water effluent in artificial wetlands (Bishay and Nix 1996); (ii) bison liver concentrations, following exposure on a reclaimed tailings sand pasture (Pauls et al. 1995).

Step 3: Compile Relevant Environmental Criteria and Select Screening Level Criteria

Human health criteria were compiled from various published sources and used to identify Screening Level Criteria (SLC). Each chemical identified in Step 1 and measured at concentrations above the analytical detection limit was compared to the SLC as outlined below.

Water - Drinking water criteria included:

- Health Canada (HC) Guidelines for Canadian Drinking Water Quality. Maximum Acceptable Concentration (HC 1996);
- U.S. EPA's (U.S. Environmental Protection Agency) Drinking Water Regulations and Health Advisories. Maximum Contaminant Level for Drinking Water_. (U.S. EPA 1996); and
- BC Environment (BCE) Contaminated Sites Regulation. Schedule 6. Generic Numerical Water Standards. Drinking Water (BCE 1997).

The lowest value of the three above criteria was used as the SLC for chemicals in drinking water for people (Table X-20).

Air - The following criteria were used for screening chemicals in air:

- Odorous compounds: odour thresholds reported by Ruth (1986) and Amoore and Hautala (1983);
- Alberta Ambient Air Quality Guidelines;
- BC Environment Air Quality Standards;
- Canadian National Ambient Air Quality Objectives;
- US EPA National Ambient Air Quality Standards; and
- National Ambient Air Quality Objectives for Particulate Matter (WGAQOG 1997).

Fish, Meat and Plants - Regulatory SLC were not available for screening of fish, meat and plants.

Steps 4 and 5: Comparison of Maximum Observed Concentration to SLC and background Concentrations

Maximum observed concentrations were first compared to SLC If the concentration of a chemical did not exceed the SLC, then the chemical was eliminated from further consideration. If the chemical concentration exceeded the SLC or if there was no SLC for a chemical, it was then compared to background concentrations. If the concentration of a chemical was less than or equal to background concentrations, it was eliminated from further consideration since these chemical concentrations were assumed to be natural in origin and not Project-related. If the concentration of a chemical exceeded background concentrations, it was carried forward to Step 6.

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

At this stage, risk-based concentrations (RBCs) were identified for all chemicals for which site concentrations exceeded both SLC and background concentrations. RBCs for the ingestion of drinking water, fish and inhalation of air are available from the U.S. EPA's Region III Risk-Based Concentration Table (Smith 1997), based on adult exposure and a target hazard quotient of 1.0. These RBCs were conservatively recalculated for non-carcinogenic chemicals to account for child exposure and a target hazard quotient of 0.1, assuming that a person could only receive one-tenth of his/her daily exposure from each media. The resulting RBCs for non-carcinogenic chemicals were approximately 27-fold lower than those reported in Smith (1997). RBCs were not recalculated from Smith (1997) for carcinogenic chemicals, since these RBCs were based on child and adult exposure during the first 30 years of life and an acceptable risk level of one-in-one million, rather than the acceptable risk level of one-in-one-hundred-thousand endorsed by Health Canada, and therefore were already conservatively calculated. RBCs for plants were calculated using the equations outlined in Smith (1997) and the conservative assumptions described previously for water, fish and meat. RBCs for fish were also applied to game meat for screening. The RBCs used were based on the assumption that people would drink the source water, inhale site air, eat fish, game meat and plants collected from the site on a daily basis, 350 days per year for 30 years.

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

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

Chemicals, for which RBCs could not be indentified, were retained for further evaluation in Step 7. Certain compounds may be eliminated from further consideration based on their importance as a dietary component, status as an essential nutrient, or general lack of toxic effects at the measured concentrations. Calcium, magnesium, potassium, iron and sodium can generally be eliminated from further evaluation at the screening stage based on dietary and nutritional status (U.S. EPA 1989). Other chemicals may be considered non-toxic under certain conditions of exposure. These are described below.

Aluminum

Aluminum is the third most abundant element in the earth's crust and is present in all rock types and most geologic materials, especially clays (CCREM 1987). Total aluminum measurements in soil reflect the natural abundance of aluminum silicate in soils, which are less than 1% bioavailable by the oral route. The daily intake of aluminum, estimated at 88 mg per day by WHO, is largely from food. For these reasons, the elevated aluminum concentrations in reclamation soils were not evaluated further in the risk assessment.

Ammonia

Although considered an odour nuisance at low concentrations in water, ammonia was not considered a human health concern via the ingestion pathway. The RBC for ammonia is based on a threshold for inhalation; drinking water thresholds (HEAST 1995) are based on aesthetic effects, rather than adverse health effects.

Chloride

Chloride is an essential nutrient for people, which functions to ensure the proper fluid-electrolyte balance. Water is a relatively minor contributor of chloride compared to intake from other sources such as food (CCREM 1987). Therefore, health implications with respect to chloride are not considered to be significant. The main consideration regarding chloride is prevention of undesirable taste in water and water-based beverages. Given that chloride is essential for human health, chloride was eliminated from further consideration.

Manganese

Manganese is an essential nutrient and concentrations related to possible health concerns are much greater than those related to aesthetic considerations (CCREM 1987). Manganese will stain plumbing and laundry, produce an undesirable taste and cause encrustation problems in piping. The water quality guideline for drinking water is based on an aesthetic objective rather human health considerations (HC 1996). In addition, the body normally controls the amount of manganese that is taken up and retained (ATSDR 1991). For example, if large amounts are ingested, the amount that is taken up in the body becomes smaller. If too much does enter the body, the excess is usually removed in the feces. Therefore, the total amount of manganese in the body usually tends to stay about the same, even when exposure rates are higher or lower than usual. Therefore, given that there is no anthropogenic source for manganese, that absorption of manganese into the body is low and that manganese is an essential nutrient, this chemical was eliminated from further consideration.

Silicon

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

Sulphate

Soluble sulphate salts of sodium, magnesium, potassium, lithium, etc. are rather slowly absorbed from the alimentary tract. The amount of sulphate anion usually absorbed has no toxicological significance

(Gosselin et al. 1984); therefore, it was considered non-hazardous for the purpose of this assessment.

Zinc

Zinc is a natural element present in the earth's crust and an essential dietary element for people and wildlife. The available Health Canada toxicity reference value for zinc is based on the recommended daily intake for this essential nutrient, rather than a level associated with toxicity. Zinc was identified in the chemical screening of plant tissue concenrations. This is not unexpected since zinc is a common constituent of food. Therefore, due to its nutrient status, zinc was not evaluated further in the risk assessment.

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

In this step, the maximum chemical concentrations measured in water, fish, plants and game animals were compared to the RBCs. If the maximum concentration of a chemical exceeded the RBC, then the chemical was retained for further evaluation in the risk assesssment. If the RBC was not exceeded, then the chemical was eliminated from further consideration.

Screening tables are presented in Tables X-24 to X-30. The final chemical list for each key question is presented in Table X-31, indicating the media in which elevated chemical concentrations were identified. For key questions HH-4 and HH-7, all chemicals that were identified in one or more media were evaluated in all media. This was done to determine the combined exposure to these chemicals from all potentially affected media (i.e., water, air, plants, game meat, fish) during operation (HH-4) and following closure (HH-7). Detailed screening tables for each media are presented at the end of this section.

Chemicals of Concern in Background Media

It should be noted that a few chemicals have been identified at elevated concentrations in background media. These include:

- mercury (water and fish)
- arsenic (water)

Levels of mercury in fish tissues are relatively high and may pose a health risk to people eating fish from this region of the river.

Relatively high levels of mercury in fish tissues have also been noted by NRBS, and the high levels of mercury have been attributed to natural sources (NRBS 1996). Arsenic concentrations in the Muskeg River are also naturally elevated. The Project site is not expected to contribute to increased levels of mercury or arsenic in water or fish tissue. However, due to interest articulated by regulators at the Human and Ecological Health Component Focus Workshop (October 30, 1997), arsenic was evaluated in the risk assessment. With respect to mercury, further analysis of water and fish tissue is required to address elevated background concentrations of this element and potential food chain effects.

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TABLE X-24

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Page 1 of 3

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

TABLE X-24

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

Page 2 of 3

Chemicals	HWC[1] Drinking Water Criteria (mg/L)	U.S. EPA[2] Drinking Water Criteria (mg/L)	BC MOE[3] Drinking Water Criteria (mg/L)	Screening Level[4] Criteria (mg/L)
m-cresol	-[5]	-[5]	-[5]	-[5]
NAPHTHENIC ACIDS				
Naphthenic acids	-[5]	-[5]	-[5]	-[5]
INORGANICS				
Aluminum	-[5]	0.2[7]	0.2	0.2[7]
Ammonia	-[5]	-[5]	-[5]	-[5]
Antimony	-[5]	0.006	-[5]	0.006
Arsenic	0.025	0.05	0.025	0.025
Barium	1	2	1	1
Beryllium	-[5]	0.004	-[5]	0.004
Boron	5	-[5]	5	5
Cadmium	0.005	0.005	0.005	0.005
Calcium	-[5]	-[5]	-[5]	-[5]
Chloride	250[7]	250[7]	250[7]	250[7]
Chromium	0.05	0.1	0.05	0.05
Cobalt	-[5]	-[5]	-[5]	-[5]
Copper	1[15]	1.3	1	1
Cyanide	0.2	0.2	0.2	0.2
Iron	0.3[7]	0.3[7]	0.3[7]	0.3[7]
Lead	0.01	0.015	0.01	0.01
Lithium	-[5]	-[5]	-[5]	-[5]
Magnesium	-[5]	-[5]	-[5]	-[5]
Manganese	0.05[7]	0.05[7]	0.05[7]	0.05[7]
Mercury	0.001	0.002	0.001	0.001
Molybdenum	-[5]	-[5]	0.25	0.25
Nickel	-[5]	0.14	0.2	0.14
Phosphorus	-[5]	-[5]	-[5]	-[5]

TABLE X-24

HUMAN HEALTH SCREENING LEVEL CRITERIA FOR CONSUMPTION OF DRINKING WATER

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

[1] Health Canada Maximum Acceptable Concentrations (MAC) (HC 1996)

[2] U.S. Environmental Protection Agency Maximum Contaminants Level for drinking water for human health (U.S. EPA 1996).

[3] British Columbia Ministry of the Environment water standards for drinking water (B.C. Contaminated Sites Regulation, 1997).

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

[5] No criterion.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

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

TABLE X-25

COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 1 of 2

Chemical	Future Muskeg River Concentrations			Screening Level Criteria[4]	Background Muskeg River[5] (median)	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHS AND SUBSTITUTED PAHS						
Benzo(a)anthracene group[7]	0	1.70E-05	3.10E-07	0.0001	nd	Does not exceed
Benzo(a)pyrene group[7]	0	3.70E-06	2.30E-08	0.00001	nd	Does not exceed
NAPHTHENIC ACIDS						
Naphthenic acids	4	3.74	3.95	-[6]	4	No criterion; Does not exceed background
INORGANICS						
Aluminum	0.06	0.22	0.05	0.2	0.05	EXCEEDS
Ammonia	0.06	0.06	0.05	-[6]	0.05	No criterion; EXCEEDS BACKGROUND[9]
Antimony	4.60E-06	0.00011	5.30E-09	0.006	nd	Does not exceed.
Arsenic	0.003	0.0032	0.0028	0.025	0.0029	Does not exceed.
Barium	0.03	0.04	0.03	1	0.03	Does not exceed.
Beryllium	9.20E-06	4.50E-04	1.60E-06	0.004	nd	Does not exceed.
Boron	0.04	0.35	0.05	5	0.05	Does not exceed.
Cadmium	0.0002	0.0008	0.0002	0.005	0.0002	Does not exceed.
Calcium	39	46.6	38.5	-[6]	38.4	No criterion; EXCEEDS BACKGROUND[9]
Chloride	3.1	7.8	3.2	250[8]	3.1	Does not exceed.
Chromium	0.001	0.002	0.001	0.05	0	Does not exceed.
Copper	0.001	0.002	0.001	1	0.001	Does not exceed.
Iron	0.83	0.97	0.81	0.3[8]	0.79	EXCEEDS
Lead	0.0004	0.0017	0.0004	0.01	0.0004	Does not exceed.
Magnesium	9.6	11.1	9.6	-[6]	9.6	No criterion; EXCEEDS BACKGROUND[9]
Manganese	0.05	0.07	0.04	-[6]	0.04	No criterion; EXCEEDS BACKGROUND
Mercury	0.0001	0.0001	0.0001	0.05	0.0001	Does not exceed.
Molybdenum	0.0002	0.0847	0.0002	0.001	0.0002	Does not exceed.
Nickel	0.0004	0.0021	0.0004	0.25	0.0004	Does not exceed.
Selenium	0.0001	0.0002	0.0001	0.01	nd	Does not exceed.
Silver	0	0.00012	5.90E-09	-[6]	5.90E-09	No criterion; EXCEEDS BACKGROUND
Sodium	10.4	54.8	10.6	200[8]	10.4	Does not exceed.

TABLE X-25

COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO BACKGROUND CONCENTRATIONS AND TO HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 2 of 2

Chemical	Future Muskeg River Concentrations			Screening Level Criteria[4]	Background Muskeg River[5] (median)	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]			
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Strontium	0.06	0.2	0.06	-[6]	0.06	No criterion; EXCEEDS BACKGROUND
Sulphate	4.52	81.17	4.61	500[8]	4.52	Does not exceed.
Vanadium	0.0004	0.011	0.0004	-[6]	0.0004	No criterion; EXCEEDS BACKGROUND
Zinc	0.013	0.015	0.011	5	0.011	Does not exceed.

[1] Maximum predicted concentration during construction and operation phases (2000-2025)

[2] Predicted concentration for second year after closure (2030).

[3] Predicted concentration for equilibrium post-closure conditions in the far future.

[4] Screening Level Criteria were based on the lowest water quality criteria for human drinking water

[5] Median concentrations in the Muskeg River in 1997 (Section E5).

[6] No data or criterion.

[7] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[8] Based on an aesthetic objective for drinking water

[9] These compounds were not evaluated in the risk assessment since they are nutrients and/or non-toxic

nd not detected

TABLE X-26
COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 1 of 2

Chemical	Release Water Concentrations			RBC for Water Ingestion[4] (RBC)	Comments
	Construction and Operation 2000-2025 (max)[1] (mg/L)	Closure 2030 (max)[2] (mg/L)	Closure Equilibrium (max)[3] (mg/L)	(mg/L)	
PAHS AND SUBSTITUTED PAHS					
Benzo(a)anthracene group[6]	0	0.000011	4.00E-07	0.00001	EXCEEDS
Benzo(a)pyrene group[6]	0	0.0000024	3.20E-08	0.000001	EXCEEDS
NAPHTHENIC ACIDS					
Naphthenic acids	4	3.8	3.9	-[5]	No criterion
INORGANICS					
Aluminum	0.06	0.22	0.05	1.37	Does not exceed.
Antimony	4.60E-06	0.00011	5.30E-09	0.0006	Does not exceed.
Arsenic	0.003	0.0032	0.0028	0.000045	EXCEEDS
Barium	0.03	0.04	0.03	0.096	Does not exceed.
Beryllium	9.20E-06	4.50E-04	1.60E-06	0.000016	EXCEEDS
Boron	0.04	0.35	0.05	0.12	EXCEEDS
Cadmium	0.0002	0.0008	0.0002	0.0007	EXCEEDS
Chromium	0.001	0.002	0.001	1.37	Does not exceed.
Copper	0.001	0.002	0.001	0.056	Does not exceed.
Lead	0.0004	0.0017	0.0004	0.0006	EXCEEDS
Manganese	0.05	0.07	0.04	0.03	EXCEEDS
Mercury	0.0001	0.0001	0.0001	0.004	Does not exceed.
Molybdenum	0.0002	0.0847	0.0002	0.01	EXCEEDS
Nickel	0.0004	0.0021	0.0004	0.03	Does not exceed.
Selenium	0.0001	0.0002	0.0001	0.007	Does not exceed.
Silver	0	0.00012	5.90E-09	0.19	Does not exceed.
Strontium	0.06	0.2	0.06	0.81	Does not exceed.
Vanadium	0.0004	0.011	0.0004	0.004	EXCEEDS

TABLE X-26
COMPARISON OF FUTURE MUSKEG RIVER CONCENTRATIONS TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH SCREENING LEVEL CRITERIA FOR WATER

Page 2 of 2

Chemical	Release Water Concentrations			RBC for Water Ingestion[4] (RBC)	Comments
	Construction and Operation 2000-2025 (max)[1]	Closure 2030 (max)[2]	Closure Equilibrium (max)[3]		
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Zinc	0.013	0.015	0.011	0.41	Does not exceed.

[1] Maximum predicted concentration during construction and operation phases (2000-2025)

[2] Predicted concentration for second year after closure (2030).

[3] Predicted concentration for equilibrium post-closure conditions in the far future.

[4] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10^{-6} (carcinogens)

[5] No data or criterion.

[6] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

TABLE X-27
COMPARISON OF CHEMICAL CONCENTRATIONS IN FISH TISSUE TO RISK-BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemical	Muskeg River[1] Longnose Sucker (ug/g) Max	Athabasca River[1] Walleye (ug/g) Max	Athabasca River[1] Goldeye (ug/g) Max	10%TID[2] Walleye (ug/g) Max - Lab	RBC for[3] Fish Ingestion (ug/g)	Comments
PAHS AND SUBSTITUTED PAHS						
Naphthalene group[4]	0.09	<0.02	<0.02	<0.02	2	Does not exceed
INORGANICS						
Copper	<1	1	2	<1	2	Does not exceed
Manganese	0.9	1.2	<0.5	6.1	1	EXCEEDS[5]
Nickel	<1	<1	2	<2	1	EXCEEDS[6]
Zinc	6	9	6	17.5	15	EXCEEDS[5]

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

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

[3] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1×10^{-6} (carcinogens).

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

[5] These compounds were not evaluated in the risk assessment since they are required nutrients and do not exceed the RBC by more than 10-fold.

[6] Nickel was not evaluated in the risk assessment for HH-1 since it was only detected in one fish sample and was not accumulated in the laboratory study; it was evaluated in HH-4 (combined exposure scenario).

< These chemicals were not detected above detection limits.

Note: Comparison of site concentrations to background concentrations was previously presented in Table X-9.

TABLE X-28

COMPARISON OF CHEMICAL CONCENTRATIONS IN PLANT TISSUE TO RISK-BASED CONCENTRATIONS FOR HUMANS

Chemical	Baseline Shell Lease 13[1] (ug/g) Max	Potential Future[2] (ug/g) Max	RBC for Plant Ingestion[3] (ug/g)	Comments
Blueberries				
Boron	7	6	6.1	EXCEEDS
Cadmium	0.09	<0.08	0.03	EXCEEDS
Copper	4.15	3.14	2.5	EXCEEDS
Lead	<0.4	0.3	0.24	EXCEEDS
Manganese	194	315	0.34	EXCEEDS[4]
Nickel	0.99	0.66	1.4	Does not exceed
Strontium	1.48	1.3	40.7	Does not exceed
Zinc	1	11	20.3	Does not exceed
Labrador Tea				
Naphthalene group	0.2	0.25	12	Does not exceed
Antimony	<0.04	0.68	0.12	EXCEEDS
Barium	120	112	21	EXCEEDS
Boron	21	25	27	Does not exceed
Cadmium	0.08	0.09	0.15	Does not exceed
Chromium	<0.5	0.4	298	Does not exceed
Cobalt	0.31	0.13	18	Does not exceed
Copper	74	23.2	11	EXCEEDS
Lead	2.9	0.8	1.1	EXCEEDS
Manganese	1070	1010	1.5	EXCEEDS[4]
Mercury	0.03	0.05	0.09	Does not exceed
Nickel	6.92	4.67	6	EXCEEDS
Strontium	8.58	19.9	179	Does not exceed
Vanadium	<0.08	0.15	2.1	Does not exceed
Zinc	54.5	34	89	Does not exceed
Cattail Root				
Mercury	0.04	0.07	12	Does not exceed
Aluminum	693	611	298	EXCEEDS[5]
Barium	46.9	47.3	21	EXCEEDS
Boron	29	13	27	EXCEEDS
Cadmium	0.17	0.09	0.15	Does not exceed
Chromium	1	1.2	298	Does not exceed
Cobalt	5.24	1.37	18	Does not exceed
Copper	3.36	14.4	11	EXCEEDS
Lead	1.4	2.5	1.1	EXCEEDS
Molybdenum	<0.4	1.7	1.5	EXCEEDS
Nickel	6.43	3.98	6	EXCEEDS
Selenium	0.2	0.7	1.5	Does not exceed
Strontium	36.4	38.5	179	Does not exceed
Vanadium	7.16	6.07	2.1	EXCEEDS
Zinc	59.2	26	89	Does not exceed

[1] Samples collected on Shell Lease 13 by Golder during 1997.

[2] Samples collected east of Suncor within zone of potential influence from air emissions by Golder during 1997.

[3] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10-6 (carcinogens).

[4] Manganese was not evaluated in the risk assessment since it is a required nutrient.

[5] Although aluminum theoretically exceeds the RBC for plant ingestion, aluminum is ubiquitous in the environment and less than 1% bioavailable by the oral route. Therefore, aluminum was excluded from further consideration.

< These compounds were not detected above detection limits.

Note: Comparison of site concentrations to background concentrations was previously presented in Tables X-11 to X-13.

TABLE X-29

COMPARISON OF OBSERVED AND ESTIMATED CHEMICAL CONCENTRATIONS IN PLANTS GROWING ON RECLAMATION SOILS TO RISK-BASED CONCENTRATIONS (RBCs) FOR HUMAN HEALTH

Chemicals	Plants Growing on Overburden[1] (mg/kg plant)	Plants Growing on Tailings Sand[2] (mg/kg plant)	RBC for Plant Ingestion[3] (mg/kg plant)	Comments
PAHS AND SUBSTITUTED PAHS				
Benzo(a)anthracene group[4]	-[5]	0.00975	0.0005	EXCEEDS
Benzo(a)pyrene group[4]	-[5]	0.002	0.00005	EXCEEDS
Benzo(b&k)fluoranthene group[4]	-[5]	0.0003	0.0005	Does not exceed
Dibenzothiophene group[4]	0.0264	0.088	-[5]	No RBC
Fluorene group[4]	0.0075	-[5]	0.19	Does not exceed
Fluoranthene group[4]	-[5]	0.00037	0.19	Does not exceed
Naphthalene group[4]	0.2156	-[5]	0.19	Does not exceed
Phenanthrene group[4]	0.015	0.056	0.14	Does not exceed
Pyrene	-[5]	0.00152	0.14	Does not exceed
INORGANICS				
Aluminum	-[5]	80.4	169.46	Does not exceed
Arsenic	-[5]	0.062	0.01	EXCEEDS
Barium	-[5]	19.1	11.86	EXCEEDS
Beryllium	0.015[1]	-[5]	0.0036	EXCEEDS
Boron	-[5]	35.9	15.25	EXCEEDS
Cadmium	-[5]	0.3	0.08	EXCEEDS
Cobalt	-[5]	0.1	10.17	Does not exceed
Chromium	-[5]	0.9	169.46	Does not exceed
Copper	-[5]	3.8	6.29	Does not exceed
Lead	-[5]	0.22	0.6	Does not exceed
Mercury	-[5]	0.013	0.05	Does not exceed
Molybdenum	-[5]	0.65	0.85	Does not exceed
Nickel	-[5]	0.96	3.39	Does not exceed
Selenium	-[5]	0.44	0.85	Does not exceed
Strontium	-[5]	48.2	101.68	Does not exceed
Vanadium	-[5]	0.43	1.19	Does not exceed
Zinc	-[5]	45.3	50.84	Does not exceed

[1] Estimated concentrations in plants based on overburden (KCa; CP3) data as reported by ETL (1993; n=1); Table X-20.

[2] Estimated PAH concentrations in plants based on tailings sand (Suncor Beach; CP5) data as reported by ETL (1993; n=1); Table X-20;
For metals, geometric mean of measured concentrations in plants grown on muskeg capped tailings sand in the Tar Island Dyke area (Golder 1997r).

[3] Risk-based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10^{-6} (carcinogens).

[4] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1

[5] No data or criterion available

TABLE X-30

COMPARISON OF CHEMICAL CONCENTRATIONS IN DUCKLING AND BISON LIVER TISSUE TO RISK BASED CONCENTRATIONS FOR HUMAN HEALTH

Chemicals	Duckling Tissue[1]				Bison Tissue[2] Concentration (ug/g)	Risk-Based[3] Concentration for meat (ug/g)	Comments
	CT Pond (ug/g)	CT Wetland (ug/g)	DD Pond (ug/g)	DD Wetland (ug/g)			
ORGANICS							
Naphthalene	-[4]	-[4]	-[4]	-[4]	0.008	2	Does not exceed
INORGANICS							
Aluminum	-[4]	-[4]	-[4]	-[4]	43	51.9	Does not exceed
Barium	1.09	0.35	0.2	0.23	2.8	3.5	Does not exceed
Cadmium	-[4]	-[4]	-[4]	-[4]	0.27	0.03	EXCEEDS
Chromium	0.5	0.09	0.2	0.1	0.4	0.3	EXCEEDS
Cobalt	-[4]	-[4]	-[4]	-[4]	0.2	3	Does not exceed
Copper	281	255	247	251	52.4	2	EXCEEDS
Lead	<1	<1	<1	1	<0.8	40	Does not exceed
Manganese	-[4]	-[4]	-[4]	-[4]	12.4	0.3	EXCEEDS[5]
Molybdenum	-[4]	-[4]	-[4]	-[4]	4.7	0.3	EXCEEDS
Nickel	0.2	<0.2	<0.2	<0.2	1	1	Does not exceed
Selenium	-[4]	-[4]	-[4]	-[4]	1	0.3	EXCEEDS
Sulfur	-[4]	-[4]	-[4]	-[4]	7550	-[4]	No RBC
Titanium	-[4]	-[4]	-[4]	-[4]	1.89	-[4]	No RBC
Zinc	-[4]	-[4]	-[4]	-[4]	121	15	EXCEEDS

[1] Duckling liver tissue residue data from Wolfe and Norman as cited in Bishay and Nix (1996); ducklings were exposed to CT water or DD water.

[2] Bison liver tissue residue data from Pauls et al. (1995); bison were grazing on a reclaimed tailings deposit.

[3] Risk-based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10-6 (carcinogens).

[4] Not analyzed or no data.

[5] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

TABLE X-31

LIST OF CHEMICALS RETAINED FOLLOWING CHEMICAL SCREENING FOR HUMAN HEALTH

Chemical	HH-1	HH-2	HH-3	HH-4	HH-7
INORGANIC CHEMICALS					
Antimony			x	x	
Arsenic	x			x	x
Barium			x	x	x
Beryllium	x			x	x
Boron	x		x	x	x
Cadmium	x		x	x	x
Chromium					x
Cobalt					x
Copper			x	x	
Lead	x		x	x	x
Molybdenum	x		x	x	x
Nickel			x	x	
Selenium					x
Vanadium	x		x	x	x
ORGANIC CHEMICALS					
Benzo(a)anthracene	x	x		x	x
Benzo(a)pyrene	x	x		x	x
Naphthenic Acids	x			x	x
Aldehydes		x			
Ketones		x			
Aliphatics		x			
Aromatics		x			
Non-carcinogenic PAHs		x			
Formaldehyde		x			
Acetaldehyde		x			
Benzene		x			
Chrysene		x			
Benzo(b)fluoranthene		x			
Benzo(k)fluoranthene		x			
Indeno(1,2,3)pyrene		x			
Dibenz(a)anthracene		x			

X.2.1 RECEPTOR SCREENING FOR WILDLIFE HEALTH

X.2 Receptor Screening

Details of the receptor screening process are described below for each key question.

X.2.1 Receptor Screening for Wildlife Health

The reclaimed site must, according to government regulations (AEP 1995b), develop into a normal, healthy ecosystem. In addition, exposure to chemicals associated with the site must not lead to unacceptable impacts in organisms supported by the ecosystem. It is, therefore, necessary to assess potential impacts for all major trophic levels. It is of course, impossible, and not necessary, to examine potential effects on every organism that might be exposed to chemicals associated with the site. Instead, representative species (or receptors) were selected as the basis for evaluating potential impacts.

The objective of wildlife receptor screening was to: i) identify wildlife that might currently use the Muskeg or Athabasca Rivers; ii) identify herbivores that might forage near the Muskeg River Mine Project during operation; iii) identify wildlife that might inhabit the reclaimed landscape; and iv) to focus the assessment on a manageable number of key receptors. Receptors were selected based on a wildlife inventory of the area, discussions with wildlife biologists conducting baseline studies, and guidance from the literature (Algeo et al. 1994; Suter 1993). The overall emphasis of the ecological receptor screening was the selection of representative receptors that would be at greatest risk, that play a key role in the food web, and that have sufficient characterization data to facilitate calculations of exposure and health risks. Receptors were also selected to include animals that have societal relevance and that are a food source for people. Wildlife species determined to be KIRs for the Muskeg River Mine Project EIA were also given extra weight in the evaluation. To be consistent, the wildlife receptors chosen in this assessment are the same as those evaluated in previous environmental impact assessments for Syncrude (BOVAR 1996a) and Suncor (Golder 1996a).

A different set of wildlife receptors were selected for evaluation of each key question, based on maximum likely exposure to the media being evaluated.

W-2: Water-Mediated Exposure (Operation and Closure)

For key question W-2, aquatic wildlife (i.e., water shrew, killdeer, river otter, great blue heron) were chosen to represent various trophic levels of receptors likely to use the Muskeg and Athabasca Rivers as a source of drinking water and food (i.e., invertebrates and fish).

Insectivores were considered important as PAHs may accumulate in some invertebrate prey. Fish-eating predators also were included to assess the potential for food chain effects. In addition to aquatic wildlife, several terrestrial wildlife species (i.e., moose, snowshoe hare and black bear) were evaluated for key question W-2, since they may drink water from local rivers.

W-3: Plant-Mediated Exposure (Operation)

For key question W-3, herbivorous or omnivorous wildlife species were selected, since these species would incur the maximum exposures through consumption of plants. The selected receptors included moose, snowshoe hare, black bear, ruffed grouse and mallards. Snowshoe hare, black bear and ruffed grouse would be exposed solely to terrestrial plants, mallards would be exposed solely to aquatic plants and moose would be exposed to both terrestrial and aquatic plants.

W-4: Water- and Plant-mediated Exposure (Operation)

Combined exposure was evaluated for all receptors assessed under W-2 and W-3.

W-7: Multi-Media Exposure (Closure)

For key question W-7, birds and mammals which may inhabit the reclaimed landscape were selected. Herbivores were selected as important receptors since metals can potentially accumulate in some plant tissues, and insectivores were considered important since PAHs may accumulate in some invertebrate prey. Some of these species (i.e., moose, snowshoe hare, ruffed grouse) are also important game animals. Predators also were considered to assess the potential for food chain effects. However, most of the chemicals identified in the screening process do not have the potential to significantly biomagnify through food chains, therefore predator wildlife species were not selected as receptors. Although mercury was identified as a chemical of concern for deer mice, the degree of exposure of deer mice to mercury was determined to be very low in exposure modelling. In addition, mercury biomagnification in terrestrial food chains would be expected to be lower than in aquatic food chains, as less methylation of mercury is expected to occur in terrestrial environments. For these reasons, it was assumed that significant biomagnification of mercury in the tissues of predators of deer mice would not likely occur. Wildlife receptors evaluated in the reclamation scenario included:

X.2.2 RECEPTOR SCREENING FOR HUMAN HEALTH

X.2.2 Receptor Screening for Human Health

HH-1: Water-Mediated Exposure (Operation and Closure)

During operation of the Muskeg River Mine Project, human use of the land will be restricted to workers. However, it is reasonable to assume that the Muskeg and Athabasca Rivers could be used by members of the Fort McKay First Nations and others for activities such as swimming, hiking, fishing and boating. Hence, the assessment of potential impacts on human health focused on: i) swimming and ii) recreational use. The swimming scenario addresses chemical intake via dermal exposure and incidental ingestion that would occur while swimming (or using the water for washing and/or bathing). The recreational scenario addresses occasional use of river water as a drinking water source, such as might occur during recreational activities. Both children and adults may take part in these activities.

HH-2: Air-Mediated Exposure (Operation)

Adults and children may be exposed to air emissions from the Project that may be dispersed by winds to nearby residential communities, such as Fort McKay and Fort McMurray.

HH-3: Plant-Mediated Exposure (Operation)

First Nations communities harvest many local nutritional and medicinal plants. Both children and adults may consume these plants and therefore both of these lifestages were evaluated for this key question.

HH-4: Water-, Air-, and Plant-Mediated Exposure (Operation)

Child, adult and composite receptors were evaluated for this key question to determine the potential risks from combined exposure to various potentially affected media.

HH-7: Multi-Media Exposure (Closure)

Due to the close proximity of the Project to Fort McKay, it is reasonable to assume that following reclamation, the site might be used by members of the Fort McKay First Nations for traditional activities, including hunting, trapping and gathering. Although all ages of people might utilize these lands, the most extensive uses would be from adults who might live on the land for extended periods of time while hunting and trapping. Therefore, the human receptors evaluated in this assessment were assumed to be adult hunters and trappers, who might reside on-site throughout the year. In addition, a child receptor was evaluated, since it was assumed the hunter/trapper would bring plants and game meat back to feed his family.

Lifestages Evaluated

Potential health impacts on children and adults were evaluated. Health Canada (1994) defines five distinct life stages for the purpose of risk assessment. In conformance with this guidance, adults are defined as 20 years of age and older (up to a lifespan of 70 years). For all exposures, except air inhalation, children were defined as between the ages of 7 months and 4 years (i.e., "pre-school children" as defined in guidance), since the exposure parameters for this lifestage maximize exposures due to ingestion of food and water (i.e., maximum ingestion rate to body weight ratio). For air inhalation, children were defined as between the ages of 5 and 11 years, since the ratio of inhalation rate to body weight is maximized for this lifestage. For these reasons, the predicted exposures for children were conservatively maximized in the risk assessment.

Senior citizens were also considered as potential receptors for the risk assessment due to concerns expressed at the Human and Ecological Health Component Focus Workshop (October 30, 1997). For the reasons outlined in Section E12.5.3 of the main text, it was concluded that results for the adult receptor (age 20+) would also apply to seniors (age 60+) and therefore a separate senior receptor was not evaluated.

For carcinogenic chemicals, a so-called "composite receptor" was evaluated from birth until 70 years of age to address the residual risk from non-threshold substances after cessation of exposure.

Mammalian Receptors

- beaver (semi-aquatic herbivore)
- moose (large herbivore)
- snowshoe hare (small terrestrial herbivore)
- deer mouse (small terrestrial omnivore)

Avian Receptors

- mallard (semi-aquatic omnivore)
- ruffed grouse (terrestrial herbivore)
- American robin (terrestrial insectivore/omnivore)

X.3.1 EXPOSURE PATHWAY SCREENING FOR WILDLIFE HEALTH

X.3.2 EXPOSURE PATHWAY SCREENING FOR HUMAN HEALTH

X.3.2 Exposure Pathway Screening for Human Health

HH-1: Water-Mediated Exposure (Operation and Closure)

Ingestion of surface water - As identified during the chemical screening, several chemicals that are of potential concern are and will be released from both operational and reclamation waters. People could be exposed by ingesting surface water intentionally or through incidental ingestion while swimming.

Ingestion of fish - The chemical screening showed no evidence that exposure to operational or reclamation waters from the Project results in accumulation of chemicals to levels above background. Thus, this exposure pathway was not considered further in the risk assessment for key question HH-1.

Direct contact with surface water - People can be exposed to chemicals released from the Project through direct contact with surface water while swimming. Although the contribution of dermal exposure to chemicals in surface water is expected to be small relative to ingestion exposure, this pathway was retained for further analysis to confirm this assumption.

HH-2: Air-Mediated Exposure (Operation)

Inhalation of volatile chemicals - Volatilization of volatile organic compounds (VOCs) from tailings ponds and mine surfaces can result in direct exposure to people through inhalation. Depending on the airborne concentrations of these chemicals, exposures may be incurred both on-site (i.e., by a worker) or off-site (i.e., by local residents in nearby communities). Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of diesel emissions - The vehicle fleet for the Muskeg River Mine Project will release a large quantity of diesel exhaust during the construction and operation phases of the Project. People may be exposed to PAHs and VOCs from diesel emissions both on-site (i.e., by a worker) or off-site (i.e., by local residents in nearby communities). Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of particulates - Particulates will be released from extraction and utilities and the vehicle fleet. Workers and off-site residents may directly inhale these particulates. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Inhalation of acid gases - Project activities are expected to release acid gases (e.g., SO_2, NO_X) into the air. Both workers and off-site residents may be exposed directly to these gases through inhalation. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-2.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to people through dermal uptake of chemicals present in air vapours. However, the contribution by this pathway, in comparison to direct inhalation was assumed to be insignificant and therefore this exposure pathway was not considered further in the risk assessment for key question HH-2.

HH-3: Plant-Mediated Exposure (Operation)

Ingestion of local plants - Certain local plants (i.e., berries, leaves and cattail/ratroot) are harvested and consumed on a regular basis by members of nearby residential communities. Some of these plants are ingested for their medicinal properties, while others are ingested for nutritional purposes. Air emissions from the Project may deposit onto plant surfaces and soils and subsequently be taken up into plant tissues. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-3.

HH-4: Water-, Air-, and Plant-Mediated Exposure (Operation)

All exposure pathways identified for HH-1, HH-2 and HH-3 were retained for evaluation of key question HH-4. In addition, ingestion of fish was included as an exposure pathway to evaluate the combined contribution from various media.

HH-7: Multi-Media Exposure (Closure)

Volatile Chemicals - Volatilization of VOCs from surface water and soils into the air can result in direct exposure to people, particularly to those that might live on the reclaimed site following reclamation, through inhalation of vapours. However, disturbed areas of the site will be capped with a layer of reconstructed soils, reducing the potential for volatile air releases. Although there is some potential for release of volatile chemicals through the capping layer and into the air above CT deposits, these releases will decrease over time as the CT consolidates. Therefore, this exposure pathway was not considered further in the risk assessment for HH-6.

Fugitive dust generation from surface soils - Fugitive dust generated from surface soils can result in exposure to people through inhalation of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because CT deposits will be capped with sand and muskeg so erodible chemical concentrations of soils will be comparable to natural background levels and landscapes will also be covered with vegetation; thereby further reducing potential for dust generation. Therefore, this exposure pathway was not considered further in the risk assessment for HH-6.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to people through dermal uptake of chemicals present in air vapours. However, dermal uptake of volatile chemicals is not expected to contribute significantly to exposure of people, and was therefore excluded from further analysis.

Direct contact with soils - Digging and fugitive dust generation can result in exposure to people through dermal contact with soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent direct contact with CT deposits.

Direct contact with surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). People could be exposed by directly contacting surface water while swimming or bathing. Although the contribution of dermal exposure to chemicals in surface water is expected to be small relative to ingestion exposure, this pathway was evaluated in the assessment for key question HH-6.

Ingestion of fugitive dust - Fugitive dust generated from surface soils can result in exposure to people through ingestion of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent dust arising from wind-based erosion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Hunters/trappers could be exposed by ingesting surface water intentionally or through incidental ingestion while swimming. Since large volumes of water are associated with CT reclamation units, drinking surface water is a potential exposure pathway for people. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-6.

Ingestion of soils/sediment - Digging and fugitive dust generation can result in exposure to people through incidental ingestion of soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent ingestion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of plants - Plants that are growing on reclaimed surfaces may accumulate metals and organic compounds in their tissue. Hunters/trappers could be exposed by consuming these plants while they are living on the reclaimed landscape. Children may also be exposed if these plants are harvested and brought back to feed the family. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-6.

Ingestion of animals - Game animals living and feeding in the reclaimed landscape may accumulate metals and organic compounds in their tissues. Hunters/trappers may be exposed to these compounds through ingestion of game meat. Children may also be exposed if game meat is brought back to feed the family. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question HH-6.

X.4 EXPOSURE ASSESSMENT EQUATIONS AND PARAMETERS

X.4 Exposure Assessment Equations and Parameters

Exposure equations used for the wildlife and human health exposure assessments are presented in Table X-32, with the exception of equations used for wildlife health key question W-7. The specific methodology used for key question W-7 is presented in the following section.

Table X-32 Wildlife and Human Exposure Assessment Equations

Pathway	Equation and Equation Parameters
Water Ingestion (W-2; HH-1)	$EDI_{water} = \frac{IR \times BA \times C_{water} \times ET \times EF \times ED}{BW \times AT}$
	EDI_{water} = incidental water consumption while swimming (mg chemical/kg body weight/day) IR = ingestion rate (L/hour) BA = oral bioavailability of compound (chemical-specific, unitless) C_{water} = chemical concentration in water (mg/L) ET = time of exposure (hr/event) EF = frequency of exposure (events/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)
Dermal Exposure (HH-1)	$EDI_{dermal} = \frac{SA \times C_{water} \times Kp \times ET \times EF \times ED \times 10^3 \text{ L / m}^3}{BW \times AT}$
	EDI_{dermal} = estimated daily intake from dermal contact while swimming (mg chemical/kg body weight/day) SA = surface area available for contact while swimming (m^2) C_{water} = chemical concentration in water (mg/L) K_p = permeability constant in water (chemical-specific; m/hr) ET = total time of exposure event (hr/event) EF = frequency of exposure events (events/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens,70 years for carcinogens)

Table X-32 Wildlife and Human Exposure Assessment Equations (continued)

Pathway	Equation and Equation Parameters
Air Inhalation (HH-2)	$\mathrm{EDI}_{\mathrm{air}} = \frac{IR \times BA \times C_{air} \times EF \times ED}{BW \times AT}$
	EDI_{air} = estimated daily intake from air (mg chemical/kg body weight/day) IR = inhalation rate (m^3/hour) BA = inhalation bioavailability of compound (chemical-specific, unitless) C_{air} = chemical concentration in air (mg/m^3) ET = time of exposure (hr/day) EF = frequency of exposure (days/year) ED = duration of exposure (days) BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)
Food Ingestion (i.e., fish, meat, plants, invertebrates) (W-2, W-3, HH-3, HH-4, HH-6)	$\mathrm{EDI}_{\mathrm{food}} = \frac{IR \times BA \times C_{food} \times EF \times ED \times SC}{BW \times AT}$
	EDI_{food} = estimated daily intake from food ingestion (mg chemical/kg body weight/day) IR = ingestion rate (kg/day) BA = oral bioavailability of compound (chemical-specific, unitless) C_{food} = chemical concentration in food (mg/kg) EF = frequency of exposure (days/year) ED = duration of exposure (days) SC = site contribution BW = receptor body weight (kg) AT = averaging time (years; ED for noncarcinogens; 70 years for carcinogens)

Reclaimed Landscape Wildlife Model (W-7)

As discussed previously, the assessment endpoint for the assessment of wildlife health impacts is the protection of wildlife populations. An exposure model was therefore developed to assess the potential for population level effects to terrestrial wildlife exposed to chemicals associated with the reclaimed landscape (W-7). The model incorporates information on the spatial distribution of chemicals within the landscape as well as foraging and movement of the wildlife species. For this model, a wildlife species population was defined as the hypothetical population foraging within the boundaries of the LSA, which includes both reclaimed areas and natural areas. Although the foraging ranges for some wildlife species may extend beyond the LSA boundaries, it was conservatively assumed that all foraging would take place within this area.

Exposure pathways include ingestion of six food and water types that may be present within fifty-seven different ELCs associated with the reclaimed landscape. Each ELC may contain up to three different soil types (6×57×3=1026 possible exposure sources). Depending upon the receptor's, dietary requirements, exposure may occur due to ingestion of water, invertebrates (aquatic or terrestrial) and/or plants (aquatic or terrestrial) growing within the LSA, either on reclaimed areas or natural areas. The amount consumed by a given receptor was determined by ingestion rates and foraging ranges of each species, which were assigned a probabilistic distribution following a literature review (refer to wildlife receptor parameters in the following section). It was assumed that each species would move randomly among the preferred habitat types.

The wildlife exposure model predicted chemical concentrations in food (plants, invertebrates and water) expected for the reclaimed landscape and for natural areas within the LSA. The model then computed a dose by randomly selecting foraging areas for each wildlife species according to foraging preferences and areas for each species. By repeating this exposure calculation many times, an estimate of the dose distribution that might be expected for the regional population was determined.

Daily intake rates were estimated for water, plants and prey (mg chemical per kg-body weight per day) according to (EDI_{water}, EDI_{plant}, and EDI_{prey}, respectively):

$$EDI_{water} = \frac{R_{water} C_{water} f}{BW}$$

$$EDI_{plant} = \frac{R_{plant} C_{plant} f}{BW}$$

$$EDI_{prey} = \frac{R_{prey} C_{prey} f}{BW}$$

where:

R = ingestion rates of soil, water, plants and prey (kg dry weight per day, except water, L per day)

f = fraction of food, water and soil derived from the site (receptor specific; unitless)

C = chemical concentration in water, plants and prey (mg/kg in plants and prey, mg/L in water)

BW = receptor body weight (receptor specific; kg)

Because of the uncertainties associated with wildlife parameter estimates, a probabilistic assessment was used to quantify intake rates. The probabilistic method offers advantages over deterministic (single point) methods. First, all valid data collected from the site and obtained from the scientific literature can be incorporated into the analysis, rather than limiting the analysis to a single data point or study. Second, the approach provides an accurate estimate of the upperbound or maximum plausible risk, since statistically-derived input distributions are used in the models rather than single upperbound values. Third, the results of the probabilistic assessment provide a quantitative estimate of the conservatism of the deterministic point estimate of risk (i.e., the probability of occurrence of the deterministic risk estimate can be identified). Fourth, the probabilistic analysis can be used to identify the variables that are most strongly affecting predicted exposure estimates (i.e., through the use of uncertainty analysis). These features provide valuable additional information for making informed decisions about reclamation options.

Intake rate distributions were estimated by modelling the exposure of a typical individual animal using probabilistic input parameters, then repeating the simulation for 500 iterations using Monte Carlo simulation. Monte Carlo simulation is the process of estimating the intake rate using random deviates for each input in the mathematical equations, then repeating the calculations with new random deviates on each cycle of the simulation, to determine the distribution of possible outcomes. Each iteration consists of a unique set of input values, which are specified by sampling the input parameters from assumed probability distributions. The iterations are repeated many times, such that the full range of the input distributions are adequately sampled in combination with the ranges from other input distributions. The Monte Carlo simulation was conducted using Excel© with Crystal Ball.©

Foraging and movement patterns of wildlife were accounted for by assuming that each species would prefer specific habitat types for foraging, and that ELCs could be used to represent preferred habitats. The landscape of the LSA following closure has been classified using 57 ELC units. Each wildlife species' preference towards specific ELCs was taken into account by specifying the likelihood that a particular species will visit a specific ELC unit on the reclaimed mine site and the surrounding region, based on each species' habitat preferences (Table X-33). The number of ELC areas selected by a specific receptor is dependent on the size of a species' home range and the size of the ELC area. The foraging areas that would be used by each species were selected randomly in the model based on each species' habitat preferences.

The spatial distribution of chemicals in the reclaimed landscape was accounted for in differences of food tissue concentrations, where tissue concentrations were assumed to vary as a function of the types of reclamation materials used on-site. These reclamation materials included overburden and tailings sand. Natural areas of the LSA were assumed to consist of natural soils (i.e., muskeg). A chemical fate model was used to predict chemical concentrations in environmental media and biota when measured concentrations were not available. Predicted concentrations were then used as input concentrations for the wildlife exposure model. In particular, exposure point concentrations were required for surface water, plant and invertebrate tissues.

Water Concentrations

Chemical concentrations in water will be highly variable within the reclaimed landscape, given the diversity of sources (CT release water, groundwater seepage and surface runoff from many different reclamation units). Wildlife may drink water from rivers, ponds, lakes or small streams. In the short-term, some CT seepage will occur on reclaimed areas of the LSA, but far future predictions indicate that CT seepage will not impact the reclaimed landscape water quality. Therefore, since this exposure modelling was performed to investigate the potential for adverse effects to wildlife populations in the far future, drinking water sources for wildlife were assumed not to be impacted by CT water. Rather, water quality on reclaimed portions of the LSA was assumed to be affected by surface runoff and sand seepage. Water concentrations on reclaimed areas of the LSA represent reasonable worst-case conditions, since undiluted sand seepage concentrations were used to estimate water exposures on reclaimed areas of the landscape. Drinking water obtained from natural areas of the LSA was assumed to be similar to the chemistry of the Muskeg River in the far future. Estimates of the Muskeg River (mean open water flow)

TABLE X-33

WILDLIFE HABITAT PREFERENCE SPECIFIED AS PERCENT LIKELIHOOD OF FINDING THE SPECIES IN THE ELC

ELC Code[1]	Ruffed Grouse[2]	Moose[2]	Deer Mouse[2]	Snowshoe Hare[2]	Mallard[2]
a1	0-20	0-10	100	0-10	0
a1/g1 complex	0-20	0-10	100	0-10	0
AIG	0	0	100	0	0
AIH	0	0	100	0	0
AIM	0	0	100	0	0
b1	30-50	0-25	100	10-65	0
b3	30-50	0-25	100	10-65	0
b4	0-5	0-35	100	0-10	0
b4(STNN)	0-5	0-25	100	0-5	0-5
c1	0-20	0-10	100	0-10	0
c1(STNN)	0-5	0-25	100	0-5	0-5
d1	40-65	50-100	100	25-75	0
d2	30-50	0-25	100	10-65	0
d2(STNN)	30-50	0-25	100	10-65	0
d3	0-5	0-35	100	0-10	0
d3(STNN)	0-5	0-35	100	0-10	0
e1	40-65	50-100	100	25-75	0
e1/f1	40-65	50-100	100	25-75	0
e2	20-40	0-25	100	0-25	0
e2/f2	20-40	0-25	100	0-25	0
e3	0-5	0-35	100	0-10	0
g1	0-20	0-25	100	0-10	0-5
g1(STNN)	0-5	0-25	100	0-5	0-5
h1	0-20	0-25	100	0-10	0-5
h1(STNN)	0-5	0-25	100	0-5	0-5
i2(BTNN)	0-5	0-25	100	0-5	0-5
j1(FTNN)	0-5	0-25	100	0-5	0-5
j1/g1 (FTNN)	0-5	0-25	100	0-5	0-5
j1/g1(FFNN)	0-5	0-25	100	0-5	0-5
j1/h1(FTNN)	0-5	0-25	100	0-5	0-5
j2(FFNN)	0-5	0-25	100	0-5	0-5

TABLE X-33

WILDLIFE HABITAT PREFERENCE SPECIFIED AS PERCENT LIKELIHOOD OF FINDING THE SPECIES IN THE ELC

ELC Code[1]	Ruffed Grouse[2]	Moose[2]	Deer Mouse[2]	Snowshoe Hare[2]	Mallard[2]
j2(FTNN)	0-5	0-25	100	0-5	0-5
j2/h1(FTNN)	0-5	0-25	100	0-5	0-5
k1(FOPN)	0-5	0-35	100	0-5	0-25
k1(FTNN)	0-5	0-35	100	0-5	0-25
k2(FONS)	0	50-100	0	0-20	0-25
k2(FTNN)	0	50-100	0	0-20	0-25
k3(FONG)	0-5	0-35	100	0-5	0-25
l1(MONG)	0-5	25-75	0	0-5	50-100
Lt(STNN)	0-5	0-35	100	0-5	0-25
Lt-Aw(STNN)	0-5	0-35	100	0-5	0-25
Lt-Pb(STNN)	0-5	0-35	100	0-5	0-25
Lt-Sb	0-5	0-35	100	0-5	0-25
Lt-Sb(STNN)	0-5	0-25	100	0-5	0-5
NMC	0	0	100	0	0
NWF(WONN)	0-5	25-75	0	0-5	50-100
NWL	0-5	25-75	0	0-5	50-100
NWR	0-5	25-75	0	0-5	50-100
Sb(STNN)	0-5	0-25	100	0-5	0-5
Sb-Lt	0-5	0-25	100	0-5	0-5
Sb-Lt(SFNN)	0-5	0-25	100	0-5	0-5
Sb-Lt(STNN)	0-5	0-25	100	0-5	0-5
(Sb-Lt)SFNN	0-5	0-25	100	0-5	0-5
shrub	0	50-100	0	0-20	0-25
shrub(SONS)	0	50-100	0	0-20	0-25

[1] For further details on ELC classifications, refer to Section E7.

[2] Percent likelihood of finding the species indicated in the ELC

concentrations in the far future were made using a mixing model, according to the methods described in Section E5.

Aquatic Plant and Invertebrate Tissue Concentrations

Aquatic plant tissue concentrations were estimated based on observed concentrations in plants grown in constructed wetlands (Table X-14). Aquatic invertebrate prey tissue concentrations were estimated based on observed concentrations in organisms collected from experimental wetlands (Table X-16).

Terrestrial Plant and Invertebrate Tissue Concentrations

The reclaimed areas of the site (i.e., CT deposits) will be covered with a thick layer (i.e., 11-13 metres) of either tailings sand or overburden. This layer will in turn be capped with 20 cm of reconstructed soil (i.e., a mix of muskeg and overburden), which is considered to be equivalent to natural soils in the area in terms of soil chemistry. Measured soil concentrations were available for each of the three soil types: overburden, tailings sand and natural soils (Table X-34). To be conservative, it was assumed that plants growing in reclaimed areas may have roots extending beyond the upper capping layer of muskeg into the tailings sand or overburden layer beneath. Therefore, for areas reclaimed with tailings sand, plant tissue concentrations were based on observed concentrations in plants grown in muskeg capped tailings sand (Table X-19; Golder 1997r). For natural areas or areas reclaimed with overburden, plant tissue concentrations, C_{tplant}, were estimated based on soil concentrations, C_{soil}, (either natural soil or overburden) and bioconcentration factors for terrestrial plants, BCF_{tplant}, according to the following equation:

$$C_{tplant} = BCF_{tplant} * C_{soil}$$

Terrestrial invertebrate tissue concentrations, $C_{tinvert}$ (mg/kg dry wt), were predicted based on soil concentrations, C_{soil}, specified for the different ELC areas (i.e., tailings sand, overburden or natural soil) and terrestrial invertebrate prey bioconcentration factors, $BCF_{tinvert}$, according to the following equation:

$$C_{tinvert} = BCF_{tinvert} * C_{soil}$$

Summary

In summary, a wildlife exposure model was developed to compute chemical intake for wildlife populations, taking into account spatial differences in

TABLE X-34

SOIL CONCENTRATION DISTRIBUTIONS[1] USED FOR WILDLIFE EXPOSURE MODEL

Parameter	Overburden[2] [mg/kg]	Tailings Sand[3] [mg/kg]	Natural (Muskeg)[4] [mg/kg]
Barium	219	4.9	121
Boron	7.2	uni(0,0.1)	uni(0,0.1)
Mercury	0.07	0.03	0.037
Molybdenum	1.4	uni(0,2)	1.4
Nickel	30	2	8.4
Selenium	0.74	uni(0,0.02)	uni(0,0.02)
Strontium	--	--	--
Vanadium	15.1	2.8	12.3
Zinc	72.7	5.8	25.5

[1] Distribution types: uni (uniform), norm (normal), tri (triangular),
-- (no data available).

[2] Overburden soil concentrations from ETL (1993; CP 3; n=1)

[3] Tailings sand chemistry data from ETL (1993; CP 5; n=1).

[4] CT chemistry data from Suncor and Syncrude (1995 unpublished data; n=1).

chemical concentrations and use of the reclaimed landscape. Intake rates for individuals within the LSA were estimated as follows:

1. Chemical concentration distributions for water, soil, plants and invertebrates within the reclaimed and natural areas of the LSA were predicted;

2. Each species was assumed to forage randomly within the LSA based on preferences for habitat, as defined by ELC type;

3. The movement of an individual within the LSA boundaries was simulated according to its foraging habitat;

4. Chemical intake rates were calculated according to the equations presented above;

5. If the species foraging area requirement was greater than the area of the first selected ELC, steps (3) and (4) were repeated to add more ELC areas to the forage range for the individual until its foraging requirements were met.

6. Steps (2) to (5) were repeated for many individual animals. On each loop, a new set of input parameters were selected based on random sampling of the input data distributions.

Thus, output from this process represents the intake rate distribution expected for all individuals of a given species foraging within the LSA boundaries following closure of the Muskeg River Mine Project.

The intake rate estimates presented here are preliminary, since the chemical database on which the calculations are based is rapidly expanding. Also, the wildlife rate estimates presented here assume background exposures are nil, therefore, the intake rates represent incremental doses resulting from exposure to the reclaimed landscape.

X.4.1 WILDLIFE RECEPTOR PARAMETERS

X.4.1 Wildlife Receptor Parameters

Details on the body weight, food ingestion, water ingestion, diet, home range and habitat preferences for each wildlife receptor evaluated in the wildlife health risk assessment are provided in the following sections.

Water Shrew *(Sorex palustris)*

Body Weight:

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

Distribution: Normal

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

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[1] Mean body mass for water shrews calculated from data given in Soper (1973), Burt (1976), Wrigley et al. (1979), and van Zyll de Jong (1983).

Food Ingestion Rate:

One 10 g animal consumed a mean of 10.3 g/day (Conoway 1952). Based on a mean O_2 consumption of 7.8 cc/g/hr, shrews require 0.95 g/g/day (Sorensen 1962).

Food ingestion rate[2] (FI rate) (kg/day):

for shrew with mean mass (0.013 kg)	0.01235
for shrew with minimum mass (0.00718 kg)	0.00682
standard deviation (SD)[3]	0.0028

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

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

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

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

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

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

Diet:

Their diet consists primarily of insects (particularly larvae and nymphs of aquatic insects, e.g. mayfly, caddisfly, and stonefly, Calder 1969). They will also eat other invertebrates (e.g. planaria), small fish (*Notropis, Cottus*) and larval amphibians (Buckner 1970, Lampman 1947, Nussbaum and Maser 1969) but these constitute an insignificant portion of the diet (van Zyll de Jong 1983). Shrews will also take fish eggs and may also hunt on land, searching the shoreline rocks for insects (Gadd 1995). Ealey et al. (1979) describe water shrews as opportunistic feeders whose diet will vary with the area inhabited.

Estimates of the composition of diet:

1) (n=13), 78% insects (mostly terrestrial), 22% planarians and vegetation (Hamilton 1930)

2) (n=87), 49% aquatic insects, 13% spiders, fish, plants, and vertebrates (Conoway 1952)

3) (n=?), 30% carabid beetles and other insects, <20% assorted invertebrates, including snails (Buckner and Ray 1968)

4) (n=13), 30% insects, 50% slugs and earthworms, 10% assorted insects and vegetation (Whitaker and Schmeltz 1973)

Home Range:

The home range of a water shrew is approximately 75 to 200 metres (M. Raine, pers. Comm.). Home range sizes are likely linear as water shrews inhabit streamside or waterside habitats.

Water Ingestion Rate:

Water ingestion rate[6] (WI rate) (L /day):	
for shrew with mean mass (0.013 kg)	0.002
for shrew with minimum mass (0.00718 kg)	0.0012
standard deviation (SD)[7]	0.0005

Distribution: Normal[8]

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

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

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

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

Time Spent On Site:

Shrews are active and present in the area year-round (Burt 1976, Smith 1993, Gadd 1995). Therefore shrews were assumed to be on-site 100% of the time.

Habitat Preferences:

Water shrews are seldom found away from water (Smith 1993). Creeks, ponds and lakes where there are overhanging banks or branches to provide cover are suitable locations for these shrews (Smith 1993). It builds its nest at the water's edge, often hidden among the sticks of a beaver dam or lodge (Gadd 1995).

General Information:

Water shrews are short-lived, surviving for approximately two summers (Gadd 1995, van Zyll de Jong 1983). Water shrews constantly build new nests (van Zyll de Jong 1983) which consist of lined depressions at the end of 10-12 cm long tunnels which they build themselves, digging with their forefeet and kicking loosened soil out of the tunnel with their hindfeet (Sorensen 1962). Damaged nests are repaired or reconstructed using its muzzle (van Zyll de Jong 1983).

Killdeer (*Charadrius vociferus*)

Body Weight:

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

Distribution: Normal

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

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[12] Mean body mass calculated from data given in Dunning (1984) and Brunton (1988).

Food Ingestion Rate:

The bulk of the diet of the killdeer is composed of beetles and other invertebrates (Semenchuk (1993). Ehrlich et al. (1988) report a diet of 75% insects with the remainder of the diet consisting of a wide variety of invertebrates and 2% weed seeds. It forages from the ground surface and does not probe for food and will forage at dusk during the night as well as during the day (Semenchuk 1993). We assume a diet of 100% invertebrate prey.

Food ingestion rate[13] (FI rate) (kg/day):

for birds with mean mass (0.0989 kg)	0.0154
for birds with minimum mass (0.0889 kg)	0.0142
standard deviation (SD)[14]	0.0008

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

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

for birds with mean mass (0.0989 kg)	0.017
for birds with minimum mass (0.0889 kg)	0.016

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[13] Food ingestion rates estimate based on an allometric equation for field metabolic rates for passerines where FMR (kcal/day) = $2.123\text{Wt}^{0.749}$ where Wt is in (g). Food ingested per day based on an estimate of the metabolizable energy available to birds eating an a insectivorous diet (i.e. 4.30 kcal/g), Nagy (1987).

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

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

Water Ingestion Rate:

Water ingestion rate[17] (WI rate) (L/day):

for birds with mean mass (0.0989 kg)	0.022
for birds with minimum mass (0.0889 kg)	0.020
standard deviation (SD)[18]	0.0011

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

Deterministic value for food ingestion rate (mean WI rate; mean + 2SD):

for birds with mean mass (0.0989 kg)	0.024
for birds with minimum mass (0.0889 kg)	0.022

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[17] Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.

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

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

Time Spent in Area:

Killdeer arrive in northern Alberta in mid-April and leave sometime between late November or early December (Semenchuk 1993, Pinel et al. 1991). Estimated total number of days in Alberta is in 233 days or 233/356 = 0.64.

Habitat Preferences:

Killdeer breed in open areas with minimal vegetative cover, not necessarily close to water (Semenchuk 1992). Its natural habitats include open grassy uplands, lakeshore clearings, river banks, woodland clearings, gravelly stream and river channels, and sedge and willow meadows with ponds and streams (Semenchuk 1992, Holroyd and Van Tighem 1983). Killdeer will also use human-modified or disturbed habitats such as pastures, cultivated fields, roadsides, gravel pits, golf courses, parking lots, lawns landfills, borrow pits, sewage lagoons and rooftops (Semenchuk 1992, Holroyd and Van Tighem 1983). After nesting, it is more likely to frequent the margins of ponds and lakes and other muddy, moist places (Semenchuk 1992).

River Otter (*Lutra canadensis*)

Body Weight:

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

Distribution: Normal

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

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[23] Mean body mass for otter calculated from Soper (1973), Lauchachinda (1978), Smith (1993), Melquist and Hornocker (1983), and Gadd (1995).

Food Ingestion Rate:

Generally, throughout all four seasons, the diet consists mainly of fish (95-100%) (Stenson et al. 1984, Wilson and Toweill 1974, Melquist and Hornocker 1983, USEPA 1993). However, Gilbert and Nancekivell (1982) observed that otters consume more waterfowl in northerly latitudes (presumably because of the ease of catching ducks during molt - if so, then this diet change would likely occur during late summer). Other than fish, otters may also take muskrats, small rodents, amphibians, insects and young or enfeebled beavers (Gadd 1995). Although they primarily feed in the water, they may also spend time on land, loping after meadow voles (Gadd 1995).

Food ingestion rate[24] (FI rate) (kg/day):	
for an otter with mean mass (7.698 kg):	0.368
for an otter with minimum mass (5.92 kg)	0.296
standard deviation (SD)[25]	0.043

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

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD)	
for an otter with mean mass (7.698 kg):	0.453
for an otter with minimum mass (5.92 kg)	0.381

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[24] Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight /day) = 0.0687(Body weight g)$^{0.822}$ (Nagy 1987).

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

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

Home Range:

Mean home range[27] (km)	31
standard deviation (SD)	9.2

Distribution: not normal

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[27] Home range size estimate from Melquist and Hornocker (1983).

Home range for animals associated with streams or rivers are measured as distances travelled on waterways as otters tend to keep to water courses, making overland trips when looking for mates or moving, open water (Melquist and Hornocker 1983). Home range shape is determined by the drainage pattern and size and home ranges tend to overlap (Melquist and Hornocker 1983). In areas where aquatic habitat is not dominated by stream or river features, home range size varies between 400 and 1900 ha for breeding adult otters (Missouri, marshes and streams Erickson et al. 1984).

Water Ingestion Rate:

Water ingestion rate[28] (WI rate) (L /day):	
for an otter with mean mass (7.698 kg):	0.621
for an otter with minimum mass (5.92 kg)	0.490
standard deviation (SD)[29]	0.072

Distribution: Normal[30]

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

---

[28] Water ingestion rate estimated an allometric equation, WI (L/day) = $0.099Wt^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

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

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

Time Spent On Site:

River otter are on site year round and do not hibernate (Smith 1993, Gadd 1995).

Habitat Preferences:

River otters prefer rivers, creeks, lakes and ponds in northern forest (Smith 1993). They prefer clear water (i.e., water that is not silty or polluted) (Gadd 1995).

General Information:

River otters give birth in late March, early April and the family breaks up in November (Melquist and Hornocker 1983). Males tend to be larger than females (Melquist and Hornocker 1983). Otters tend to be in their aquatic habitat almost all of the time except during seasons where water becomes inaccessible (i.e. frozen) and are noted to be diurnal in winter and nocturnal in summer (Melquist and Hornocker 1983). Otters are well known for their habit of sliding either on muddy slopes into water or on snow during winter (Gadd 1995).

Otter families are close and may stay together for a relatively long time (Gadd 1995). Females are not reproductive until they are at least two years old, males are not ready until they are six or seven (Gadd 1995).

Great Blue Heron (*Ardea herodias*)

Body Weight:

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

Distribution: Normal

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

Food Ingestion Rate:

The diet of the great blue heron is composed primarily of fish, but birds will also take nestlings, small mammals and aquatic invertebrates (Erhlich et al. 1988). Herons will also take frogs, water snakes, and plant seeds Semenchuk 1992).

Food ingestion rate[35] (FI rate) (kg/day):

for birds with mean mass (2.204 kg)	0.0976
for birds with minimum mass (1.53 kg)	0.0742
standard deviation (SD)[36]	0.0149

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

Deterministic value for food ingestion rate (kg/day) (maximum FI rate; mean + 2SD):

for birds with mean mass (2.204 kg)	0.127
for birds with minimum mass (1.53 kg)	0.104

Foraging Home Range Size:

Mean home range size[38] (ha)	4.5
standard deviation (SD)	5.52
coefficient of variation (CV)	1.23
sample size (n)	2

Distribution: not normal

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[34] Mean body mass calculated from data given in Hartman (1961).

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

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

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

Mean foraging distance from colony[39] (km)	5.3
standard deviation (SD)	3.11
coefficient of variation (CV)	0.59
sample size (n)	2

---

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

[39] Mean foraging distance from colony calculated from data given in Parnell and Soots (1978) and in Dowd and Flake (1985).

Water Ingestion Rate:

Water ingestion rate[40] (WI rate) (L/day):

for birds with mean mass (2.204 kg)	0.223
for birds with minimum mass (1.53 kg)	0.169
standard deviation (SD)[41]	0.034

Distribution: Given mean and standard deviation, MEI is a normal distribution.[42]

Deterministic value for water ingestion rate (mean WI rate; mean + 2SD):

for birds with mean mass (2.204 kg)	0.291 L/day
for birds with minimum mass (1.53 kg)	0.238 L/day

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[40] Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.

[41] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = cv x WI rate for mean mass heron).

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

Time Spent On Site:

Great Blue Herons arrive in Alberta the last half of March, early April and most leave by mid October (Semenchuk 1992). Thus, the estimated total number of days in the province is 213. Assuming that birds spend 100% of their time on site while in Canada, the maximum fraction of food and water from the contaminated sites would be 213/365 = 0.58 of their annual requirements.

Habitat Preferences:

Great Blue Herons are found in and about open shallow water at the edges of lakes, streams, rivers, ponds, sloughs, ditches, and mudflats (Semenchuk 1992). In the study area, these birds most often nest in dead aspen, balsam poplar and spruce (Semenchuk 1992).

Ruffed Grouse (*Bonasa umbellus*)

Body Weight:

Mean body mass adult female grouse (kg)[1]	0.543
standard deviation (SD)	0.0303
coefficient of variation (CV)	0.0558
sample size	12

Distribution: Normal

Deterministic value for body mass (minimum mean body mass; mean - 2SD)	0.482

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[1] Mean body mass for female ruffed grouse given in Bump et al. (1947) for New York, USA.

Food Ingestion Rate:

Primarily herbivorous, ruffed grouse consume 80% buds, leaves, flowers, seeds and fruit and the remaining 20% of their diet consists of insects, spiders, snails and young vertebrates (Ehrlich et al. 1988). Principal species of trees, shrubs and forbs consumed (i.e., buds, catkins, fruits and leaves) include aspen, poplar, apple, grape, sumac, beech and alder (Johnsgard 1983). Other plants include, clover, greenbrier, hazelnut blueberry, birches, chokecherry, maple, rosehips, dogwood fruits, willow buds, wild strawberry leaves and fruit, wintergreen leaves, saskatoon berries (see Johnsgard 1983). Ruffed grouse chicks consume primarily insects during the first week to 10 days of life (Bump et al. 1947). Approximately 70% of the food taken in the first 2 weeks consists of insects, as compared with 30% during the third and fourth weeks and dropping to 5% by the end of July (Bump et al. 1947). Ants are a frequent food item and other invertebrate species consumed include sawflies, ichneumons, beetles, spiders, grasshoppers and a variety of caterpillar species (Bump et al. 1947). Plant foods taken include sedge achenes and the fruits of strawberries, raspberries, blackberries and cherries (Bump et al. 1947).

Food ingestion rate[2] (FI rate) (kg/day): (dry weight - herbivorous diet)	
for birds with mean mass (0.532 kg)	0.0391
for birds with minimum mass (0.482 kg)	0.0362
Standard deviation[3]	0.0022

Distribution: Normal[4]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD):	
for birds with mean mass (0.532 kg)	0.0435 kg/day
for birds with minimum mass (0.482 kg)	0.0406 kg/day

[2] Food ingestion rates estimate based on an allometric equation for all birds (Nagy 1987): FI (kg dry weight /day) = 0.0582(Body weight kg)$^{0.651}$.

[3] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass bird).

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

Foraging Home Range Size:

Mean home range size[5] (ha)	11.3
standard deviation (SD)[6]	4.6
coefficient of variation (CV)	0.41
sample size[5]	3

Distribution: not normal[7]

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[5] Mean foraging home range size calculated from three study groups (Godfrey 1975, Maxon 1978).

[6] Standard deviation calculated from the three studies.

[7] Distribution considered not normal due to variation given in Godfrey (1975).

Water Ingestion Rate:

Water ingestion rate[8] (WI rate) (L/day):

for birds with mean mass (0.532 kg)	0.0780
for birds with minimum mass (0.482 kg)	0.0712
standard deviation (SD)[9]	0.0043

Distribution: Given mean and standard deviation, MEI is a normal distribution.[10]

Deterministic value for food ingestion rate (mean WI rate; mean + 2SD):

for birds with mean mass (0.532 kg)	0.0864
for birds with minimum mass (0.482 kg)	0.080

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[8] Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.

[9] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass grouse).

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

Time Spent On Site:

Ruffed grouse are present and active year-round in the study area (Semenchuk 1992).

Habitat Preferences:

In Alberta, ruffed grouse are most abundant in aspen-dominated and mixed wood forests (Semenchuk 1992). Small openings in the deciduous forest function as brood cover and represent an important part of their overall preferred habitat type (Johnsgard 1973). A heavy understory is needed for drumming sites (Johnsgard 1973).

General Information:

Alberta populations of ruffed grouse are quite healthy and populations generally vary on a 10 year cycle (Semenchuk 1992). High winter mortality is often experienced due to predators (i.e., raptors) and severe weather conditions (Semenchuk 1992).

Mallards (*Anas platyrhyncos*)

Body Weight:

Mean body mass adult female (kg)[14]	1.107
standard deviation (SD)	0.129
coefficient of variation (CV)	0.117
sample size (# studies)	3

Distribution: Normal

Deterministic value for body mass (minimum mean body mass; mean - 2SD)	0.849 kg

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[14] Mean body mass calculated from data given in Owen and Cook (1977), Nelson and Martin (1953) and Krapu and Doty (1979).

Food Ingestion Rate:

Mallards are considered 'dabbling' ducks which means that they feed in shallow water tipping up and down while foraging on bulrush seeds, snails and invertebrates from the bottom (Gadd 1995). Infrequently, they may also ingest tadpoles or scavenge dead fish (Gadd 1995). Other items included in the diet are crustacea, annelids, various seeds, tubers and stems (Dillon 1959, Swanson et al. 1985).

Food ingestion rate[15] (FI rate) (kg/day): (dry weight - 75% invertebrates; 25% plant material)[16]	animal	plant
for birds with mean mass (1.107 kg)	0.0464	0.0157
for birds with minimum mass (0.849 kg)	0.039	0.0132
standard deviation (SD)[17]	0.0072	

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[18]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD):	animal	plant
for birds with mean mass (1.107 kg)	0.0573	0.0194
for birds with minimum mass (0.849 kg)	0.0499	0.0169

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[15] Food ingestion rates estimate based on an allometric equation for all birds (Nagy 1987): FI (g dry weight /day) = 0.648 (Body weight g)$^{0.651}$.

[16] Diet composition from Swanson et al. (1985).

[17] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass bird).

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

Foraging Home Range Size:

Mean home range size[19] (ha)	468
standard deviation (SD)	159
coefficient of variation (CV)	0.34
sample size (n)	6

Distribution: not normal

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[19] Mean foraging home range size calculated from data given in Dwyer et al. (1979) in north Dakota.

Water Ingestion Rate:

Water ingestion rate[20] (WI rate) (L/day):	
for birds with mean mass (1.107 kg)	0.133
for birds with minimum mass (0.849 kg)	0.109
standard deviation (SD)[21]	0.016

Distribution: Given mean and standard deviation, MEI is a normal distribution.[22]

Deterministic value for water ingestion rate (mean WI rate; mean + 2SD):	
for birds with mean mass (1.107 kg)	0.164 L/day
for birds with minimum mass (0.849 kg)	0.140 L/day

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[20] Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = $0.059(\text{Body weight kg})^{0.67}$; Ohmart et al. (1970), WI (L/day) = $0.111(\text{Body weight kg})^{0.69}$; Thomas and Phillips (1975) WI (L/day) = $0.203(\text{Body Weight kg})^{0.81}$; Walter and Hughes (1978), WI (L/day) = $0.119(\text{Body Weight kg})^{0.75}$.

[21] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass duck).

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

Time Spent On Site:

Mallards are migratory birds which breed in the study area during the summer months. Mallards arrive in Alberta in late March, early April and leave by late November (estimated number of days present is approximately 197) (Semenchuk 1992). Some birds may overwinter in Fort McMurray (Semenchuk 1992).

Habitat Preferences:

Habitat preferences for mallards are variable. They are adaptable birds that may use marshes, ponds, the margins of small and large lakes, islands, quiet waters of rivers, ditches, or flooded land in both treeless and wooded country (Semenchuk 1992).

Moose (*Alces alces*)

Body Weight:

Mean body mass (kg)[26]	381.17
standard deviation (SD)	35.14
coefficient of variation (CV)	0.0922
sample size (# studies)	3

Distribution: Normal

Deterministic value for body mass (minimum body mass; mean - 2SD)	310.88

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[26] Mean body mass for female moose calculated for data given in Doutt (1970), Smith (1993) and Stelfox (1993).

Food Ingestion Rate:

Common forages for moose include a variety of tree and shrub species, fallen leaves, bark, forbs, sedges and horsetail (Stelfox 1993).

Food ingestion rate[27] (FI rate) (kg/day):

for moose with mean mass (381.17 kg)	6.59
for moose with minimum mass (310.88 kg)	5.68
standard deviation (SD)[28]	0.607

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[29]

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

for moose with mean mass (381.17 kg)	7.801 kg/day
for moose with minimum mass (48.9 kg)	6.894 kg/day

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[27] food ingestion rate calculated as a function of body mass using one allometric equation FI (g dry weight /day) = $0.577(\text{Body weight g})^{0.727}$ (Nagy 1987).

[28] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass moose).

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

Home Range:

Mean home range[30] (ha)
we have three very different values for home range 1352 ha; 25800 ha (sd=6820) and 8180 ha (sd=1120)

standard deviation (SD)
coefficient of variation (CV)
sample size (n)

Distribution: not normal

[U] Home range calculated from data given in Ballard et al. (1991) and from Harestad and Bunnell's (1979) allometric equation: Home range (ha) = 6.06(Body weight kg)$^{0.91}$.

Water Ingestion Rate:

Water ingestion rate[31] (WI rate) (L /day):	
for moose with mean mass (381.17 kg)	20.83
for moose with minimum mass (310.88 kg)	17.34
standard deviation (SD)[32]	1.92

Distribution: Normal[33]

Deterministic value for water ingestion rate, L/day (maximum WI rate; mean + 2SD):	
for moose with mean mass (381.17 kg)	24.67
for moose with minimum mass (310.88 kg)	21.18

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

[32] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass moose).

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

Time Spent On Site:

Moose are present in the area year-round (Burt 1976, Smith 1993, Gadd 1995).

Habitat Preferences:

Preferred habitat of moose in Alberta is mixedwoods (Smith 1993). Moose are often found near the edges of lakes, bogs and streams (Smith 1993).

Snowshoe Hare (*Lepus americanus*)

Body Weight:

Mean body mass (kg)[37]	1.505
standard deviation (SD)	0.065
coefficient of variation (CV)	0.043
sample size(# studies)	4

Distribution: Normal

Deterministic value for body mass (kg) (minimum body mass; mean - 2SD)	1.376

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[37] Mean body mass for snowshoe hare based on data from four studies (Roman and Keith 1959, Soper 1973, Windberg and Keith 1976 and Smith 1993).

Food Ingestion Rate:

During summer, snowshoe hares feed on succulent vegetation and during winter, twigs, buds and bark (Burt 1976). Summer foods include grasses, wildflowers (especially pea-family plants and clover) and new leaves of aspen, willow and birch (Gadd 1995). In winter they eat the leaves of plants that stay green, such as kinnikinnick and wintergreen, the twig-ends and buds of shrubs and sometimes lichens (Gadd 1995).

Food ingestion rate[38] (FI rate) (kg/day):

for hare with mean mass (1.505 kg)	0.118
for hare with minimum mass (1.376 kg)	0.110
standard deviation (SD)[39]	0.005

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[40]

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

for hare with mean mass (1.505 kg)	0.128 kg/day
for hare with minimum mass (1.376 kg)	0.121 kg/day

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[38] Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight /day) = 0.577(Body weight g)$^{0.727}$ (Nagy 1987).

[39] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass hare).

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

Home Range:

Mean home range[41] (ha)	4-7
standard deviation (SD)	

coefficient of variation (CV)
sample size (n)

Distribution: not normal

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[41] Home range size estimate given in the U.S. EPA (1993) and Gadd (1995); see also Burt (1976).

Water Ingestion Rate:

Water ingestion rate[42] (WI rate) (L /day):	
for snowshoe hare with mean mass (1.505 kg)	0.143
for snowshoe hare with min. mass (1.376 kg)	0.132
standard deviation (SD)[43]	0.006

Distribution: Normal[44]

Deterministic value for water ingestion rate (L/day) (maximum WI rate; mean + 2SD):	
for snowshoe hare with mean mass (1.505 kg)	0.155
for snowshoe hare with min. mass (1.376 kg)	0.144

---

[42] Water ingestion rate estimated an allometric equation, $WI\ (L/day) = 0.099Wt^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

[43] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass hare).

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

Time Spent On Site:

Snowshoe hares are resident year round on the study area (Burt 1976, Smith 1993, Gadd 1995).

Habitat Preference:

Snowshoe hares prefer forests and shrubby areas and will use open areas only rarely and only if a quick route to brushy cover is available (Smith 1993). Daytime resting spots are called ‘forms’ which consist of a beaten-down spot under the drooping, thickly needled lower branches of spruce trees, sometime in dense brush and long grass, or under a log in a tangle of fallen trees (Gadd 1995).

General Information:

Generally, snowshoe hares are common throughout their range although populations may fluctuate dramatically (Smith 1993).

Beaver (*Castor canadensis*)

Body Weight:

Mean body mass (kg)[48]	17.9
standard deviation (SD)	2.62
coefficient of variation (CV)	0.165
sample size (# studies)	4

Distribution: Normal

Deterministic value for body mass (kg) (minimum body mass; mean - 2SD)	12.232

---

[48] Mean body mass for beaver calculated from four estimates in three studies (Soper 1973, Lancia et al. 1978 and Smith 1993).

Food Ingestion Rate:

Preferred food includes, the cambium layer of aspen, poplar, birch, maple, willow and alder. Beaver also feed on leaves, bark and small twigs and they will store branches and small sections of logs underwater near their lodge (Burt 1976, Gadd 1995). They will also eat the seeds of some water plants (Gadd 1995).

Food ingestion rate[49a] (FI rate) (kg/day):

for beaver with mean mass (18.275 kg)	0.724
for beaver with minimum mass (12.232 kg)	0.541
standard deviation (SD)[50]	0.120

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[51]

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

for beaver with mean mass (18.275 kg)	0.963
for beaver with minimum mass (12.232 kg)	0.780

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[49] Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weigh /day) = $0.577(\text{Body weight g})^{0.727}$ (Nagy 1987).

[50] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass beaver).

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

Home Range:

Mean home range[52] (ha)	4.5

Distribution: not normal

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[52] Home range size estimated based on a family unit of 7 kits and two adult beavers and a requirement of 0.5 ha per beaver to support it for one year (Gadd 1995).

Water Ingestion Rate:

Water ingestion rate[53] (WI rate) (L /day):

for beaver with mean mass (18.275 kg)	1.353
for beaver with minimum mass (12.232 kg)	0.943
standard deviation (SD)[54]	0.224

Distribution: Normal[55]

Deterministic value for water ingestion rate (L/day)
(maximum WI rate; mean + 2SD):

for beaver with mean mass (18.275 kg)	1.8
for beaver with minimum mass (12.232 kg)	1.39

---

[53] Water ingestion rate estimated an allometric equation, WI (L/day) = $0.099Wt^{0.90}$ where Wt is body weight in (kg) (Calder and Braun 1983).

[54] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass beaver).

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

Time Spent On Site:

Beaver are on site year round and do not hibernate (Smith 1993, Gadd 1995).

Habitat Preference:

Beavers require water. Areas attracting beavers include sloughs, rivers, creeks and lakes with trees (for foraging) within easy access (Smith 1993). Aspen is a favoured forage species (Gadd 1995).

American Robin (*Turdus migratorius*)

Body Weight:

Mean body mass (kg) [70]	0.0836 kg
standard deviation (SD)	0.0064
coefficient of variation (CV)	0.077
sample size	18

Distribution: Normal

Deterministic value for body mass (minimum mean body mass; mean - 2SD)	0.0708 kg

---

[70] Mean body mass calculated from data given in Wheelwright (1988).

Food Ingestion Rate:

Robins primarily consume invertebrates and fruits (Ehrlich et al. 1988). Specifically, their diet includes earthworms, snails, beetles, caterpillars, moths, grasshoppers, spiders and millipedes (Martin et al. 1951, Wheelwright 1988, Paszkowski 1982) and various fruits including plums, dogwood, sumac, hackberries, blackberries, cherries, greenbriers, raspberries and juniper (Martin et al. 1951, Wheelwright 1988). Based on data in Howell (1942) and Wheelwright (1988), the diet of the American robin consists of 72% invertebrate material and 28% vegetative material on average over the breeding season (i.e., the period during which they are on-site).

Food ingestion rate[71] (FI rate) (kg/day):	Invertebrate	Vegetation
for birds with mean mass (0.0836kg)	0.0126	0.0049
for birds with minimum mass (0.0708 kg)	0.0111	0.0043
standard deviation[72]		

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[73]

Deterministic value for food ingestion rate (maximum FI rate; mean + 2SD):	Invertebrate	Vegetation
for birds with mean mass (0.0836 kg)	0.0145	0.0056
for birds with minimum mass (0.0708 kg)	0.0130	0.0051

---

[71] Food ingestion rates estimate based on an allometric equation for the free-living metabolic rate for passerines (Nagy 1987): FMR (kcal/day) = $2.123(Wt)^{0.749}$ where Wt is in (g); and assuming an omnivorous diet with a metabolizable energy value of 3.35 kcal/g (Nagy 1987).

[72] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass bird).

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

Foraging Home Range Size:

Mean home range size[74] (ha)	0.25
standard deviation (SD)	0.16
coefficient of variation (CV)	0.64
sample size (n)	3

Distribution: not normal

Mean foraging home range size[75] (ha)	0.48
standard deviation (SD)	0.47
coefficient of variation (CV)	0.97
sample size (n)	2

Distribution: not normal

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[74] Mean territory size calculated from data given in Pitts (1984) and Howell (1942).

[75] Mean foraging home range size calculated from data given in Weatherhead and McRae (1990).

Water Ingestion Rate:

Water ingestion rate[76] (WI rate) (L/day):

for birds with mean mass (0.0836 kg)	0.019
for birds with minimum mass (0.0708 kg)	0.017
standard deviation (SD)[77]	0.0015

Distribution: Given mean and standard deviation, MEI is a normal distribution.[78]

Deterministic value for food ingestion rate (mean WI rate; mean + 2SD):

for birds with mean mass (0.0836 kg)	0.022
for birds with minimum mass (0.0708 kg)	0.020

---

[76] Water ingestion rate estimated using four allometric equations: (1) Calder and Braun (1983), WI (L/day) = 0.059(Body weight kg)$^{0.67}$; Ohmart et al. (1970), WI (L/day) = 0.111(Body weight kg)$^{0.69}$; Thomas and Phillips (1975) WI (L/day) = 0.203(Body Weight kg)$^{0.81}$; Walter and Hughes (1978), WI (L/day) = 0.119(Body Weight kg)$^{0.75}$.

[77] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass bird).
[78] Assumed to be the same as for body mass.

Time Spent On Site:

American robins are reported to arrive in Alberta in early March and move south by October (Semenchuk 1992). The estimated number of days on site is 214.

Habitat Preferences:

American robins require open, grassy ground for feeding and sturdy trees and shrubbery for nesting (Semenchuk 1992). In forested areas, this species inhabits open and broken woodlands, forest edges along rivers, lakes and natural openings and second growth in burnt or cut-over areas (Semenchuk 1992). Breeding areas also include moist forests, swamps, open woodlands, orchards, parks and lawns (U.S. EPA 1993).Robins forage on the ground in open areas, along habitat edges, or the edges of streams; they also forage above the ground in shrubs and within the lower branches of trees (Paszkowski 1982, Malmborg and Wilson 1988).

Deer Mouse (*Peromyscus maniculatus*)

Body Weight:

Mean body mass (kg)[92]	0.0187
standard deviation (SD)	0.0043
coefficient of variation (CV)	0.23
sample size (n)	73

Distribution: Normal

Deterministic value for body mass (minimum body mass; mean - 2SD)	0.0101 kg

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[92] Mean body mass for pre-parous female in the Kananaskis region of Alberta (Millar et al. 1992).

Food Ingestion Rate:

Generally, deer mice diets vary with the time of year. For example, during spring deer mice rely heavily on invertebrates. During summer, they largely consume seeds and some insects; and throughout winter, it believed that deer mice rely entirely on cached and gathered seeds (pers. commun. S. Sharpe, B.C.M.O.E., Smithers, B.C.). Based on this information, deer mice diet is assumed to be composed as reported below.

Diet Composition:

May through June:	100% insects
July through Sept.:	25% insects, 75% seeds
Oct. through April:	100% seeds

Food ingestion rate[93] (FI rate) (kg/day):

for mouse with mean mass (0.0187 kg)	0.00324
for mouse with minimum mass (0.0101 kg)	0.0023
standard deviation (SD)[94]	0.0007

Distribution: Normal (based on the fact that FI is dependant on body mass which is normally distributed.[95]

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

for mouse with mean mass (0.0187 kg)	0.00473 kg/day
for mouse with minimum mass (0.0101 kg)	0.00378 kg/day

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[93] Food ingestion rate calculated as a function of body mass using Nagy's (1987) allometric equation for rodents, FI (g dry weight /day) = 0.621(Body weight g)$^{0.564}$.

[94] Standard deviation for food ingestion based on the coefficient of variation for body mass as FI is correlated to body mass (standard deviation = CV x FI rate for mean mass deer mouse).

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

Home Range:

Mean home range[96] (ha)	0.223
standard deviation (SD)	0.222
coefficient of variation (CV)	1
sample size (n)	10

Distribution: not normal

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[96] Home range calculated from data given in Banfield (1974), Mullican (1988) and King (1968).

Water Ingestion Rate:

Water ingestion rate[97] (WI rate) (L /day):	
for mouse with mean mass (0.0187 kg)	0.0028
for a mouse with minimum mass (0.0101 kg)	0.0016
standard deviation (SD)[98]	0.000634

Distribution: Normal[99]

Deterministic value for water ingestion rate (maximum WI rate; mean + 2SD):	
for mouse with mean mass (0.0187 kg)	0.004 L/day
for mouse with minimum mass (0.0101 kg)	0.003 L/day

---

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

[98] Standard deviation for water ingestion based on the coefficient of variation for body mass as WI is correlated to body mass (standard deviation = CV x WI rate for mean mass deer mouse).

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

Time Spent in Area:

Deer mice are present on site year round and are active year round (Burt 1976, Gadd 1995). *Peromyscus maniculatus* is active throughout the year in Alberta (Robinson and Bolen 1989).

Habitat Preference:

Deer mice are found in almost all habitats in the province from human habitation to open sand dunes, dense northern forests, alpine meadows and open grasslands (Smith 1993). A common species, the deer mouse is likely the most abundant mammal in the province (Smith 1993).

Black Bears (*Ursus americanus*)

Body Weight:

Mean body mass kg[1]	129.7
standard deviation (SD)	5.69
sample size (# studies)	3

Distribution: Normal

---

[1] Mean body mass for black bears calculated from data given in Tietje et al. (1986), Soper (1973).

Food Ingestion Rate:

Black bears are omnivorous however, 75% of their diet is vegetarian. Throughout the early spring, black bears feed on newly emergent vegetation such as grasses, buds and leaves. With the progression of summer, there is a need to increase the intake of foods high in sugars in order to gain weight for hibernation. Dietary preferences at this time switches to berries and fruit. The remaining 25% of the black bear diet is composed of carrion (10-15%), insects (5-10%) and small mammals and fish (<1%). (Gadd, 1995; Towers, 1980).

Food ingestion rate[2] (FI rate) (kg/day):	
for black bear with mean mass (129.7 kg)	3.01
for black bear with minimum mass (118.32 kg)	2.81

Distribution: Distribution: Normal[4]
for black bear with mean mass (129.7 kg)

[2] Food ingestion rate calculated as a function of body mass using the allometric equation FI (g dry weight/day)=0.577(Body weight g)$^{0.727}$ (Nagy, 1987).

Home Range:

Mean home range[5] (ha)	20,000

Distribution: not normal

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[5] Ranges of male black bears range through overlapping areas in the mountains. This figure varies depending on the bear's age, population density, and the availability of food. Home ranges of sows are smaller and non-overlapping (Gadd, 1995).

Water Ingestion Rate:

Water ingestion rate[6] (WI rate) (L /day):	
for black bears with mean mass (129.7 kg)	7.89

for black bears with minimum mass (118.32 kg)	7.27

Distribution: Normal

[6] Water ingestion rate estimated based on one allometric equation, WI(L/day)= $0.099Wt^{0.90}$ where Wt is body weight in (kg) Calder and Braun (1983).

Time Spent On Site

In the Canadian Rockies, nearly all bears are in hibernation by the end of October until emergence in mid-April. Denned bears do not eat, drink or eliminate waste during this time (Gadd, 1995; Towers, 1980). Considering that bears are hibernating for 5 months of the year, they are foraging for only 7 months per year (or 58% of the available calendar days).

Habitat Preferences

Habitat selection is closely related to food availability, particularly the availability of berries. Black bears prefer areas with dense tree and shrub cover in order to escape from predators. Since bears also climb trees to escape predators, areas with tree diameters large enough to support the weight of a climbing bear are favored (Gadd, 1995).

General Information

Black bears are active day and night (unless hibernating), constantly searching for food. They are generally solitary animals, except for females with cubs, but will share large berry patches if necessary (Gadd, 1995).

After a 220-day gestation period, cubs are born in mid-January or February. They stay with there mother until their second spring. The species generally breeds every other year with breeding taking place between June 20 to July 10 (Gadd, 1995). The average life span for a black bear is twelve years (Towers, 1980).

For hibernation, each bear digs a simple shelter, under a tree or tall shrub. During hibernation, body temperatures decrease from 38°C to 34-31°C. This ensures that muscles stay warm enough so that they can become active quickly if required. The black bears use 1 kJ of energy per day during hibernation which is converted from fat reserves and from protein which is converted from urea (Gadd, 1995).

X.4.2 HUMAN RECEPTOR PARAMETERS

X.4.2 Human Receptor Parameters

Exposure pathways considered for the human health risk assessment included ingestion of water (intentional and incidental during swimming); ingestion of plant material and wild game; transdermal absorption of waterborne chemicals during swimming; and inhalation of airborne chemicals. Exposure scenarios and equations for human receptors are described in the main text of the report, the exposure parameters and values employed for the calculations are presented here, in Tables X-35 and X-36.

In addition to the receptor exposure parameters, several additional items respecting the exposure assessment should be noted:

1. For the exposure assessment involving inhalation of petroleum hydrocarbons, the exposure was conducted with consideration of the approach recently reported by the Total Petroleum Hydrocarbon Criteria Working Group in the U.S. (TPHCWG 1997). Briefly, this approach recognizes that petroleum hydrocarbon exposures often involve complex hydrocarbon mixtures for which the majority of compounds have no toxicity data. To accommodate this, the approach involves grouping the known chemicals and mass concentrations into groups defined by general structure such as aliphatics (i.e., alkanes and alkenes) and aromatics, and additionally by carbon chain length and boiling point. The TPHCWG then proposed that exposures to these grouped chemicals be compared to toxicity reference values for these various groups. The toxicity reference values were based on consideration of the most potent substance known in a group, or toxicity data from bioassays involving applicable mixtures (discussed further in Appendix X.5.2).

2. Therefore, for the inhalation exposure assessment presented here, aliphatics and aromatics were segregated into groups with carbon chain lengths typically involving C1-C10 (aliphatics) and C5-8 or C9-C18 (aromatics, excluding benzene which was assessed separately). For aliphatics this grouping spans two of the TPHCWG categories (C5-C8, and C8-C10), and includes several high emission substances, such as methane and ethylene, which are very low in toxicity and normally left out of the TPHCWG approach. Therefore, by adopting this slightly modified approach, the exposure assessment becomes very conservative in that the C1-C5 substance are included in the exposure assessment, and are effectively treated as more potent substances in the C6-C10 range. This conservative approach to the petroleum hydrocarbon inhalation exposure assessment would therefore overestimate exposure and associated risks.

3. The chemical groupings, exposure concentrations and resultant exposure estimates for the airborne petroleum hydrocarbons are presented for each emission source in Table X-44.

4. For airborne substances that were non-carcinogenic aldehydes or ketones, the exposure assessment was conducted by collectively adding the exposure concentrations according to the chemical family, and then expressing the total aldehyde or ketone concentration as equivalent to the most toxic surrogate substance for that group. This approach allowed for assessment of some substances for which toxicity is not well defined, and was also a conservative strategy which treated less toxic substances as the more toxic group surrogate. For aldehydes and ketones, the surrogates were acrolein and acetone, respectively.

5. For non-carcinogenic polycyclic aromatic hydrocarbons (PAHs), substances were grouped as derivatives of either naphthalene, fluorene , fluoranthene or pyrene, The total concentration for each group was then used for the exposure assessment and the group surrogates used to define the associated exposure and health risk. Several PAHs did not readily fit into these categories based on structural differences, and additionally were poorly defined for toxic potency (including lack of confirmed carcinogenic potential); therefore these substances were grouped and the collective exposure treated conservatively as pyrene, the most potent non-carcinogenic PAH from the above surrogates.

6. For carcinogenic PAHs, these substances were treated as equivalents of benzo(a)pyrene with an adjustment for potency in carcinogenic potential. For ease in calculations, an adjusted exposure rate was derived by adjusting the exposure concentration of the carcinogenic PAH according to the substance's toxicity equivalence factor (TEF), relative to benzo(a)pyrene. For example, if the TEF was 0.1, then the exposure concentration was adjusted by this factor, then summed to that of benzo(a)pyrene. The resultant exposure estimate for carcinogenic PAHs was then treated as benzo(a)pyrene during risk estimation. Table X-44 lists

Table X-35 Human Receptor Parameters

Parameter	Child	Adult	Source
Operational Scenario: Swimming			
Body Weight (kg)	13	70	Health Canada (1994)
Incidental Water Ingestion Rate while	0.05	0.05	assumed
Surface Area for dermal contact (m^2)	0.94	1.82	Health Canada (1994)
Exposure Time (hr/event)	2.6	2.6	assumed
Exposure Frequency (events/yr)	7	7	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)
Operational Scenario: Recreational Activities (eg., hiking, boating)			
Body Weight (kg)	13	70	Health Canada (1994)
Water Ingestion Rate (L/day)	0.8	1.5	Health Canada (1994)
Surface Area for dermal contact (m^2)	0.94	1.82	Health Canada (1994)
Exposure Frequency (events/yr)	104	104	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)
Operational Scenario: Air Inhalation			
Body Weight (kg)	27	70	Health Canada (1994)
Air Inhalation Rate (m^3/day)	12	23	Health Canada (1994)
Exposure Frequency (days/yr)	365	365	assumed
Exposure Duration (years)	7	50	assumed
Averaging Time - Non-carcin. (years)	7	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)
Operational Scenario: Local Plant and Fish Ingestion			
Body Weight (kg)	13	70	Health Canada (1994)
Blueberry Ingestion Rate (kg/day)	0.005-0.01	0.005-0.01	assumed, based on information for Ft. McKay, Ft. Smith and Ft. Chipewyan (Wein, 1989; Fort McKay Environmental Services, 1995; 1997)
Labrador Tea/Cattail Root Ingestion Rate (kg/day)	0.001-0.005	0.001-0.005	
Fish Ingestion Rate (kg/day)	0.094	0.247	Richardson (1997)
Exposure Frequency - blueberries and meat	365	365	assumed
Exposure Frequency - Labrador tea and cattail	52	52	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)
Closure Scenario: Reclaimed Landscape			
Body Weight	13	70	Health Canada (1994)
Water Ingestion Rate (L/d)	n/a	1.5	Health Canada (1994)
Meat Ingestion Rate (kg/d)	0.0225	0.046	Health Canada (1994; 25% of daily requirements)
Plant Ingestion Rate (kg/d)	0.008	0.011	Health Canada (1994; 10% of daily requirements in the summer)
Exposure Frequency (days/yr)	365	365	assumed
Exposure Duration (years)	3.5	50	assumed
Averaging Time - Non-carcin. (years)	3.5	50	assumed
Averaging Time - Carcinogen (years)	70	70	Health Canada (1994)

Table X-36 Dermal Permeability Constants (Kp) for Water

Chemical	**Kp**[1]
Aluminum	0.00001
Antimony	0.00001
Barium	0.00001
Boron	0.00001
Cadmium	0.00001
Copper	0.00001
Lead	0.00000004
Molybdenum	0.00001
Nickel	0.000001
Vanadium	0.00001
Zinc	0.000006
Benzo[a]pyrene	0.012
Benzo[a]anthracene	0.0081

[1] Source: EPA, 1992b.

X.5.1 TOXICITY ASSESSMENT FOR WILDLIFE HEALTH

X.3 Exposure Pathway Screening

The objective of screening exposure pathways is to: i) identify potential routes through which people and wildlife could be exposed to chemicals and, ii) determine the relative significance or importance of operable exposure pathways. A chemical represents a health risk only if it can reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. If there is no pathway for a chemical to reach a receptor, there can be no risk, regardless of the source concentration. The goal of this task is to identify all possible exposure pathways and then to evaluate which pathways are likely to be realistic and applicable to the site under investigation.

X.3.1 Exposure Pathway Screening for Wildlife Health

W-2: Water-Mediated Exposure (Operation and Closure)

Ingestion of surface water **-** Wildlife may be exposed to water releases from the Project by ingesting surface water as a drinking water source. Thus, this exposure pathway was retained for further evaluation in the risk assessment for key question W-2.

Ingestion of fish and/or aquatic invertebrates **-** Water releases from the Project may contribute to increased concentrations of metals and organic chemicals in the tissues of fish and aquatic invertebrates. Since a large part of the diet of aquatic wildlife (e.g., water shrew, river otter, great blue heron) consists of fish and/or aquatic invertebrates, this exposure was retained for further evaluation in the risk assessment for key question W-2.

Direct contact with surface water **-** Although wildlife may be exposed by directly contacting surface water, birds and fur-bearing mammals likely receive insignificant doses through this route relative to other routes, such as direct ingestion of water (Environment Canada 1994). Therefore, this pathway was excluded from further consideration.

W-3: Plant-Mediated Exposure (Operation)

Ingestion of plants **-** Air emissions from the Project may deposit onto plant surfaces and soils and subsequently be taken up into plant tissues. Herbivorous wildlife could be exposed by consuming the plants. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-3.

W-4: Water- and Plant-Mediated Exposure (Operation)

All exposure pathways identified for W-2 and W-3 were retained for evaluation of key question W-4. Inhalation of air was considered to be a minor exposure pathway for wildlife in comparison to the exposures incurred from ingestion of plants, fish, invertebrates and/or water. Furthermore, indirect exposure to air emissions via consumption of plants growing in areas within the zone of potential influence of air emissions from existing facilities was considered. Therefore, air inhalation was not retained as an exposure pathway for the risk assessment of key question W-4.

W-7: Multi-Media Exposure (Closure)

Volatile Chemicals - Volatilization of VOCs from surface water and soils into the air can result in direct exposure to wildlife, especially soil dwelling and burrowing insects and mammals, through inhalation of vapours. However, this pathway was not evaluated since it was considered to be a minor exposure pathway for wildlife and concentrations of volatile chemicals are expected to decrease over time.

Fugitive dust generation from surface soils - Fugitive dust generated from surface soils can result in exposure to wildlife through inhalation of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because CT deposits will be capped with sand and muskeg so erodible chemical concentrations of soils will be comparable to natural background levels and landscapes will also be covered with vegetation; thereby further reducing potential for dust generation. Therefore, this exposure pathway was excluded from further evaluation.

Direct contact with air - Volatilization of chemicals from surface water and soils into the air can result in direct exposure to wildlife through dermal uptake of chemicals present in air vapours. However, dermal uptake of volatile chemicals is not expected to contribute significantly to exposure of wildlife, and was therefore excluded from further analysis.

Direct contact with soils - Digging and fugitive dust generation can result in exposure to wildlife through dermal contact with soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent direct contact with CT deposits. In addition, dermal exposure of birds and furbearing mammals is generally considered an insignificant exposure pathway, except directly after pesticide spraying (Environment Canada 1994). Therefore, this exposure pathway has been excluded from further consideration.

Direct contact with surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Although wildlife could be exposed by directly contacting surface water, birds and fur-bearing mammals likely receive insignificant doses through this route relative to other routes, such as direct ingestion of water (Environment Canada 1994). Therefore, this pathway was excluded from further consideration.

Ingestion of fugitive dust - Fugitive dust generated from surface soils can result in exposure to wildlife through ingestion of chemicals bound to soil particles. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent dust arising from wind-based erosion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of surface water - Water soluble chemicals can leach from the tailings materials into groundwater and ultimately seep into surface water bodies (e.g., springs, wetlands, streams). Wildlife could be exposed by drinking surface water. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-7.

Ingestion of soils/sediment - Digging and fugitive dust generation can result in exposure to wildlife through incidental ingestion of soils. However, this is not expected to be a significant exposure pathway because the proposed capping and reclamation scheme will prevent ingestion of CT deposits. Therefore this pathway was removed from further consideration.

Ingestion of plants - Plants that are growing on reclaimed surfaces may accumulate metals and organic compounds in their tissue. Herbivorous wildlife could be exposed by consuming the plants. Since large areas of reclaimed landscape are to be constructed, ingestion of plants is a potential exposure pathway for wildlife. Therefore, this exposure pathway was retained for further evaluation in the risk assessment for key question W-7.

Ingestion of animals - Carnivorous and omnivorous animals have the potential to accumulate some metals and organic compounds in tissue from their prey. Although consumption of prey is a potential exposure pathway for wildlife, none of the chemicals of concern identified during chemical screening are expected to bioaccumulate through the food chain. For this reason, ingestion of animals was not considered further in the risk assessment for key question W-7.

X.5 Toxicity Assessment

The following condensed toxicological profiles describe the key studies and dose-response relationships upon which the toxicity reference values are based.

X.5.1 Toxicity Assessment for Wildlife Health

Toxicity Reference Values for Metals

Antimony

No specific data were identified regarding the oral toxicity of antimony to mammalian wildlife. A LOAEL of 1.25 mg/kg-day was reported for lifespan and longevity in laboratory mice that were exposed to antimony in drinking water for one lifetime (Schroeder et al. 1968). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL of 0.125 mg/kg-day. Exposure was considered to be chronic because it was throughout the entire lifespan.

For this assessment, the chronic NOAEL for mice was used to estimate a receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in the Sample et al. (1996) and summarized in Table X-27. For moose, snowshoe hare, and black bear, receptor-specific NOAELs of 0.012, 0.047, and 0.015 mg/kg-BW/day, respectively, were derived.

Barium

No specific data were identified regarding the oral toxicity of barium to mammalian wildlife. A NOAEL of 5.06 mg/kg-day was reported for effects on growth, food and water consumption and hypertension in laboratory rats that were exposed to barium chloride in drinking water for 16 months (Perry et al. 1983). Exposure was considered to be chronic because it was greater than one year.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in the Sample et al. (1996) and summarized in Table X-27. For deer mouse, moose, water shrew, snowshoe hare and black bear, receptor-specific NOAELs of 11.1, 0.93, 12.2, 3.7, 1.2 mg/kg-day respectively, were derived.

No specific data were identified regarding the oral toxicity of barium to avian wildlife. A NOAEL of 208.26 mg/kg-day was reported for mortality for day-old chicks that were exposed to barium hydroxide in the diet for four weeks (Johnson et al. 1960). An uncertainty factor of 10 was applied to the NOAEL to extrapolate from subchronic to chronic exposure resulting in a chronic NOAEL of 20.826 mg/kg-day.

For this assessment, the chronic NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer, mallard and grouse, a NOAEL of 20.8 mg/kg-day was used in the current assessment.

Boron

No specific data were identified regarding the oral toxicity of boron to mammalian wildlife. A NOAEL of 28 mg/kg-BW/day was reported for effects on reproduction in laboratory rats that were exposed to boric acid in the diet for 3 generations (Weir and Fisher 1972). Exposure was considered to be chronic because it occurred for over a year and throughout critical lifestages.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for moose by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. A receptor-specific NOAEL of 4.9 mg/kg-day was derived for moose.

Cadmium

No specific data were identified regarding the oral toxicity of cadmium to mammalian wildlife. A LOAEL of 1.913 mg/kg-day was reported for reproductive effects (i.e., reduced survival and congenital deformities) in laboratory mice that were exposed to cadmium for two generations (Schroeder and Mitchener 1971). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL resulting in an RfD of 0.1913 mg/kg-day. This study was selected by Opresko et al. (1994) as an appropriate RfD to use for mammalian wildlife risk assessments. However, after further review of the toxicological data for cadmium in 1996, it was determined that the RfD derived from the Schroeder and Mitchener (1971) study was too conservative as it frequently predicted risks in uncontaminated areas (Sample et al. 1996). Therefore, Sample et al. (1996) selected an alternative RfD from a study by Sutou et al. (1980), which was considered to be more appropriate for use in wildlife risk assessments. In this study, a NOAEL of 1.0 mg/kg-day was reported for reproductive effects (i.e., reduced fetal implantation and survivorship, increased fetal resorptions) in laboratory rats that were exposed to cadmium for six weeks throughout mating and gestation periods. Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL of 1.0 mg/kg-day for laboratory rats was used to estimate a receptor-specific NOAEL for moose by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. A receptor-specific NOAEL of and 0.018 mg/kg-day was derived for moose.

Chromium

No specific data were identified regarding the oral toxicity of chromium to avian wildlife. A NOAEL of 1 mg/kg-day was reported for reproduction for black ducks that were exposed to chromium in the diet for ten months (Haseltine et al. unpublished). Exposure was considered to be chronic because it occurred during a critical lifestage and for greater than ten weeks.

For this assessment, the chronic NOAEL for black ducks was used as the NOAEL for killdeer with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer, a NOAEL of 1 mg/kg-day was used in the current assessment.

Cobalt

No specific data were identified regarding the oral toxicity of cobalt to mammalian wildlife. A maximum tolerable level of 10 mg/kg diet was determined to be suitable for cattle (NAS 1980). Considering an average body weight and food ingestion rate for cattle of 400 kg and 22 kg/day, this maximum tolerable level was converted to a NOAEL of 0.55 mg/kg-day.

For this assessment, the NOAEL for cattle was used to estimate receptor-specific NOAELs for water shrews by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. A receptor-specific NOAEL of 3.0 mg/kg-day was derived.

No specific data were identified regarding the oral toxicity of cobalt to avian wildlife. A maximum tolerable level of 10 mg/kg diet was determined to be suitable for chicks (NAS 1980). Considering an average body weight and food ingestion rate for chicks of 0.5 kg and 0.04 kg/day, this maximum tolerable level was converted to a NOAEL of 0.8 mg/kg-day.

For this assessment, the NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer and grouse, a NOAEL of 0.8 mg/kg-day was used in the current assessment.

Copper

No specific data were identified regarding the oral toxicity of copper to mammalian wildlife. A NOAEL of 11.7 mg/kg-BW/day was reported for effects on reproduction (kit survivorship) in laboratory minks that were exposed to copper sulfate in their diet for 357 days (Aulerich et al. 1982). Exposure was considered to be chronic because it was approximately one year in duration and occurred during a critical lifestage (i.e. during reproduction).

For this assessment, the chronic NOAEL for mink was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For moose, water shrew, snowshoe hare and black bear, receptor-specific NOAELs of 2.7, 34.6, 10.6, and 3.5 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of copper to avian wildlife. A NOAEL of 47 mg/kg-day was reported for mortality for day-old chicks that were exposed to copper oxide in the diet for ten weeks (Mehring et al. 1960).

For this assessment, the chronic NOAEL for chicks was used as the NOAEL for killdeer and grouse, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for the killdeer and grouse, a NOAEL of 47 mg/kg-day was used in the current assessment.

Manganese

No specific data were identified regarding the oral toxicity of manganese to mammalian wildlife. A NOAEL of 88 mg/kg-day was reported for effects reproduction (i.e. litter size, ovulations, resorptions, preimplantation death, and fetal weights) in laboratory rats that were exposed to manganese oxide in their diet throughout gestation (224 days) (Laskey et al. 1982). Exposure was considered to be chronic because it occurred during a critical life stage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For snowshoe hare, black bear, water shrew, and moose, receptor-specific NOAELs of 61.1, 20.0, 200.5 and 15.3 mg/kg-day, respectively, were derived.

Mercury

No specific data were identified regarding the oral toxicity of mercury to mammalian wildlife. A NOAEL of 1 mg/kg-day was reported for effects reproduction (i.e. kit weight, fertility and kit survival) in laboratory minks that were exposed to mercuric chloride in their diet throughout gestation (six months) (Aulerich et al. 1974). Exposure was considered to be chronic because it occurred during a critical life stage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For deer mouse, receptor-specific NOAELs of 2.7, mg/kg-day, respectively, was derived.

Molybdenum

No specific data were identified regarding the oral toxicity of molybdenum to mammalian wildlife. A LOAEL of 2.6 mg/kg-BW/day was reported for reproductive effects (i.e. reduced reproductive success, high incidence of runts) in laboratory mice that were exposed to molybdenum in water for three generations (Schroeder and Mitchener, 1971). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL resulting in an RfD of 0.26 mg/kg-day. Exposure was considered to be chronic because it was greater than one year and occurred during a critical lifestage.

For this assessment, the chronic NOAEL for laboratory mice was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For moose, deer mouse and black bear, receptor-specific NOAELs of 0.024, 0.29, and 0.03 mg/kg-day, respectively, were derived.

Nickel

No specific data were identified regarding the oral toxicity of nickel to mammalian wildlife. A NOAEL of 80 mg/kg-BW/day was reported for reproductive effects (i.e. offspring body weights) in laboratory rats that were exposed to nickel sulfate hexahydrate in diet for three generations (Ambrose et al. 1988). Exposure was considered to be chronic because it was greater than one year and occurred during a critical lifestage.

For this assessment, the chronic NOAEL for laboratory rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For deer mouse, a receptor-specific NOAEL of 83.2 mg/kg-day, was derived.

Selenium

No specific data were identified regarding the oral toxicity of selenium to mammalian wildlife. A NOAEL of 0.2 mg/kg-BW/day was reported for reproductive effects (i.e. decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to potassium selenate in the diet for one year through two generations (Rosenfeld and Beath 1954). Exposure was considered to be chronic because it occurred during a critical lifestage and was one year in duration.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for moose and deer mouse by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For moose and deer mouse, receptor-specific NOAEL of 0.035 and 0.4 mg/kg-day respectively were derived.

Strontium

No specific data were identified regarding the oral toxicity of strontium to mammalian wildlife. A NOAEL of 263 mg/kg-BW/day was reported for body weight and bone changes in laboratory rats that were exposed to strontium chloride in the diet for three years (Skoryna 1981). Exposure was considered to be chronic because it was one year in duration.

For this assessment, the chronic NOAEL for rats was used to estimate a receptor-specific NOAEL for deer mouse by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For deer mouse, a receptor-specific NOAEL of 547 mg/kg-day was derived.

Vanadium

No specific data were identified regarding on the oral toxicity of vanadium to mammalian wildlife a LOAEL of 2.1 mg/kg-day was reported for reproductive effects (i.e. decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to sodium metavanadate by oral gavage for 60 days prior to gestation, during gestation, delivery and lactation (Domingo et al. 1986). An uncertainty factor of 10 was applied to the LOAEL to extrapolate from the LOAEL to a NOAEL, resulting in an RfD of 0.21 mg/kg-day. Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAEL for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For moose, deer mouse, bear, and hare, receptor-specific NOAELs of 0.034, 0.41, 0.04, and 0.14 mg/kg-day, respectively, were derived.

Zinc

No specific data were identified regarding the oral toxicity of zinc to mammalian wildlife. A NOAEL of 160 mg/kg-day was reported for reproductive effects (i.e. fetal resorption and reduced fetal growth rates) in laboratory rats that were exposed to zinc oxide in the diet during days 1 through 16 of gestation (Schlicker and Cox 1968). Exposure was considered to be chronic because it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for rats was used to estimate receptor-specific NOAELs for mammalian wildlife by adjusting the dose according to differences in body size as outlined in Sample et al. (1996) and summarized in Table X-27. For water shrew and deer mouse, receptor-specific NOAELs of 347 and 333 mg/kg-day, respectively, were derived.

No specific data were identified regarding the oral toxicity of zinc to avian wildlife. A NOAEL of 14.5 mg/kg-day was reported for reproductive effects in leghorn hens that were exposed to zinc sulphate in the diet for 44 weeks (Stahl et al. 1990). Exposure was considered to be chronic because it was greater than 10 weeks and it occurred during a critical lifestage.

For this assessment, the chronic NOAEL for leghorn hens was used as the NOAEL for killdeer in this assessment, with no adjustment for species differences. According to Sample et al. (1996), dose scaling methods for interspecies extrapolation among mammals are not applicable to birds. The most appropriate scaling factor for dose extrapolation among bird species is 1. Therefore, for killdeer, grouse and mallard, a NOAEL of 14.5 mg/kg-day was used in the current assessment.

X.5.2 TOXICITY ASSESSMENT FOR HUMAN HEALTH

X.5.2 Toxicity Assessment for Human Health

Toxicity Reference Values for Metals

Antimony

An oral reference dose (RfD) of 0.0004 mg/kg-day was established for antimony by the US EPA (1997), based on a chronic study in rats (Schroeder *et al.* 1968). A lowest observed adverse effect level (LOAEL) of 0.35 mg/kg-day was reported in this study, based on effects on longevity, blood glucose and cholesterol. An uncertainty factor of 1000 was applied to the LOAEL for derivation of the RfD.

Arsenic

Arsenic has been classified as a Type A carcinogen indicating that arsenic is a probable human carcinogen based on sufficient evidence from human evidence. An oral slope factor of 1.5 (mg/kg-day)$^{-1}$ was developed based on skin cancer (U.S. EPA 1997), resulting in an RsD of 6.7 x 10 $^{-6}$ mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000.

Barium

An oral RfD of 0.07 mg/kg-day was established for barium by the US EPA (1997), based on studies of humans exposed to barium via drinking water. Populations exposed to barium levels of between 2 and 10 mg/L compared to populations exposed to low levels (0.02 mg/L or less) showed higher mortality rates for cardiovascular disease. From a sub-chronic study involving human volunteers, a no observed adverse effect level (NOAEL) of 10 mg/L was determined. An uncertainty factor of 3 was applied to the NOAEL for derivation of an RfD.

Beryllium

Berylium has been classified as a Type B2 carcinogen indicating that beryllium is a probable human carcinogen based on sufficient evidence from animal experiments but inadequate or limited evidence from human exposure data. An oral slope factor of 4.3 (mg/kg-day)$^{-1}$ was developed based on tumour incidence in rats (US EPA 1997), resulting in an RsD of 2.3 x 10^{-6}, based on an acceptable cancer risk level of 1 in 100, 000.

Boron

US EPA (1997) has established an oral RfD for boron and borates of 0.09 mg/kg-day based on a two year study in dogs. Testicular atrophy and spermatogenic arrest was observed in dogs exposed to borax and boric acid in the diet. The study identified 350 ppm, or 8.8 mg/kg-day, as a NOAEL. Testicular effects were also observed in a chronic bioassay in rats, but dogs appear to be more sensitive. An uncertainty factor of 100 was applied to the NOAEL from the dog study to derive the RfD.

Cadmium

Heath Canada has set an oral tolerable daily intake (TDI) of 0.00081 mg/kg-day (Barry Jessiman pers. comm. 1994). This is the highest cadmium level not associated with significant kidney disease (Health Canada 1990). US EPA has established an oral RfD for cadmium in water of 0.0005 mg/kg-day which is adjusted to 0.001 mg/kg-day if cadmium is consumed in food. US EPA employed a toxicokinetic model to identify the highest level of cadmium in the human renal cortex that was not associated with significant proteinuria. The resulting value was used to derive the RfD. The oral absorption factor was set at different levels in the toxicokinetic model depending on the source of the metal (*i.e.*, food vs. drinking water).

Chromium

An oral reference dose of (RfD) 1 mg/kg/day was established by the US EPA (1997), based on a chronic study in rats (Ivankovic and Preussmann 1975). A NOAEL of 1468 mg/kg/day was reported in this study, based on effects on longevity.

Copper

The safe and adequate dietary requirements for copper are estimated by Health Canada to be 0.05 to 0.1 mg/kg-day for children aged 3 to 10 years (CCME 1997, Health and Welfare Canada 1990). The value of 0.1 mg/kg-day was used as the TDI in the derivation of the CCME (1997) human health soil quality guideline, and was selected as the oral toxicity reference value for the current assessment.

Lead

A TDI of 0.00357 mg/kg-day was established for children by the World Health Organization. This TDI was used to establish Canadian drinking water standards for lead (CCME 1987), and it is considered sufficient to protect against neurobehavioural effects and anemia in children. The TDI was based on the results of metabolic studies using infant subjects which showed that an intake of 3 to 4 μg/kg-day was not associated with an increase in blood lead levels while an intake of 5 μg/kg-day or more was associated with lead retention. A TDI of 0.00714 mg/kg-day was used for adults.

Molybdenum

Molybdenum is an essential dietary nutrient which has established "Estimated Safe and Adequate Daily Intake" values of 0.002-0.004 mg/kg-day for infants, 0.002-0.005 mg/kg-day for children, and 0.002-0.004 mg/kg-day for adults (NRC 1989). U.S. EPA (1997) developed an oral RfD of 0.005 mg/kg-day for people exposed to molybdenum. This value is based on a LOAEL of 0.14 mg/kg-day in humans exposed to molybdenum orally, with effects including increased uric acid levels, pain and swelling of the joints, and decreased copper levels in the blood (Koval'skiy et al. 1961). The epidemiological study was based on people in a community in Armenia exposed to high concentrations of molybdenum in soils and plants, An uncertainty factor of 30 was applied to the LOAEL to establish the RfD (i.e., a factor of 10 for extrapolation from a LOAEL to NOAEL, and a factor of 3 for protection of sensitive members of the population).

Nickel

An oral RfD for nickel of 0.02 mg/kg-day, established by the US EPA (1997), was used for this assessment. The US EPA derived the RfD based on a chronic study in rats administered nickel in the diet for a two-year period (Ambrose *et al.* 1976). A NOAEL of 100 ppm in the diet (equivalent to 5 mg/kg-day) was identified, based on decreased body and organ weights at a LOAEL of 1000 ppm nickel in the diet. An uncertainty factor of 300 was applied to the NOAEL (10 for interspecies extrapolation, 10 for intraspecies extrapolation, and 3 for inadequacies in the reproduction studies) to derive the RfD of 0.02 mg/kg-day.

Selenium

An oral reference dose (RfD) of 0.005 mg/kg/day was established for selenium by the US EPA (1997), based on a data from a human epidemiological study (Yang et al. 1989). A no observed adverse effect level (NOAEL) of 0.015 mg/kg/day was reported in this study, based on the diagnosis of clinical selenosis (relation between selenium intake and the manifestation of clinical signs and certain biochemical alterations in blood and urine). An uncertainty factor of 3 was applied to the NOAEL for derivation of the RfD.

Vanadium

An RfD of 0.007 mg/kg-day was reported by US EPA (1995) based on a lifetime exposure drinking water study in rats (Schroeder *et al.* 1970). An uncertainty factor of 100 was applied to the NOAEL of 5 ppm to derive this RfD.

Toxicity Reference Values for Organic Chemicals

Various organic compounds associated with petroleum hydrocarbons (PAHs, aliphatics and aromatics) have recently been reviewed by the Total Petroleum Hydrocarbon Working Group (TPHWG 1997). That review has been used here for the toxicity assessment. Some of the following profiles have been reproduced from the TPHWG document and are indicated by the reference to TPHCWG (1997).

Acetaldehyde

Acetaldehyde has been reviewed by the US EPA (1997) and is considered a potential human carcinogen via inhalation. The definitive animal data relates to the production of nasal squamous cell carcinomas and adenocarcinomas in rats (males). The potency has been defined through designation of a unit risk of $2.2x10^{-6}$. The unit risk factor was used to back calculate a slope factor based on an inhalation rate of $23m^3$/day and body weight of 70 kg and then applied to the estimated daily intake via inhalation.

Acetone

The US EPA (1997) have reviewed acetone and assigned an oral RfD, but insufficient data exists to develop a toxicity reference value for exposure via inhalation (i.e., RfC). An oral RfD of 0.1 mg/(kg*day) was assigned based on data from a subchronic rat study where increased liver and kidney weights and nephrotoxicity were noted at a dose of 500mg/(kg*day), but not at 100mg/(kg*day). Using an uncertainty factor of 1000 to accommodate inter- and intra-species uncertainties and uncertainties associated with the subchronic data, the NOEL was extrapolated to the RfD noted above. For the purposes of this assessment, the oral RfD was employed to assess the exposure via inhalation.

Acrolein

Acrolein was reviewed by the US EPA (1997) and was assigned and RfC of $2x10^{-5}$ mg/m^3. Acrolein is a reactive compound which reacts readily at the point of contact and consequently evokes its effects in the nasal epithelium. A subchronic study involving rats resulted in no detection of the NOAEL, only a LOAEL which was based on squamous metaplasia and neutrophilic infiltration of nasal epithelium at an equivalent exposure concentration of 0.02 mg/m3. An uncertainty factor of 1000 was applied to accommodate the inter- and intra-species variability, subchronic nature of the study, lack of a NOAEL and lack of reproductive toxicity data., resulting in the above noted RfC.

Anthracene (C_{14}) (TPHCWG 1997)

Anthracene was administered to groups of 20 male and female CD-1 (ICR) BR mice by oral gavage at doses of 0, 250, 500, and 1000 mg/kg/day for at least 90 days (USEPA 1989c). Mortality, clinical signs, body weights, food consumption, opthalmology findings, hematology and clinical chemistry results, organ weights, organ-to-body weight ratios, gross pathology, and histopathology findings were evaluated. No treatment-related effects were noted. The no observed-effect level (NOEL) is the highest dose tested (1000 mg/kg/day).

The RfD of 0.3 mg/kg/day was calculated using the NOAEL of 1 000 mg/kg/day. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (1000 mg/kg/day) to obtain 0.3 mg/kg/day.

US EPA. 1989. Subchronic Toxicity in Mice with Anthracene. Final Report. Hazelton Laboratories America, Inc. Prepared for the Office of Solid Waste, Washington, DC.

Benzene

The U.S. EPA (1996) has proposed an inhalation slope factor of 2.9E-2 $(mg/kg\text{-}d)^{-1}$ for benzene. Benzene is classified as a human carcinogen based on increased incidence of leukemia in workers exposed to benzene via inhalation. The slope factor was identified based on reports from studies by Rinsky *et al.* (1981), Ott *et al.* (1978), and Wong *et al.* (1983). The U.S. EPA also reported increased neoplasia in rodents exposed to benzene by inhalation and gavage.

Benzo(a)anthracene

Although benzo(a)anthracene has been classified as a B2 carcinogen indicating that benzo(a)anthracene is a probable human carcinogen, a slope factor has not been developed for benzo(a)anthracene (U.S. EPA 1997). The carcinogenic potency of certain PAHs, such as benzo(a)anthracene, can be estimated by using toxicity equivalency factors (TEFs). TEFs are unitless factors which indicate the carcinogenic potency of carcinogenic PAHs relative to benzo(a)pyrene, for which sufficient toxicity information is available for derivation of a slope factor. The TEF for benzo(a)anthracene used in this report (0.1) was provided by the U.S. EPA (1992) memo "Risk Assessment for Polyaromatic Hydrocarbons: Interim Region IV Guidance". A TEF of 0.1 has also been suggested by Nisbet and LaGoy (1992). The oral slope factor for benzo[a]anthracene was then calculated by multiplying the oral slope factor for benzo(a)pyrene by the associated TEF for benzo[a]anthracene (i.e., 0.1). Thus, the slope factor for benzo(a)anthracene is 7.3 $(\text{mg/kg-day})^{-1}$ x 0.1 = 0.73 $(\text{mg/kg-day})^{-1}$, resulting in an RsD of $1.4\text{x}10^{-5}$ mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000 (i.e., $1\text{x}10^{-5} \div 0.73\ (\text{mg/kg-day})^{-1} = 1.4 \text{ x } 10^{-5}$ mg/kg-day).

Benzo(b)fluoranthene (TPHCWG 1997)

Classified as a B2 carcinogen - use B (a) P slope factor and a potency factor. Seven PAHs (benzo(a)pyrene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, cyclopentadieno(cd)pyrene, and coronene) were tested at varying concentrations to determine their dose-response relationships as carcinogens when applied topically to the backs of female NMRI mice two times a week for the lifetime of the animal (40 mice/dose) (Habs et al.,1980). At death, all animals were dissected and their dorsal skin examined histologically for tumor formation. A clear dose-response relationship was observed at the site of application for benzo(a)pyrene. Benzo(b)fluoranthene showed a clear carcinogenic effect. Benzo(j)fluoranthene exhibited weak carcinogenic effects, while benzo(k)fluoranthene and indeno(1,2,3-cd) pyrene showed no carcinogenic effect. In this study, the results were reported as tumors and no other distinction was defined. However, it is assumed that the tumors were all carcinomas based on this statement from the study, "Animals at an advanced state of macroscopically clearly infiltrative growth were killed".

Benzo(a)pyrene, benzo(b)fluoranthene, benz(j)fluoranthene, benzo(k) fluoranthene at concentrations between 0.01% and 0.5% dissolved in acetone were applied to the clipped backs of female Swiss mice (20/dose/chemical) three times per week for the lifetime of the animals (Wynder and Hoffmann, 1959). Results show that benzo(a)pyrene, benzo(b)fluoranthene, and benzo(j)fluoranthene produced high incidences of skin papillomas and carcinomas at all dose levels. Benzo(k)fluoranthene produced a limited number of papillomas only at the high dose level (0.5%). There were no control groups in the study.

Habs, M., Schmahl, D., and Misfeld, J. (1980). Local carcinogenicity of some environmentally relevant polycyclic aromatic hydrocarbons after lifelong topical application to mouse skin. Arch. Geschwulstforsch. 50:266-274.

Wynder, E.L. and Hoffmann, D. (1959). The carcinogenicity of benzo(b)fluoranthene. Cancer. 12:1194.

Benzo(a)pyrene

Benzo(a)pyrene has been classified as a B2 carcinogen indicating that benzo(a)pyrene is a probable human carcinogen based on sufficient evidence from animal experiments but inadequate or limited evidence from human exposure data. An oral slope factor of 7.3 $(mg/kg\text{-}day)^{-1}$ was developed based on stomach tumours (U.S. EPA 1997), resulting in an RsD of $1.4x10^{-6}$ mg/kg-day, based on an acceptable cancer risk level of 1 in 100,000.

2-Butene (TPHCWG 1997)

Male and female Wistar rats were exposed to 2-butene (42.4% cis-2-butene; 55.3% trans-2-butene) in a combined repeat dose and reproductive/developmental toxicity study. Animals were exposed at nominal concentrations of 0, 2500 and 5000 ppm 2-butene, 6 hours/day, 7 days/week. Actual concentrations were 0, 2476 and 5009 ppm or 0, 5.7 and 11.5 g/m^3 , respectively. Exposure of mated females ended after treatment on day 19 of gestation. A significant decrease in body weight was noted in the high dose females during premating weeks 0 to 2, and one day after parturition. Food consumption was decreased for this group in the first pre-mate week. In males, total white blood cell count and lymphocyte number were significantly increased. However, this increase did not follow a dose relationship and was within historical control values. Plasma Ca-levels were significantly decreased in males at 11.5 g/m^3. No reproductive effects were observed in the parental animals. No effects were observed on the number of pups born, sex ratio or viability index. The NOAEL was 5.7 g/m^3 for the P generation and > 11.5 g/m^3 for the F_1 generation.

Koten-Vermeulen, J.E.M.v., Plassche, E.J. vd. 1992. SIDS Dossier on the HPV Pl Chemical: 2-Butene, RIVM, Rijksinstituut Voor Volksgezondheid en Milieuhygiene National Inst.

Chrysene (TPHCWG 1997)

Classified as a B2 carcinogen - use B (a) P slope factor and a potency factor.

Cyclohexane (TPHCWG 1997)

Under TSCA Section 4, the EPA and cyclohexane producers entered into an Enforceable Consent Agreement in November 1994 to conduct the following studies: 2-generation reproduction study (in progress, report to CMA 2/97); 90-day inhalation study in mice (report to CMA 6/96); 90-day neurotoxicity study in rats (report to CMA 6/96); 90-day inhalation study in rats (in progress, report to CMA 1/97); and a developmental study in rats (pilot completed, study start 3/96). In the inhalation developmental pilot study conducted under TSCA Section 4, rats were exposed to 0, 3000, 6000 or 9000 ppm cyclohexane. At 6000 and 9000 ppm, maternal weight gain and overall food consumption was reduced. There was an increased incidence of "stain chin" and "stain face," and generally diminished response of the animals to a sound stimulus while being exposed. No statistically significant differences were noted between control and treated groups in fertility, number of implants, number of resorptions, number of live fetuses, sex ratio, or mean fetal weight. There were no external fetal alterations noted.

Bevan, C. J. (Draft Document). 1995. Cyclohexane Testing Program Update.

Rabbits exposed to 786 ppm cyclohexane, 6 hours/day, 5 days/week for 10 weeks showed microscopic changes in the liver and kidney. No effects occurred in rabbits exposed to 434 ppm for either 10 or 26 weeks. No treatment related effects occurred in monkeys exposed at 1243 ppm cyclohexane for 10 weeks.

Treon, J.F, Crutchfield, W.E., Jr., and Kitzmiller, KV. 1943. The physiological response of animals to cyclohexane, methylcyclohexane, and certain derivatives of these compounds. J. Ind. Hyg. Toxicol. 25:323-347.

In a study to assess the neurotoxic potential of cyclohexane, rats were exposed to a vapor of 1500 or 2500 ppm, 3 to 10 hours/day, 5 to 6 days/week, for periods up to 30 weeks. No histopathologic effects were detected in the peripheral nervous system; however, the central nervous system was not evaluated.

Frontali, N., Amantini, M.C., Spagnoto, A., Guarcini, A.M., Saltari, M.C., Burgnone, F., and Perbillini, L. Experimental neurotoxicity and urinary metabolites of C_5-C_7 aliphatic hydrocarbons used as glue solvents in shoe manufacture. Clinical Toxicol., 18(12):1357-1367, 1981.

N-Decane (TPHCWG 1997)

Rats were exposed to 540 ppm n-decane vapor 18 hours/day, 7 days/week for a total of 123 days. There was a significant weight gain and increase in total leukocyte count compared to controls. No changes were noted in polymorphonuclear lymphocyte ratios, in bone marrow composition, and no significant gross or microscopic organ changes were noted. No information was given as to whether the hematological changes were within normal biological variation. Some rats held for one month without additional exposure did not differ from the controls.

Nau, C.A., Neal, J., and Thornton, M. 1966. C_9-C_{11} fractions obtained from petroleum distillates. Arch Environ. Health 12: 382-393.

Dibenz(a,h)anthracene (TPHCWG 1997)

Classified as a B2 carcinogen - use B(a)P slope factor and a potency factor.

Ethylbenzene (TPHCWG 1997)

The chosen study is a rat 182-day oral bioassay in which ethylbenzene was given 5 days/week at doses of 13.6, 136, 408, or 680 mg/kg/day), in olive oil gavage (Wolf et al., 1956). There were 10 albino female rats/dose group and 20 controls. The criteria considered in judging the toxic effects on the test animals were growth, mortality, appearance and behavior, hematologic findings, terminal concentration of urea nitrogen in the blood, final average organ and body weights, histopathologic findings, and bone marrow counts. The LOAEL of 408 mg/kg/day is associated with histopathologic changes in liver and kidney.

The RfD of 0.1 mg/kg/day was calculated using the NOAEL of 136 mg/kg, which was converted to 97.1 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) was applied to the NOAEL (97.1 mg/kg/day) to obtain 0.1 mg/kg/day.

Fluoranthene (TPHCWG 1997)

Male and female CD-1 mice (20/sex/group) were gavaged for 13 weeks with 0, 125, 250, or 500 mg/kg/day fluoranthene (USEPA, 1988). A fifth group of mice (30/sex) was established in the study for baseline blood evaluations. Body weight, food consumption, and hematological and serum parameter values were recorded at regular intervals during the experiment. At the end of 13 weeks, the animals were sacrificed and autopsied, which included organ weight measurement and histological evaluation. All treated mice exhibited nephropathy, increased salivation, and increased liver enzyme levels in a dose-dependent manner. However, these effects were either not significant, not dose-related, or not considered adverse at 125 mg/kg/day. Mice exposed to 500 mg/kg/day had increased food consumption and increased body weight. Mice exposed to 250 and 500 mg/kg/day had statistically increased SGPT values and increased absolute and relative liver weights. Compound-related microscopic liver lesions (indicated by pigmentation) were observed in 65 and 87.5% of the mid- and high-dose mice, respectively. Based on increased SGPT levels, kidney and liver pathology, and clinical and hematological changes, the LOAEL is considered to be 250 mg/kg/day, and the NOAEL is 125 mg/kg/day.

The RfD of 0.04 mg/kg/day was calculated using the NOAEL of 125 mg/kg/day. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (125 mg/kg/day) to obtain 0.04 mg/kg/day.

US EPA. 1988. 13-Week mouse oral subchronic toxicity study. Prepared by Toxicity Research Laboratories, Ltd., Muskegon, MI for the Office of Solid Waste, Washington, DC.

Fluorene (TPHCWG 1997)

Fluorene (C_{13}) has an RfD of 0.04 mg/kg/day that is on IRIS. This value is based on an oral 13-week study in mice. Mice (25/sex/group) were exposed to 0, 125, 250, or 500 mg/kg/day of fluorene suspended in corn oil by gavage for 13 weeks (USEPA, 1989b). A significant decrease in the red blood cell count and packed cell volume were observed in females in the 250 mg/kg/day group and in males and females at the 500 mg/kg/day dose level. In both high dose males and females, there was a significant decrease in BUN and a significant increase in total serum bilirubin. At 250 and 500 mg/kg/day, there was a significant increase in liver weight. A significant increase in spleen and kidney weight was observed in males and females at 500 mg/kg/day and males at 250 mg/kg/day. Increases in liver and spleen weights in high dose animals were accompanied by histopathological increases in the amounts of hemosiderin in the spleen and Kupffer cells of the liver. The LOAEL is 250 mg/kg/day based on hematological effects and the NOAEL is 125 mg/kg/day.

The RfD for fluorene was calculated by taking the NOAEL of 125 mg/kg/day and applying an uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) and a modifying factor of 3 for lack of adequate toxicity data in a second species and reproductive/developmental data.

US EPA. 1989. Mouse oral subchronic toxicity study. Prepared by Toxicity Research Laboratories, LTD., Muskegon, MI for the Office of Solid Waste, Washington, DC.

Formaldehyde

Formaldehyde has been demonstrated to be a probable human carcinogen (US EPA 1997), when exposure is via inhalation. The definitive animal data relates to the production of squamous cell carcinomas in the nasal turbinates of rats (males and females). The US EPA (1997) defined the potency of formaldehyde using the linearized multistage model on the rat data resulting in a unit risk of 1.3x 10^{-5}, and also specified a risk-specific (10^{-5}) concentration of 8x10^{-4} µg/m^3.. For risk estimation purposes, the slope factor was back calculated from the unit risk using an inhalation rate of 23 m^3/day and body mass of 70kg, then applied to the estimated daily intake

Isopropylbenzene (Cumene) (TPHCWG 1997)

Rats were exposed to cumene vapor at concentrations of 0, 100, 500 and 1200 ppm (0, 0.50, 2.48 and 6.01 mg/L), 6 hours/day, 5 days/week for 13 weeks. A satellite group received a single 6-hour exposure, in order to evaluate neurobehavior. Alterations in functional observational battery (FOB) were observed in the satellite group at 500 and 1200 ppm, at 1 and 6 hours post exposure, but not at 24 hours post exposure. Effects included abnormal gaits, increased activity, decreased rectal temperature, and decreased toe pinch withdrawal reflexes. Necropsies were not performed in the single exposure study. In the 13 week inhalation study, no exposure related deaths occurred. No differences were observed in mean body weight; however, decreased food consumption was noted Week 1 for females exposed at 500 and 1200 ppm. A consistent increase in water consumption was noted in males exposed at 500 and 1200 ppm from week 2 onward. These groups also demonstrated changes in several hematologic and clinical chemistry parameters. No exposure-related changes were seen in brain measurements, functional observational battery, or nervous system histopathology. Motor activity decreased in males exposed to 500 and 1200 ppm. This effect was not observed in a subsequent 13 week inhalation study, reported by the same author. There were no exposure-related effects on spermatogenesis. Liver, kidney and adrenal gland weights were increased in the 500 and 1200 ppm groups. Renal proximal tubular cell hypertrophy, hyperplasia, and hyaline droplet formation was evident in males exposed to 500 and 1200 ppm cumene. Cataracts were observed, however, in a non-dose dependent manner and in both exposed and control animals. Cumene was not considered neurotoxic. The NOAEL for this study was determined at 100 ppm.

Cushman, J.R., Norris, J.C., Dodd, D.E., Darmer, K.I., and Morris, C.R. 1995. Subchronic inhalation toxicity and neurotoxicity assessment of cumene in Fischer 344 rats. J. Am. Coll. Tox. 14(2): 129-147.

In a second 13 week inhalation study, conducted to assess the high incidence of cataracts observed in the first study, rats were exposed to cumene vapor, 6 hours/day, 5 days/week at concentrations of 0, 50 (permissible exposure limit),100, 500 and 1200 ppm (0, 0.25, 0.50, 2.50 and 6.00 mg/L), with a 4 week recovery period. No animals died during the study. Body weights were unremarkable. Although some relative and absolute liver, kidney and adrenal gland weights were increased in rats exposed at 500 or 1200 ppm, no histopathological evaluations were conducted. The eyes were the only tissue evaluated histopathologically. No treatment related ophthalmic effects were observed. No serum chemistry or hematological evaluations were conducted. No changes in functional observational battery, auditory brain stem response, or motor activity were observed in any dose group. No treatment related neurotoxic or ototoxic effects were noted. The NOAEL for this study is 100 ppm, and is in agreement with the initial 13 week study conducted by Cushman et al. (1995).

Cushman, J.R., Norris, J.C., Dodd., D.E., Darmer, K.I., and Morris, C.R. 1995. Subchronic inhalation toxicity and neurotoxicity assessment of cumene in Fischer 344 rats. J. Am. Coil. Tox. 14(2): 129-147.

Rats were exposed to cumene vapor at concentrations of 0, 105, 300, or 599 ppm (0, 0.53, 1.5 and 3.0 mg/L), 6 hours/day, 5 days/week for approximately 28 days. No animals died during the study. Hypoactivity and irritation effects were noted during exposure. Absolute and relative liver and/or kidney weights were increased. No changes were reported in mean body weight, clinical, gross or microscopic pathology findings. The NOAEL was > 3 mg/L.

EUCLID Data Sheet: Cumene. 1995. Section 5.4 Repeated Dose Toxicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Female rats were exposed to 0, 100, 500 or 1200 ppm cumene vapor, 6 hours/day, on days 6 - 15 of gestation. No dams died, aborted or delivered early. However, body weight gain was significantly reduced throughout the exposure period in dams in the 1200 ppm group, and maternal food consumption was reduced at 1200 and 500 ppm. Gross observations, body weight, and organ weights were unremarkable except for a significant increase in relative liver weight at 1200 ppm. No significant changes were noted in gestational parameters and no increased incidence of either malformations or variations were noted. The NOEL for developmental toxicity was greater than 1200 ppm.

EUCLID Data Sheet: Cumene. 1995. Section 5.9 Developmental Toxicity/Teratogenicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Female rabbits were exposed to 0, 500, 1200 or 2300 ppm cumene vapor, 6 hours/day on days 6 - 18 of gestation. Maternal toxicity occurred in all three treatment groups as evidenced by maternal deaths, reduced relative liver weight (2300 ppm), and reduced maternal weight gain and food consumption during the exposure period. There were no significant changes in gestational parameters and no increased incidence of malformations or variations. However, one significant variation, ecchymosis of the head, was observed at 500 ppm but was within range of historical control values. The NOEL for developmental toxicity was greater than 2300 ppm.

EUCLID Data Sheet: Cumene. 1995. Section 5.9 Developmental Toxicity/Teratogenicity. ICI Chemicals & Polymers. EBSI Document No. 96MRR 54.

Groups of 10 female Wistar rats were administered 139 doses of cumene by gavage in olive oil at 154, 462, or 769 mg/kg/day over a 194-day period; 20 rats given olive oil served as controls (Wolf et al., 1956). Body weights were measured throughout the study. Most hematological evaluations were conducted after the 20, 40, 80, and 130th doses, and blood urea nitrogen determinations, and gross and histological examinations (lungs, heart, liver, kidneys, testes, spleen, adrenals, pancreas, femoral bone marrow) were conducted at the end of the study. Effects were not observed at 154 mg/kg/day but a "slight" but significant increase in average kidney weight occurred at 462 mg/kg/day. A "moderate' increase in average kidney weight occurred at 769 mg/kg/day. Therefore, 154 mg/kg/day is the NOAEL and 462 mg/kg/day is the LOAEL based on increased kidney weight.

The RfD of 0.04 mg/kg/day was calculated using the NOA.EL of 154 mg/kg, which was converted to a 110 mg/kg/day based dosing schedule of 139 doses in 194 days. An uncertainty factor of 3000 (10 for animal to human; 10 for most sensitive; 10 for subchronic; and an additional 3 for inadequate database) was applied to the NOAEL (110 mg/kg/day) to obtain 0.04 mg/kg/day.

Methylcyclohexane (TPHCWG 1997)

Rats, mice, hamsters and dogs were exposed to a vapor of methylcyclohexane at 0, 400 or 2000 ppm, 6 hours/day, 5 days per week for 19 months. At 12 months, some of the rats, mice, and hamsters were terminated. The remaining rodents were held an additional year and the dogs for five years. There was no increase in tumors in any of the exposed animals. The only treatment related finding was kidney nephropathy in the 2000 ppm exposed rats. Hemolysis of blood samples prohibited clinical chemistry evaluations for the female rats.

Kinkead, E.R., Haun, C.C., Schneider, M.G., Vemot, E.H., and Macewen, J.D. (1985) Chronic inhalation exposure of experimental animals to methylcyclohexane. Air Force Aerospace Medical Research Report AFAMRL-TR-85-03.

Rabbits were exposed to a vapor of methylcyclohexane for 10 weeks. Liver and kidney effects were reported in rabbits exposed to 2880 ppm; however, there were no effects at 1200 ppm. No treatment related effects were reported in a monkey exposed to 370 ppm methylcyclohexane for 10 weeks.

Treon, J.F., Crutchfield, W.E., Jr., and Kitzmiller, K.V. (1943). The physiological response of animals to cyclohexane, methylcyclohexane, and certain derivatives of these compounds. J. Ind. Hyg. Toxicol. 25:323-347.

Naphthalene (TPHCWG 1997)

Rabbits exposed to naphthalene by oral route at doses up to 400 mg/kg/day, on gestation days 6 to 18 showed no apparent adverse reproductive effects (or signs of developmental toxicity).

Pharmakon Research International (PRI), Inc. 1986. Developmental toxicity study in rabbits: Naphthalene. Report to Texaco, Inc. Beacon, NY. PH 329-TX-001-85.

Mice exposed to naphthalene (in corn oil) at a dose of 300 mg/kg/day on days 7 to 14 of gestation had a decreased number of live pups per litter. No congenital abnormalities were observed.

Plasterer, M.R., Bradshaw, W.S., Booth, G.M., et al. 1985. Developmental toxicity of nine selected compounds following prenatal exposure in the mouse: naphthalene,12-nitrophenol, sodium selenite, dimethyl phthalate, ethylene thiourea and four glycol ether derivatives. Toxicol. Environ. Health 15:25-38.

In a 90 day oral gavage study, mice were administered 5.3, 53 or 133 mg/kg naphthalene. No treatment-related mortalities or body weight changes were reported in either sex, and no organ weight changes were observed in males. A significant decrease in absolute brain, liver and spleen weight was noted for females at the highest dose; however, organ to body weight ratios were significantly different only for the spleen. Although spleen weight decreased, there was no evidence of immunotoxicity in any treatment group for either sex. No histopathologic evaluations were performed in this study. Exposed mice showed no alterations in hematology. Several serum chemistry parameters including BUN levels in females (all doses) and total serum protein in both sexes (53 and 133 mg/kg), showed significant dose-related changes. A corresponding increase in albumin levels was noted in males, and an increase in globulin levels was noted in both males and females. Electrolyte values were generally unaffected by treatment, except for decreased calcium levels in males administered 53 or 133 mg/kg naphthalene. Although there were some changes, serum chemistry parameters gave little evidence of significant toxicity at any dose level.

Shopp, G.M., White, K.L., Jr., Holsapple, M.R, et al., 1984. Naphthalene toxicity in CD-1 mice: General toxicology and immunotoxicology. Fund. App. Toxicol. 4:406-419.

Naphthalene was not teratogenic to pregnant rats administered up to 450 mg/kg/day, by gavage, on gestation days 6 to 15. However, there was a trend toward a dose-related increase in malformations.

National Toxicology Program (NTP). 1991a. Developmental toxicity of naphthalene (CAS No. 91-20-3) administered by gavage to Sprague-Dawley (CD) rats on gestational days 6 through 15. Research Triangle Park, NC: National Toxicology Program, National Institute of Environmental Health Sciences, U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. TER-91006.

In a 13 week subchronic oral study, rats and mice exposed to naphthalene at doses up to 400 and 200 mg/kg/day, respectively, showed no evidence of cardiovascular, gastrointestinal, respiratory, neurologic, renal or hepatic effects. No histopathological lesions of the testes were noted in mice or rats at any dose level.

Battelle's Columbus Laboratories (Battelle). 1980a. Subchronic toxicity study: Naphthalene (C52904) $B_6C_3F_1$ mice. Report to U.S. Department of Health and Human Services, National Toxicology Program, Research Triangle Park, NC.

Battelle's Columbus Laboratories (Battelle). 1980b. Subchronic toxicity study: Naphthalene (C52904), Fischer 344 rats. Report to U.S. Department of Health and Human Services, National Toxicology Program, Research Triangle Park, NC.

B6C3F1 mice were exposed to naphthalene vapors at 10 or 30 ppm, 6 hours/day, 5 days/week for a 2 year period. Both sexes displayed chronic inflammation and metaplasia of the olfactory epithelium, hyperplasia of the respiratory epithelium, and a dose-related increase in inflammatory lesions of the lungs. No treatment- related effects were observed for gastrointestinal, hematological, renal, hepatic, immunological or neurological systems. Female (but not male) mice exposed to 30 ppm naphthalene for a lifetime exhibited a significant increase in pulmonary alveolar/bronchiolar adenomas. NTP concluded no incidence of carcinogenicity in males and limited evidence in female mice based on increased incidence of pulmonary alveolar/bronchiolar adenomas.

National Toxicology Program (NTP). 1992a. Technical report series No. 410. Toxicology and carcinogenesis studies of naphthalene (CAS No. 91-20-3) in $B_6C_3F_1$ mice (inhalation studies). Research Triangle Park, NC: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health. NIH Publication No. 92-3141.

In a 13 week subchronic dermal study, rats treated with up to 1000 mg/kg/day naphthalene, 6 hours/day, 5 days/week, showed an increased incidence of excoriated skin lesions and papules. Similar lesions were seen in the control and low dose groups. At the high dose, naphthalene exacerbated the severity of the lesions. No reported respiratory, cardiovascular, gastrointestinal, hematological, hepatic or renal effects.

Frantz, S.W., VanMilier, J.R, and Jengler, W.C. 1986. Ninety-day (subchronic) study with naphthalene in albino rats. Report to Texaco, Inc., Beacon, NY, by Bush Run Research Center Union Carbide, Export,PA. Project No. 49-539 revised (unpublished).

A provisional RfD for naphthalene of 0.04 mg/kg/day was developed by the USEPA. This RfD was based on an oral subchronic NTP unpublished study (NTP, 1980). In this study, rats were administered naphthalene by gavage 5 days/week for 13 weeks. The dose levels used in this study were not published in any of the available summaries. However, the NOEL was identified to be 50 mg/kg/day. The critical effect was decreased body weight. Using the gavage schedule of 5 days/week, the 50 mg/kg/day is converted to 35.7 mg/kg/day. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) is used to calculate the RfD of 0.04 mg/kg/day. This provisional RfD is not on IRIS nor is it in HEAST. This value was on IRIS but was pulled pending further review. The value was also removed from HEAST due to the uncertainty in the calculation of the RfD.

Naphthenic Acids

No regulatory toxicity reference values are available for naphthenic acids. Thus, an extensive literature search was performed to identify toxicity information on naphthenic acids that would be applicable to human and ecological health risk assessment. The following is a summary of the toxicity data available.

Acute Toxicity Studies

An oral (gavage) dose of 3,500 mg/kg and an intraperitoneal dose of 860 mg/kg of naphthenic acid each resulted in 50% mortality (LD_{50}) in young male white mice. These lethal doses also demonstrated symptoms of toxicity including central nervous depression (without analgesia), corneal eye opacity, dryness of mouth, convulsions and diarrhea. Death was due to respiratory arrest (Pennisi and dePaul Lynch 1977).

The acute oral toxicities of two naphthenic acid fractions and seven commercial metal naphthenates were determined in rats using oral gavage. A fraction of naphthenate derived from crude kerosene acids produced 50% mortality at a dose of 3,000 mg/kg and a fraction derived from mixed crude acids proved lethal at 5,200 mg/kg. The metal naphthenates, with their respective metal contents (calcium, 4%; cobalt, 6%; copper, 8%; lead, 24%; mercury, 10 %; manganese, 6% and zinc, 8%) produced 50% mortality at various concentrations. Four of the metal salts (Mn, Cu, Zn and Ca) possessed an LD_{50} greater than 6,000 mg/kg, while lead was slightly below at 5,100 mg/kg and cobalt was at 3,900 mg/kg. Only the phenyl mercury naphthenate proved to be more toxic than the naphthenic acids at 390 mg/kg. Symptomatically, the deaths appeared to result from gastrointestinal disturbances including anorexia, diarrhea, and severe weakness (Rockhold 1955). This study also included an investigation of the subchronic toxicity of lead naphthenate administered orally. Rats received 20 daily doses of 1% (as Pb) solution of lead naphthenate over a four week period. No abnormal characteristics in either action or appearance were observed. No deaths occurred and no changes were noted during gross and histopathological examinations conducted on animals sacrificed on termination of the 30 day experimentation period.

Table X-37 compares the doses of naphthenates that cause 50% mortality in various species.

Table X-37 Acute Toxicity Values for Naphthenates

Chemical	LD_{50} rat	LD_{50} mice	Reference
naphthenic acids	3,000 mg/kg	3550 mg/kg	Rockhold 1955, Pennisi & dePaul Lynch 1977
calcium naphthenate	>6,000 mg/kg	NA	Rockhold 1955
cobalt naphthenate	3,900 mg/kg	NA	Rockhold 1955
copper naphthenate	>6,000 mg/kg	NA	Rockhold 1955
lead naphthenate	5,100 mg/kg	NA	Rockhold 1955
phenyl mercury naphthenate	390 mg/kg	NA	Rockhold 1955
manganese naphthenate	>6000 mg/kg	NA	Rockhold 1955
zinc naphthenate	>6000 mg/kg	NA	Rockhold 1955

Subchronic Toxicity Studies

A daily oral (gavage) dose of 1,000 mg/kg-day repeated for 30 days produced central nervous system depression (without loss of analgesia), hematological changes, weight loss and death due to respiratory arrest. Gross morphological changes in the liver and stomach were noted as well as histopathological changes in a few selected organs (Pennisi and dePaul Lynch 1977).

Developmental Toxicity Studies

A developmental and teratogenic toxicity study evaluated zinc naphthenate administered to pregnant rats during the major period of fetal organogenesis. Maternal toxicity was confined to the highest dose group (938 mg/kg/day) and indicated symptoms of lethargy and reduced body weight gain. That dosage also produced a higher incidence of resorptions and lower average fetal body weight. Dams receiving 94.0 or 188 mg/kg/day were not affected, nor were their developing fetuses. It was concluded that zinc naphthenate only affected the developing fetus at a dosage level which produced signs of maternal toxicity (Angerhofer et al. 1991).

Chronic Toxicity Studies

No chronic studies assessing the effects of naphthenic acids were available in the literature.

Human Toxicity Studies

Insufficient data regarding the effects of naphthenic acids on human health were available in the literature. There was also insufficient evidence to suggest that naphthenic acids are carcinogenic to humans.

Studies were identified that assessed the acute toxicity of naphthenic acids as well as the acute and subchronic toxicity of various naphthenic compounds. These investigations did not, however, provide a range of data adequate to derive human health criteria. Therefore, an RfD was not derived for naphthenic acids.

N-Nonane (TPHCWG 1997)

Harlan-Wistar rats were exposed by inhalation to 0, 1900, 3100 or 8400 mg/m^3 (0, 360, 590, or 1600 ppm) n-nonane 6 hours/day, 5 days/week for 13 weeks. Two deaths resulted at 1600 ppm. Exposure to 1600 ppm produced excessive salivation, mild coordination loss, and fine tremors throughout the first 4 days of exposure. Salivation and lacrimation continued throughout the study. Mean body weights or mean body weight changes were significantly lower in the 1600 ppm group. There were no hematological, serum chemistry or histopathologic changes that were considered treatment-related. No effects were observed at 360 or 590 ppm.

Carpenter et al. 1975. Petroleum hydrocarbon toxicity studies XVII. Animal response to n-nonane vapor. Toxicol. Appl. Pharmacol. 44: 53-61.

Petroleum Hydrocarbon--Airborne Mixtures (TPHCWG 1997)

Airborne mixtures of petroleum hydrocarbons were assessed for exposure by way of grouped compounds as previously noted in Appendix X.4.2, using the approach of TPHCWG (1997). Consequently, the toxicity reference values for this complex mixture were also taken from TPHCWG (1997), however a slight conservative modification was made. As noted in the previous section, the petroleum hydrocarbon categories involved aliphatics and aromatics , segregated into groups with carbon chain lengths typically involving C1-C10 (aliphatics) and for aromatics, C5-C8 (excluding benzene which was assessed separately) or C9-C18. For aliphatics this grouping spans two of the TPHCWG categories (C5-C8, and C8-C10), and includes several high emission substances, such as methane and ethylene, which are very low in toxicity and normally left out of the TPHCWG approach.

The modification employed here simply involved the use of the more conservative toxicity reference value if more than one was available because of the amalgamation of two groups. Thus, for C1-C19 aliphatics, the toxicity reference value (RfC) employed was 1.0mg/m^3 (normally applicable to C8-C16, for protection against hepatic and hematological changes), which is about 18-fold more potent than the reference value ascribed to the C5-C8 fraction regarding neurotoxicity (TPHCWG 1997). For the aromatic fractions C5-C8 and C8-C10, the toxicity reference values employed were 0.4 and 0.2 mg/m^3 for hepatotoxicity and decreased body weight, respectively.

Pyrene (THPCWG 1997)

An oral RfD of 0.03 mg/kg/day for pyrene is currently on IRIS. This value was based on a subchronic oral gavage study in mice (USEPA, 1989d). Groups of 20 mice/sex/group were administered pyrene in corn oil at levels of 0, 75, 125, or 250 mg/kg for 13 weeks. Nephropathy was present in 4 (control), 1 (75 mg/kg/day),1 (125 mg/kg/day), and 9 (250 mg/kg/day) male mice. Similar lesions were seen in female mice: 2 (control), 3 (75 mg/kg/day), 7 (125 mg/kg/day), and 10 (250 mg/kg/day). Decreased kidney weights were observed in the 125 and 250 mg/kg/day dose groups. The NOAEL was determined to be 75 mg/kg/day and the LOAEL was 125 mg/kg/day for nephropathy and decreased kidney weights.

The RfD for pyrene was calculated by taking the NOAEL of 75 mg/kg/day and applying an uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) and a modifying factor of 3 for lack of adequate toxicity data in a second species and reproductive/developmental data.

US EPA. 1989. Mouse Oral Subchronic Toxicity of Pyrene. Study conducted by Toxicity Research Laboratories, Muskegon, MI for the Office of Solid Waste, Washington, DC.

1,3,5-Trimethylbenzene (TPHCWG 1997)

Sprague Dawley rats (10/sex/dose group) were administered 1,3,5-trimethylbenzene in corn oil by oral gavage for a 14 day period at concentrations of 0, 60, 150 and 600 mg/kg/day at a constant volume of 5mL/kg/day. A high dose recovery group was retained an additional 14 days. All animals survived treatment. No adverse clinical signs or treatment-related effects were observed in body weight, body weight gain or food consumption. Ophthalmic and necropsy findings were unremarkable. An increase in cholesterol levels was noted in mid- and high-dose females. An increase in white blood cell counts with corresponding increases in neutrophils and lymphocytes was noted in high dose males. At treatment termination, relative liver weights were significantly increased for mid- and high dose females and high dose males. In addition, relative adrenal weight was significantly increased in high dose males. All high dose animals exhibited centrilobular hepatic hypertrophy following treatment. All noted effects reversed by the end of the 14-day recovery period. The NOEL for this study was determined at 60 mg/kg, based on increased cholesterol levels and liver weight at 150 and 600 mg/kg.

IIT Research Institute. 14-Day Oral Gavage Toxicity Study of 1,3,5-Trimethylbenzene in Rats with a Recovery Group. IITRI Project No. L08512. Study1. February 1995.

Sprague Dawley rats (10/sex/dose group) were administered 1,3,5-trimethylbenzene in corn oil by oral gavage, 5 days per week for a 90 day period at concentrations of 0, 50, 200 and 600 mg/kg/day at a constant volume of 5mL/kg/day. A high dose recovery group was retained an additional 28 days without treatment. All tissues from the control and high dose groups underwent microscopic examination. Lesions and limited tissues were evaluated in the low and mid-dose groups. No histologic evaluations were conducted for the recovery group. All animals survived treatment. No statistically significant effects were reported for body weight, body weight gain or food consumption. However, cumulative body weight gain decreased by 11% in high dose males. Ophthalmic exams were unremarkable. Phosphorus levels increased for high dose females. Also, a significant increase in absolute and relative liver weight was reported for high dose females at treatment termination. In males, relative liver and kidney weights were significantly increased at treatment termination. No treatment-related microscopic lesions were observed in any animal. Any treatment-related effect was absent by the end of the 28-day recovery period. A NOEL was established at 200 mg/kg based on increased phosphorous levels, liver and kidney weight reported at 600 mg/kg/day.

IIT Research Institute. 90-Day Oral Gavage Toxicity Study of 1,3,5-Trimethylbenzene in Rats with a Recovery Group. IITRI Project No. L0851. Study May 1995.

Toluene (TPHCWG 1997)

An oral RfD of 0.2 mg/kg/day for toluene is currently on IRIS. This value is based on a subchronic oral gavage study in rats (NTP 1989). Groups of 10 rats/sex/group were administered toluene in corn oil at levels of 0, 312, 625, 1250, 2500, or 5000 mg/kg for 5 days/week for 13 weeks. All animals in the 5000 mg/kg dose group died within the first week. At the 2500 mg/kg dose level, one female and 8 males died; however, two of these deaths were attributed to gavage errors. No significant changes in hematology or urinalysis were observed in the treated animals at any dose level. In females, liver, kidney and brain weights were all significantly increased at doses of 1250 mg/kg or greater. In males, liver and kidney weights were significantly increased at the 625 mg/kg dose level and above. Lesions in the liver and nephrosis were observed in animals at 2500 and 5000 mg/kg. Histopathological changes were also observed in the brain and urinary bladder at 1250, 2500, and 5000 mg/kg dose levels. The NOAEL for this study is 312 mg/kg based on liver and kidney weight changes in the male rats at 625 mg/kg.

The RfD of 0.2 mg/kg/day was calculated using the NOAEL of 312 mg/kg, which was converted to 223 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 1000 (10 for animal to human; 10 for most sensitive; and 10 for subchronic) was applied to the NOAEL (223 mg/kg/day) to obtain 0.2 mg/kg/day.

NTP (National Toxicology Program). 1989. Toxicology and Carcinogenesis Studies of Toluene in F344/N rats and B6C3F1 mice. Technical Report Series No. 371. Research Triangle, NC.

Xylenes (TPHCWG 1997)

Groups of 50 male and 50 female Fischer 344 rats and 50 male and 50 female B6C3F1 mice were given gavage doses of 0, 250, or 500 mg/kg/day (rats) and 0, 500, or 1000 mg/kg/day (mice) for 5 days/week for 103 weeks (NTP 1986). The animals were observed for clinical signs of toxicity, body weight gain, and mortality. All animals that died or were killed at sacrifice were given gross necropsy and comprehensive histologic examinations. There was a dose-related increased mortality in male rats, and the increase was significantly greater in the high-dose group compared with controls. Although increased mortality was observed at 250 mg/kg/day, the increase was not significant. Although many of the early deaths were caused by gavage error, NTP (1986) did not rule out the possibility that the rats were resisting gavage dosing because of the behavioral effects of xylene. Mice given the high dose exhibited hyperactivity, a manifestation of CNS toxicity. There were no compound related histopathologic lesions in any of the treated rats or mice. Therefore, the high dose is a FEL and the low dose a NOAEL.

The RfD of 2 mg/kg/day was calculated using the NOAEL of 250 mg/kg, which was converted to 179 mg/kg/day based on the gavage schedule of 5 days/week. An uncertainty factor of 100 (10 for animal to human and 10 for most sensitive) was applied to the NOAEL (179 mg/kg/day) to obtain 2 mg/kg/day.

NTP (National Toxicology Program). 1986. Technical Report on the Toxicology and Carcinogenesis Studies of Xylenes (mixed) in F344/N rats and B6C3F1 mice. NIH Publ. No. 86-2583. Research Triangle, NC.

X.6.1 RISK ESTIMATION RESULTS FOR WILDLIFE HEALTH

X.6 Risk Estimation Results

X.6.1 Risk Estimation Results for Wildlife Health

Pursuant to the methods and equations outlined in the previous sections for Exposure and Effects Assessments, the following section provides the resultant exposure estimates and exposure ratios, according to the key questions analyzed in Tables X-38 to X-41. For each medium, the chemical exposure concentrations, estimated daily intake rates (EDI) and exposure ratios (ER) for wildlife receptors are presented.

Table X-38 Ingestion of Water (W-2 and W-4)

Chemical	Years	Water Concentrations (mg/L)	EDI	ER
Water Shrew				
Barium	2000-2025	0.03	0.0046	3.8e-04
	2030	0.04	0.0062	5.0e-04
	far future	0.03	0.00015	3.8e-04
Copper	2000-2025	0.001	0.00015	4.5e-06
	2030	0.002	0.00031	8.9e-06
	far future	0.001	0.00015	4.5e-06
Manganese	2000-2025	0.05	0.0062	3.1e-05
	2030	0.07	0.011	5.4e-05
	far future	0.04	0.0062	3.1e-05
Zinc	2000-2025	0.013	0.0018	5.5e-06
	2030	0.015	0.0023	6.3e-06
	far future	0.011	0.0017	4.6e-06
Killdeer				
Barium	2000-2025	0.03	0.0067	3.2e-04.
	2030	0.04	0.0089	4.2e-04
	far future	0.03	0.0067	3.2e-04
Chromium	2000-2025	0.001	0.00022	2.2e-04
	2030	0.002	0.00044	4.5e-04
	far future	0.001	0.00022	2.2e-04
Copper	2000-2025	0.001	0.00022	4.7e-06
	2030	0.002	0.00044	9.5e-06
	far future	0.001	0.00022	4.7e-06
Manganese	2000-2025	0.04	0.011	1.1e-05
	2030	0.07	0.016	1.6e-05
	far future	0.04	0.009	9.1e-06
Zinc	2000-2025	0.013	0.0028	2.0e-04
	2030	0.015	0.0033	2.3e-04
	far future	0.011	0.0024	1.73-04
Moose				
Antimony	2000-2025	4.6e-06	2.5e-07	2.1e-05
	2030	1.1e-04	6.0e-06	5.0e-04
	far future	5.3e-09	2.9e-07	2.4e-08
Barium	2000-2025	0.03	0.0016	1.8e-03
	2030	0.04	0.0022	2.4e-03
	far future	0.03	0.0016	1.8e-03
Boron	2000-2025	0.04	0.0022	4.5e-04

	2030	0.35	0.019	3.9e-03
	far future	0.05	0.0027	5.6e-04
Cadmium	2000-2025	0.0002	1.1e-05	6.1e-04
	2030	0.0008	4.3e-05	2.4e-03
	far future	0.0002	1.1e-05	6.1e-04
Copper	2000-2025	0.001	5.5e-05	2.0e-05
	2030	0.002	1.1e-04	4.1e-05
	far future	0.001	5.5e-05	2.0e-05
Manganese	2000-2025	0.05	0.0022	1.8e-04
	2030	0.07	0.0038	2.5e-04
	far future	0.04	0.0022	1.4e-04
Molybdenum	2000-2025	0.0002	1.1e-05	0.00046
	2030	0.0847	4.6e-03	0.19
	far future	0.0002	1.1e-05	0.00046
Selenium	2000-2025	0.0001	5.5e-06	1.6e-04
	2030	0.0002	1.1e-05	3.1e-04
	far future	0.0001	5.5e-06	1.6e-04
Vanadium	2000-2025	0.0004	2.2e-05	6.4e-04
	2030	0.011	3.0e-04	0.018
	far future	0.0004	2.2e-05	6.4e-04
Snowshoe Hare				
Antimony	2000-2025	4.6e-06	4.4e-07	9.3e-06
	2030	1.1e-04	1.0e-05	2.2e-04
	far future	5.3e-09	5.1e-10	1.1e-08
Barium	2000-2025	0.03	0.0029	7.7e-04
	2030	0.04	0.0038	1.0e-03
	far future	0.03	0.0029	7.7e-04
Copper	2000-2025	0.001	9.5e-05	9.0e-06
	2030	0.002	1.9e-04	1.8e-05
	far future	0.001	9.5e-05	9.0e-06
Manganese	2000-2025	0.05	0.0048	7.8e-05
	2030	0.07	0.0067	1.1e-04
	far future	0.04	0.0038	6.2e-05
Black Bear				
Antimony	2000-2025	4.6e-06	2.8e-07	1.9e-05
	2030	1.1e-04	6.7e-06	4.5e-04
	far future	5.3e-09	3.2e-10	2.2e-08
Barium	2000-2025	0.03	0.0018	1.5e-03
	2030	0.04	0.0024	2.0e-03
	far future	0.03	0.0018	1.5e-03
Copper	2000-2025	0.001	6.1e-05	1.7e-05
	2030	0.002	1.2e-04	3.5e-05
	far future	0.001	6.1e-05	1.7e-05
Manganese	2000-2025	0.05	0.0030	1.5e-04
	2030	0.07	0.0043	2.1e-04
	far future	0.04	0.0024	1.2e-04
Molybdenum	2000-2025	0.0002	1.2e-05	4.1e-04
	2030	0.0847	5.2e-03	0.17
	far future	0.0002	1.2e-05	4.1e-04
Ruffed Grouse				
Barium	2000-2025	0.03	0.0043	2.1e-04
	2030	0.04	0.0057	2.8e-04
	far future	0.03	0.0043	2.1e-04
Copper	2000-2025	0.001	1.4e-04	4.3e-06
	2030	0.002	2.9e-04	8.7e-06
	far future	0.001	1.4e-04	4.3e-06

Table X-39 Ingestion of Invertebrates (W-2 and W-4)

Chemical	Invertebrate Concentrations (mg/kg)	EDI	ER
Water Shrew			
Barium	29	27.6	2.26
Cobalt	1.4	1.3	0.44
Copper	45	42.8	1.24
Manganese	314	298.3	1.49
Zinc	133	126.4	0.35
Killdeer			
Barium	29	4.5	0.22
Chromium	10.5	1.6	1.63
Cobalt	1.4	0.22	0.31
Copper	45	7.0	0.15
Manganese	314	48.9	0.05
Zinc	133	20.7	1.43

Table X-40 Ingestion of Plants (W-3 and W-4)

Chemical	Plant Species	Plant Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Moose				
Antimony	blue Lab cattail	nd 0.68 nd	0.0039	0.33
Barium	blue Lab cattail	15.5 120 47.3	1.06	1.13
Boron	blue Lab cattail	7 25 29	0.35	0.072
Cadmium	blue Lab cattail	0.09 0.09 0.17	0.002	0.11
Cobalt	blue Lab cattail	nd 0.31 5.24	0.032	0.14
Copper	blue Lab cattail	4.6 74 14.4	0.54	0.20
Manganese	blue Lab cattail	576 1070 541	12.6	0.83
Molybdenum	blue Lab cattail	0.11 0.12 1.7	0.011	0.46
Selenium	blue Lab cattail	nd nd 0.7	0.004	0.12
Vanadium	blue Lab	nd 0.15	0.042	1.24

	cattail	7.16		
Hare				
Antimony	blue Lab	nd 0.68	0.027	0.57
Barium	blue Lab	15.5 120	5.33	1.44
Copper	blue Lab	4.6 74	3.09	0.29
Manganese	blue Lab	576 1070	64.74	1.06
Black Bear				
Antimony	blue Lab	nd 0.68	0.0059	0.39
Barium	blue Lab	15.5 120	1.18	0.98
Copper	blue Lab	4.6 74	0.68	0.20
Manganese	blue Lab	576 1070	14.3	0.72
Molybdenum	blue Lab	0.11 0.12	0.002	0.067
Ruffed Grouse				
Barium	blue Lab	15.5 120	5.0	0.24
Copper	blue Lab	4.6 74	2.9	0.087

blue = blueberries; Lab = Labrador tea leaves; cattail = cattail root

Table X-41 Reclaimed Landscape Exposure (W-7)

Chemical	Media	Median ER	90th % ER
Moose			
Barium	terr. plants (mg/kg) aquatic plants (mg/kg)	0.04	0.10
Boron	terr. plants (mg/kg) aquatic plants (mg/kg)	0.06	0.15
Molybdenum	terr. plants (mg/kg) aquatic plants (mg/kg)	0.60	1.63
Selenium	terr. plants (mg/kg) aquatic plants (mg/kg)	0.0003	0.006
Vanadium	terr. plants (mg/kg) aquatic plants (mg/kg)	0.28	0.74
Snowshoe Hare			
Barium	terr. plants (mg/kg)	0.24	0.46
Vanadium	terr. plants (mg/kg)	0.25	0.66
Mallard			
Barium	aquatic plants (mg/kg) aquatic inverts (mg/kg)	0.05	0.08
Zinc	aquatic plants (mg/kg) aquatic inverts (mg/kg)	0.20	0.30
Ruffed Grouse			
Zinc	terr. plants (mg/kg) terr. inverts (mg/kg)	0.10	0.46
Deer Mouse			

Barium	terr. plants (mg/kg) terr. inverts (mg/kg)	1.16	1.44
Mercury	terr. plants (mg/kg) terr. inverts (mg/kg)	0.001	0.002
Molybdenum	terr. plants (mg/kg) terr. inverts (mg/kg)	0.47	0.60
Nickel	terr. plants (mg/kg) terr. inverts (mg/kg)	0.002	0.006
Selenium	terr. plants (mg/kg) terr. inverts (mg/kg)	0.03	0.07
Strontium	terr. plants (mg/kg) terr. inverts (mg/kg)	0.00002	0.00008
Vanadium	terr. plants (mg/kg) terr. inverts (mg/kg)	2.94	3.62
Zinc	terr. plants (mg/kg) terr. inverts (mg/kg)	0.01	0.1

X.6.2 RISK ESTIMATION RESULTS FOR HUMAN HEALTH

X.6.2 Risk Estimation Results for Human Health

Pursuant to the methods and equations outlined in the previous sections for Exposure and Effects Assessments, the following section provides the resultant exposure estimates and exposure ratios, according to the key questions analyzed in Tables X-42 to X-47. For each medium, the chemical exposure concentrations, estimated daily intake rates (EDI) and exposure ratios (ER) for child, adult and composite receptors are presented.

Table X-42 Water (Swimming Exposure)

Chemical	Years	Water Concentrations (mg/L)	EDI	ER
Child				
Antimony	2000-2025	4.6e-06	2.33-09	5.8e-06
	2030	1.1e-04	5.5e-08	1.4e-04
	far future	5.3e-09	2.7e-12	6.64-09
Barium	2000-2025	0.03	1.5e-05	0.00021
	2030	0.04	2.0e-05	0.00029
	far future	0.03	1.5e-05	0.00021
Boron	2000-2025	0.04	2.0e-05	0.00022
	2030	0.35	1.7e-04	0.0019
	far future	0.05	2.5e-05	0.00028
Cadmium	2000-2025	0.0002	1.0e-07	0.00018
	2030	0.0008	4.0e-07	0.00074
	far future	0.0002	1.0e-07	0.00018
Copper	2000-2025	0.001	5.0e-07	1.0e-06
	2030	0.002	1.0e-06	2.0e-06
	far future	0.001	5.0e-07	1.0e-06
Lead	2000-2025	0.0004	1.7e-07	0.00005
	2030	0.0017	7.2e-07	0.0002
	far future	0.0004	1.7e-07	0.00005
Molybdenum	2000-2025	0.0002	1.0e-07	0.00002
	2030	0.0847	4.2e-05	0.008
	far future	0.0002	1.0e-07	0.00002
Nickel	2000-2025	0.0004	1.7e-07	8.6e-06
	2030	0.0021	9.0e-07	1.5e-05
	far future	0.0004	1.7e-07	8.6e-06
Vanadium	2000-2025	0.0004	2.0e-07	0.00003
	2030	0.011	5.5e-06	0.00079
	far future	0.0004	2.0e-07	0.00003
Adult				
Antimony	2000-2025	4.6e-06	2.0e-10	4.9e-07
	2030	1.1e-04	4.7e-09	1.2e-05
	far future	5.3e-09	2.3e-13	5.7e-10
Barium	2000-2025	0.03	1.3e-06	1.8e-05
	2030	0.04	1.7e-06	2.4e-05
	far future	0.03	1.3e-06	1.8e-05
Boron	2000-2025	0.04	1.7e-06	1.9e-05
	2030	0.35	1.5e-05	1.7e-04
	far future	0.05	2.1e-06	2.4e-05
Cadmium	2000-2025	0.0002	8.5e-09	1.5e-05
	2030	0.0008	3.4e-08	5.9e-05
	far future	0.0002	8.5e-09	1.5e-05
Copper	2000-2025	0.001	4.3e-08	8.5e-08
	2030	0.002	8.5e-08	1.7e-07
	far future	0.001	4.3e-08	8.5e-08
Lead	2000-2025	0.0004	1.3e-08	1.8e-06
	2030	0.0017	5.3e-08	7.5e-06

	far future	0.0004	1.3e-08	1.8e-06
Molybdenum	2000-2025 2030 far future	0.0002 0.0847 0.0002	8.5e-09 3.6e-06 8.5e-09	1.7e-06 7.2e-04 1.7e-06
Nickel	2000-2025 2030 far future	0.0004 0.0021 0.0004	1.3e-08 6.8e-08 1.3e-08	6.5e-07 3.4e-06 6.5e-07
Vanadium	2000-2025 2030 far future	0.0004 0.011 0.0004	1.7e-08 4.7e-07 1.7e-08	2.4e-06 6.7e-05 2.4e-06
Composite				
Arsenic	2000-2025 2030 far future	0.003 0.0032 0.0028	3.0e-07 3.2e-07 2.8e-07	0.046 0.049 0.043
Beryllium	2000-2025 2030 far future	9.2e-06 4.5e-04 1.6e-06	9.3e-10 4.5e-08 1.6e-10	0.0004 0.020 0.00007
Benzo(a)pyrene	2000-2025 2030 far future	0 3.7e-06 2.3e-08	0 9.2e-08 5.7e-10	0 0.066 0.00041
Benzo(a) anthracene	2000-2025 2030 far future	0 1.7e-05 3.1e-07	0 2.9e-07 5.2e-09	0 0.020 0.00037

Table X-43 Water (Recreational Exposure)

Chemical	**Years**	**Water Concentrations (mg/L)**	**EDI**	**ER**
Child				
Antimony	2000-2025 2030 far future	4.6e-06 1.1e-04 5.3e-09	8.3e-08 2.0e-06 9.6e-11	0.00021 0.005 2.4e-07
Barium	2000-2025 2030 far future	0.03 0.04 0.03	5.4e-04 7.2e-04 5.4e-04	0.0077 0.010 0.0077
Boron	2000-2025 2030 far future	0.04 0.35 0.05	7.2e-04 6.3e-03 9.0e-04	0.008 0.07 0.01
Cadmium	2000-2025 2030 far future	0.0002 0.0008 0.0002	3.6e-06 1.4e-05 3.6e-06	0.0072 0.029 0.0072
Copper	2000-2025 2030 far future	0.001 0.002 0.001	1.8e-05 3.6e-05 1.8e-05	0.00004 0.00007 0.00004
Lead	2000-2025 2030 far future	0.0004 0.0017 0.0004	7.2e-06 3.1e-05 7.2e-06	0.002 0.0086 0.002
Molybdenum	2000-2025 2030 far future	0.0002 0.0847 0.0002	3.6e-06 1.5e-03 3.6e-06	0.00072 0.31 0.00072
Nickel	2000-2025 2030 far future	0.0004 0.0021 0.0004	7.2e-06 3.8e-05 7.2e-06	0.00036 0.0019 0.00036
Vanadium	2000-2025 2030 far future	0.0004 0.011 0.0004	7.2e-06 2.0e-04 7.2e-06	0.001 0.028 0.001
Adult				
Antimony	2000-2025 2030 far future	4.6e-06 1.1e-04 5.3e-09	2.8e-08 6.8-07 3.3e-11	0.00007 0.0017 8.1e-08
Barium	2000-2025	0.03	1.8e-04	0.0026

	2030	0.04	2.5e-04	0.0035
	far future	0.03	1.8e-04	0.0026
Boron	2000-2025	0.04	2.5e-04	0.0027
	2030	0.35	2.2e-03	0.024
	far future	0.05	3.1e-04	0.0034
Cadmium	2000-2025	0.0002	1.2e-06	0.0025
	2030	0.0008	4.9e-06	0.0098
	far future	0.0002	1.2e-06	0.0025
Copper	2000-2025	0.001	6.1e-06	0.00001
	2030	0.002	1.2e-05	0.00002
	far future	0.001	6.1e-06	0.00001
Lead	2000-2025	0.0004	2.5e-06	0.00034
	2030	0.0017	1.0e-05	0.0015
	far future	0.0004	2.5e-06	0.00034
Molybdenum	2000-2025	0.0002	1.2e-06	0.00025
	2030	0.0847	5.2e-04	0.10
	far future	0.0002	1.2e-06	0.00025
Nickel	2000-2025	0.0004	2.5e-06	0.00012
	2030	0.0021	1.3e-05	0.00064
	far future	0.0004	2.5e-06	0.00012
Vanadium	2000-2025	0.0004	2.5e-06	0.00035
	2030	0.011	6.8e-05	0.0097
	far future	0.0004	2.5e-06	0.00035
Composite				
Arsenic	2000-2025	0.003	2.2e-05	3.29
	2030	0.0032	2.3e-05	3.51
	far future	0.0028	2.0e-05	3.08
Beryllium	2000-2025	9.2e-06	6.7e-08	0.072
	2030	4.5e-04	3.3e-06	1.45
	far future	1.6e-06	3.3e-08	0.049
Benzo(a)pyrene	2000-2025	0	0	0
	2030	3.7e-06	1.2e-07	0.061
	far future	2.3e-08	7.4e-10	0.00069
Benzo(a) anthracene	2000-2025	0	0	0
	2030	1.7e-05	4.1e-07	0.022
	far future	3.1e-07	7.4e-09	0.00064

Table X-44 Airborne Chemicals: Exposure Concentrations, Estimated Daily Intake Rates(Doses) and Risk Estimates.

Maximum predicted concentrations from the indicated Shell Muskeg River Mine Project Sources.
All exposure concentrations are expressed in (ug/m3).
Locations include: **Overall Maximum (usually on the plant/mine/tailings site)**
Fort McKay
Fort McMurray
Fort Chipeywan
Predictions do not include Suncor, Syncrude or community sources.

Source: Stationary Mine Point Sources (eg., Stacks)

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
NOx	1.30E+02	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
NO2	6.60E+01	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
CO	5.78E+01	1.38E+01	1.02E+00	1.92E+01	2.38E+00	1.03E-01	6.82E+00	1.68E+00	6.39E-02	4.00E+00	3.07E-01	1.51E-02
PM	1.87E+01	4.47E+00	3.31E-01	6.22E+00	7.72E-01	3.34E-02	2.21E+00	5.46E-01	2.07E-02	1.30E+00	9.94E-02	4.90E-03
THC	3.61E+00	8.60E-01	6.38E-02	1.20E+00	1.49E-01	6.44E-03	4.26E-01	1.05E-01	3.99E-03	2.50E-01	1.91E-02	9.43E-04
VOC	2.41E+00	5.74E-01	4.26E-02	8.00E-01	9.93E-02	4.30E-03	2.84E-01	7.02E-02	2.66E-03	1.67E-01	1.28E-02	6.30E-04

Source: Mine Fleet Exhaust Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
CO	5.71E+02	2.43E+02	5.61E+01	1.60E+02	1.69E+01	1.01E+00	6.77E+01	1.19E+01	3.00E-01	4.18E+01	2.34E+00	1.01E-01
NOx	1.59E+03	6.76E+02	1.56E+02	4.45E+02	4.69E+01	2.80E+00	1.88E+02	3.31E+01	8.35E-01	1.16E+02	6.51E+00	2.80E-01
SO2	1.07E+02	4.56E+01	1.05E+01	3.00E+01	3.17E+00	1.89E-01	1.27E+01	2.23E+00	5.64E-02	7.85E+00	4.40E-01	1.89E-02
CO2	1.05E+05	4.45E+04	1.03E+04	2.93E+04	3.09E+03	1.84E+02	1.24E+04	2.18E+03	5.50E+01	7.65E+03	4.29E+02	1.84E+01
PM10	8.10E+01	3.44E+01	7.95E+00	2.26E+01	2.39E+00	1.43E-01	9.59E+00	1.68E+00	4.25E-02	5.92E+00	3.32E-01	1.43E-02
PM2.5	5.15E+01	2.19E+01	5.05E+00	1.44E+01	1.52E+00	9.07E-02	6.09E+00	1.07E+00	2.70E-02	3.76E+00	2.11E-01	9.07E-03
ALIPHATICS												
ALKANES												
methane	1.10E+01	4.68E+00	1.08E+00	3.08E+00	3.25E-01	1.94E-02	1.30E+00	2.29E-01	5.79E-03	8.05E-01	4.51E-02	1.94E-03
ethane	6.31E+00	2.68E+00	6.20E-01	1.76E+00	1.86E-01	1.11E-02	7.47E-01	1.31E-01	3.31E-03	4.61E-01	2.58E-02	1.11E-03
propane	4.45E+00	1.89E+00	4.37E-01	1.24E+00	1.31E-01	7.84E-03	5.27E-01	9.26E-02	2.34E-03	3.25E-01	1.82E-02	7.84E-04
butane	6.57E+00	2.79E+00	6.45E-01	1.84E+00	1.94E-01	1.16E-02	7.78E-01	1.37E-01	3.45E-03	4.80E-01	2.69E-02	1.16E-03
pentane	4.28E+00	1.82E+00	4.20E-01	1.20E+00	1.26E-01	7.53E-03	5.06E-01	8.89E-02	2.25E-03	3.13E-01	1.75E-02	7.53E-04
hexane	8.16E+00	3.47E+00	8.02E-01	2.28E+00	2.41E-01	1.44E-02	9.67E-01	1.70E-01	4.29E-03	5.97E-01	3.34E-02	1.44E-03
heptane	5.49E+00	2.33E+00	5.39E-01	1.53E+00	1.62E-01	9.66E-03	6.50E-01	1.14E-01	2.88E-03	4.01E-01	2.25E-02	9.66E-04
octane	2.15E+00	9.12E-01	2.11E-01	6.00E-01	6.33E-02	3.78E-03	2.54E-01	4.46E-02	1.13E-03	1.57E-01	8.79E-03	3.78E-04
nonane	1.42E+00	6.05E-01	1.40E-01	3.98E-01	4.20E-02	2.51E-03	1.69E-01	2.96E-02	7.48E-04	1.04E-01	5.83E-03	2.51E-04
decane	6.68E+00	2.84E+00	6.56E-01	1.87E+00	1.97E-01	1.18E-02	7.91E-01	1.39E-01	3.51E-03	4.89E-01	2.74E-02	1.18E-03
undecane	6.80E+00	2.89E+00	6.67E-01	1.90E+00	2.01E-01	1.20E-02	8.05E-01	1.41E-01	3.57E-03	4.97E-01	2.78E-02	1.20E-03
dodecane	4.18E+00	1.77E+00	4.10E-01	1.17E+00	1.23E-01	7.36E-03	4.95E-01	8.69E-02	2.19E-03	3.05E-01	1.71E-02	7.36E-04
ALKANES TOTAL CONC.	6.75E+01	2.87E+01	6.63E+00	1.89E+01	1.99E+00	1.19E-01	7.99E+00	1.40E+00	3.55E-02	4.93E+00	2.76E-01	1.19E-02
ALKENES												
ethylene	3.16E+01	1.34E+01	3.10E+00	8.82E+00	9.31E-01	5.56E-02	3.74E+00	6.56E-01	1.66E-02	2.31E+00	1.29E-01	5.56E-03
propylene	5.44E+00	2.31E+00	5.34E-01	1.52E+00	1.61E-01	9.58E-03	6.44E-01	1.13E-01	2.86E-03	3.98E-01	2.23E-02	9.58E-04
butene	1.17E+00	4.99E-01	1.15E-01	3.28E-01	3.46E-02	2.07E-03	1.39E-01	2.44E-02	6.17E-04	8.58E-02	4.81E-03	2.07E-04
pentene	2.04E-01	8.65E-02	2.00E-02	5.70E-02	6.01E-03	3.59E-04	2.41E-02	4.24E-03	1.07E-04	1.49E-02	8.34E-04	3.59E-05
ALKENES TOTAL CONC.	3.84E+01	1.63E+01	3.77E+00	1.07E+01	1.13E+00	6.76E-02	4.54E+00	7.98E-01	2.02E-02	2.80E+00	1.57E-01	6.76E-03
SUM:ALIPHATICS CONC.	1.06E+02	4.50E+01	1.04E+01	2.96E+01	3.12E+00	1.86E-01	1.25E+01	2.20E+00	5.56E-02	7.74E+00	4.34E-01	1.86E-02
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				1.30E+01	1.37E+00	8.20E-02	5.52E+00	9.69E-01	2.45E-02	3.41E+00	1.91E-01	8.20E-03
ALIPHATICS ER CHILD (using RfC)				1.30E-01	1.37E-02	**1.86E-04**	5.52E-02	9.69E-03	**5.56E-05**	3.41E-02	1.91E-03	**1.86E-05**
ADULT INHALED DOSE ug/(kg*d)						1.15E+00			1.12E+00			1.11E+00
ALIPHATICS ER ADULT (using RfC)						**3.59E-03**			**3.50E-03**			**3.48E-03**
AROMATICS												
Ethylbenzene	8.16E-01	3.47E-01	8.02E-02	2.28E-01	2.41E-02	1.44E-03	9.67E-02	1.70E-02	4.29E-04	5.97E-02	3.34E-03	1.44E-04
Toluene	1.38E-01	5.84E-02	1.35E-02	3.85E-02	4.06E-03	2.42E-04	1.63E-02	2.86E-03	7.23E-05	1.01E-02	5.63E-04	2.42E-05
Xylene	2.21E-01	9.38E-02	2.17E-02	6.17E-02	6.51E-03	3.89E-04	2.61E-02	4.59E-03	1.16E-04	1.61E-02	9.04E-04	3.89E-05
AROMATICS TOTAL (excl. benzene)	1.17E+00	4.99E-01	1.15E-01	3.28E-01	3.47E-02	2.07E-03	1.39E-01	2.44E-02	6.17E-04	8.59E-02	4.81E-03	2.07E-04
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*					1.52E-02	9.10E-04	6.12E-02	1.07E-02	2.72E-04	3.78E-02	2.12E-03	9.10E-05
AROMATICS ER CHILD (using RfC)					7.62E-05	**5.17E-06**	3.06E-04	5.37E-05	**1.54E-06**	1.89E-04	1.06E-05	**5.17E-07**
*ADULT INHALED DOSE ug/(kg*d)*						1.27E-02			1.24E-02			1.23E-02
AROMATICS ER ADULT (using RfC)						**9.96E-05**			**9.72E-05**			**9.65E-05**
ALDEHYDES												
Acrolein (RfC=2.0E-02 mg/m^3)	1.23E+00	5.21E-01	1.20E-01	3.43E-01	3.62E-02	2.16E-03	1.45E-01	2.55E-02	6.45E-04	8.97E-02	5.02E-03	2.16E-04
Methacrolein	4.08E-01	1.73E-01	4.01E-02	1.14E-01	1.20E-02	7.19E-04	4.83E-02	8.49E-03	2.14E-04	2.98E-02	1.67E-03	7.19E-05
n-Butanal	5.12E-01	2.18E-01	5.03E-02	1.43E-01	1.51E-02	9.02E-04	6.06E-02	1.06E-02	2.69E-04	3.74E-02	2.10E-03	9.02E-05
3-Methylbutanal	7.05E-02	3.00E-02	6.92E-03	1.97E-02	2.08E-03	1.24E-04	8.35E-03	1.47E-03	3.70E-05	5.15E-03	2.89E-04	1.24E-05
TOTAL AS Acrolein/Methacrolein	2.22E+00	9.42E-01	2.18E-01	6.20E-01	6.54E-02	3.91E-03	2.63E-01	4.61E-02	1.17E-03	1.62E-01	9.08E-03	3.91E-04
RfC (Acrolein & Methacrolein)	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
ER-Child Aldehydes (Based on RfC)						**1.95E-01**			**5.83E-02**			**1.95E-02**
ER-Adult Aldehydes (Based on RfC)						**3.76E+00**			**3.67E+00**			**3.64E+00**
KETONES												
Acetone (RfD=1.0E-01 mg/(kg*d))	2.23E+00	9.46E-01	2.19E-01	6.23E-01	6.57E-02	3.92E-03	2.64E-01	4.63E-02	1.17E-03	1.63E-01	9.12E-03	3.92E-04
Methyl Ethyl Ketone	4.75E-01	2.02E-01	4.66E-02	1.33E-01	1.40E-02	8.37E-04	5.62E-02	9.88E-03	2.50E-04	3.47E-02	1.95E-03	8.37E-05
3-Buten-2-one	8.91E-01	3.78E-01	8.74E-02	2.49E-01	2.63E-02	1.57E-03	1.05E-01	1.85E-02	4.68E-04	6.51E-02	3.65E-03	1.57E-04
TOTAL AS Acetone	3.59E+00	1.53E+00	3.53E-01	1.00E+00	1.06E-01	6.33E-03	4.25E-01	7.47E-02	1.89E-03	2.63E-01	1.47E-02	6.33E-04
*Inhhaled Child Dose (ug/(kg*d)*				4.42E-01	4.66E-02	2.78E-03	1.87E-01	3.29E-02	8.30E-04	1.16E-01	6.47E-03	2.78E-04
ER CHILD Ketones (RfD from IRIS)						**2.78E-05**			**8.30E-06**			**2.78E-06**
Inhaled Adult Dose ug/(kg*d)						3.90E-02			3.80E-02			3.78E-02
ER ADULT Ketones (RfD from IRIS)						**3.90E-04**			**3.80E-04**			**3.78E-04**
PAHs												
*Naphthalene (RfD=4.0E-02 mg/(kg*d))*	8.25E-02	3.51E-02	8.10E-03	2.31E-02	2.43E-03	1.45E-04	9.77E-03	1.72E-03	4.33E-05	6.03E-03	3.38E-04	1.45E-05

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
Acenapthylene	5.86E-03	2.49E-03	5.75E-04	1.64E-03	1.73E-04	1.03E-05	6.94E-04	1.22E-04	3.08E-06	4.28E-04	2.40E-05	1.03E-06
Acenaphthene	2.97E-03	1.26E-03	2.91E-04	8.30E-04	8.75E-05	5.23E-06	3.51E-04	6.17E-05	1.56E-06	2.17E-04	1.22E-05	5.23E-07
SUM:NAPHTHA	9.13E-02	3.88E-02	8.97E-03	2.55E-02	2.69E-03	1.61E-04	1.08E-02	1.90E-03	4.80E-05	6.68E-03	3.74E-04	1.61E-05
*Inhhaled Child Dose (ug/(kg*d)*				1.12E-02	1.19E-03	7.08E-05	4.76E-03	8.36E-04	2.11E-05	2.94E-03	1.65E-04	7.08E-06
NAPHTHALENE ER-Child (using RfC)						1.77E-06			5.28E-07			1.77E-07
*Inhhaled Adult Dose (ug/(kg*d)*						9.91E-04			9.67E-04			9.60E-04
NAPHTHALENE ER-Adult (using RfC)						2.48E-05			2.42E-05			2.40E-05
Fluorene (RfD=4.0E-02 mg/(kg*d))	8.12E-03	3.45E-03	7.97E-04	2.27E-03	2.40E-04	1.43E-05	9.61E-04	1.69E-04	4.26E-06	5.93E-04	3.32E-05	1.43E-06
2-Methylfluorene	1.78E-05	7.57E-06	1.75E-06	4.98E-06	5.25E-07	3.14E-08	2.11E-06	3.70E-07	9.36E-09	1.30E-06	7.29E-08	3.14E-09
SUM:FLOURENE	8.14E-03	3.46E-03	7.99E-04	2.28E-03	2.40E-04	1.43E-05	9.63E-04	1.69E-04	4.27E-06	5.95E-04	3.33E-05	1.43E-06
*Inhhaled Child Dose (ug/(kg*d)*				1.00E-03	1.06E-04	6.31E-06	4.24E-04	7.44E-05	1.88E-06	2.62E-04	1.47E-05	6.31E-07
FLUORENE ER-Child (using RfC)						1.58E-07			4.70E-08			1.58E-08
*Inhhaled Adult Dose (ug/(kg*d)*						8.83E-05			8.61E-05			8.55E-05
FLUORENE ER-Adult (using RfC)						2.21E-06			2.15E-06			2.14E-06
Fluoranthene (RfD=4.0E-02 mg/(kg*d))	2.12E-03	8.99E-04	2.08E-04	5.92E-04	6.24E-05	3.73E-06	2.50E-04	4.40E-05	1.11E-06	1.55E-04	8.66E-06	3.73E-07
Anthracene	8.84E-04	3.76E-04	8.68E-05	2.47E-04	2.61E-05	1.56E-06	1.05E-04	1.84E-05	4.64E-07	6.46E-05	3.62E-06	1.56E-07
Phenanthrene	2.39E-02	1.01E-02	2.34E-03	6.67E-03	7.04E-04	4.20E-05	2.83E-03	4.96E-04	1.25E-05	1.74E-03	9.77E-05	4.20E-06
3-Methylphenanthrene	9.28E-03	3.94E-03	9.11E-04	2.59E-03	2.74E-04	1.63E-05	1.10E-03	1.93E-04	4.87E-06	6.78E-04	3.80E-05	1.63E-06
2-Methylanthracene	1.06E-02	4.51E-03	1.04E-03	2.97E-03	3.13E-04	1.87E-05	1.26E-03	2.21E-04	5.57E-06	7.76E-04	4.35E-05	1.87E-06
4-+9-Methylphenanthrene	1.14E-02	4.86E-03	1.12E-03	3.20E-03	3.37E-04	2.01E-05	1.35E-03	2.38E-04	6.00E-06	8.35E-04	4.68E-05	2.01E-06
1-Methylphenanthrene	9.50E-03	4.04E-03	9.33E-04	2.66E-03	2.80E-04	1.67E-05	1.12E-03	1.98E-04	4.99E-06	6.94E-04	3.89E-05	1.67E-06
SUM:FLUOANTHENE	6.77E-02	2.88E-02	6.65E-03	1.89E-02	2.00E-03	1.19E-04	8.01E-03	1.41E-03	3.56E-05	4.95E-03	2.77E-04	1.19E-05
*Inhhaled Child Dose (ug/(kg*d)*				8.33E-03	8.79E-04	5.25E-05	3.53E-03	6.19E-04	1.56E-05	2.18E-03	1.22E-04	5.25E-06
FLUORANTHENE ER-Child (using RfC)						1.31E-06			3.91E-07			1.31E-07
*Inhhaled Adult Dose (ug/(kg*d)*						7.34E-04			7.16E-04			7.11E-04
FLUORANTHENE ER-Adult (using RfC)						1.84E-05			1.79E-05			1.78E-05
Pyrene (RfD=3.0E-02 mg/(kg*d))	1.67E-03	7.08E-04	1.64E-04	4.66E-04	4.92E-05	2.94E-06	1.97E-04	3.47E-05	8.76E-07	1.22E-04	6.83E-06	2.94E-07
2-Methylpyrene	1.58E-04	6.72E-05	1.55E-05	4.42E-05	4.66E-06	2.78E-07	1.87E-05	3.29E-06	8.30E-08	1.16E-05	6.47E-07	2.78E-08
SUM:PYRENE	1.83E-03	7.76E-04	1.79E-04	5.10E-04	5.38E-05	3.21E-06	2.16E-04	3.79E-05	9.59E-07	1.33E-04	7.47E-06	3.21E-07
*Inhhaled Child Dose (ug/(kg*d)*				2.25E-04	2.37E-05	1.41E-06	9.51E-05	1.67E-05	4.22E-07	5.87E-05	3.29E-06	1.41E-07
PYRENE ER-Child (using RfC)						4.71E-08			1.41E-08			4.71E-09
*Inhhaled Adult Dose (ug/(kg*d)*						1.98E-05			1.93E-05			1.92E-05
PYRENE ER-Adult (using RfC)						6.60E-07			6.44E-07			6.39E-07
PAH-CHILD HAZARD INDEX						**3.29E-06**			**9.80E-07**			**3.29E-07**
PAH-ADULT HAZARD INDEX						**4.60E-05**			**4.49E-05**			**4.46E-05**
OTHER PAH SUBSTANCES												
Benzo(g,h,l)perylene	1.82E-04	7.72E-05	1.78E-05	5.08E-05	5.36E-06	3.20E-07	2.15E-05	3.78E-06	9.54E-08	1.33E-05	7.44E-07	3.20E-08
Benzo[a]fluorene	1.91E-04	8.14E-05	1.88E-05	5.35E-05	5.65E-06	3.37E-07	2.27E-05	3.98E-06	1.01E-07	1.40E-05	7.84E-07	3.37E-08
Benzo[ghi]fluoranthene	1.11E-04	4.73E-05	1.09E-05	3.11E-05	3.28E-06	1.96E-07	1.32E-05	2.31E-06	5.85E-08	8.14E-06	4.56E-07	1.96E-08
Cyclopenta[cd]pyrene	1.34E-05	5.68E-06	1.31E-06	3.74E-06	3.94E-07	2.35E-08	1.58E-06	2.78E-07	7.02E-09	9.76E-07	5.47E-08	2.35E-09
Benzo[e]pyrene	1.19E-05	5.05E-06	1.17E-06	3.32E-06	3.50E-07	2.09E-08	1.41E-06	2.47E-07	6.24E-09	8.68E-07	4.86E-08	2.09E-09
Perylene	1.48E-06	6.31E-07	1.46E-07	4.15E-07	4.38E-08	2.61E-09	1.76E-07	3.09E-08	7.80E-10	1.08E-07	6.08E-09	2.61E-10
Indeno[1,2,3-cd]fluoranthene	7.42E-06	3.15E-06	7.29E-07	2.08E-06	2.19E-07	1.31E-08	8.79E-07	1.54E-07	3.90E-09	5.42E-07	3.04E-08	1.31E-09
Picene	1.48E-06	6.31E-07	1.46E-07	4.15E-07	4.38E-08	2.61E-09	1.76E-07	3.09E-08	7.80E-10	1.08E-07	6.08E-09	2.61E-10
Benzo[ghi]perylene	1.04E-05	4.41E-06	1.02E-06	2.91E-06	3.07E-07	1.83E-08	1.23E-06	2.16E-07	5.46E-09	7.59E-07	4.25E-08	1.83E-09
Coronene	1.48E-06	6.31E-07	1.46E-07	4.15E-07	4.38E-08	2.61E-09	1.76E-07	3.09E-08	7.80E-10	1.08E-07	6.08E-09	2.61E-10
1-Nitropyrene	1.19E-04	5.05E-05	1.17E-05	3.32E-05	3.50E-06	2.09E-07	1.41E-05	2.47E-06	6.24E-08	8.68E-06	4.86E-07	2.09E-08
Dibenzothiophene	1.26E-05	5.36E-06	1.24E-06	3.53E-06	3.72E-07	2.22E-08	1.49E-06	2.62E-07	6.63E-09	9.22E-07	5.17E-08	2.22E-09
4-Methyldibenzothiophene	2.08E-05	8.83E-06	2.04E-06	5.81E-06	6.13E-07	3.66E-08	2.46E-06	4.32E-07	1.09E-08	1.52E-06	8.51E-08	3.66E-09
3-Methyldibenzothiophene	3.27E-05	1.39E-05	3.21E-06	9.13E-06	9.63E-07	5.75E-08	3.87E-06	6.79E-07	1.72E-08	2.39E-06	1.34E-07	5.75E-09
SUM: (AS PYRENE UNITS)			7.04E-05			1.26E-06			3.76E-07			1.26E-07
*Inhhaled Child Dose (as pyrene units, ug/(kg*d)*						5.55E-07			1.66E-07			5.55E-08
ER-Child (as pyrene units, using RfC)						1.85E-08			5.52E-09			1.85E-09
*Inhhaled Adult Dose (as pyrene units, ug/(kg*d)*						7.78E-06			7.59E-06			7.53E-06
ER-Adult (as pyrene units, using RfC)						2.59E-07			2.53E-07			2.51E-07
CARCINOGENS (Fleet Emissions)	(Note: Inhalation dose assumes lifetime exposure (70yrs), with ages 20-70 involving 8hrs worker on site & 16hrs at residence.) (Note: See footnote for explanation of carcinogen dose equation.)											
Formaldehyde	2.67E+01	1.14E+01	2.63E+00	7.48E+00	7.89E-01	4.71E-02	3.17E+00	5.56E-01	1.41E-02	1.96E+00	1.10E-01	4.71E-03
Exposure Ratio based on RsC						**5.89E-02**			**1.76E-02**			**5.89E-03**
*Lifetime Residential Composite Dose (ug/(kg*d)*						1.60E-02			4.78E-03			1.60E-03
FORMALDEHYDE RESIDENTIAL LCR						**6.34E-07**			**1.89E-07**			**6.34E-08**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						2.18E-01			2.09E-01			2.07E-01
FORMALDEHYDE WORKER + RESID'L LCR						**8.63E-06**			**8.28E-06**			**8.19E-06**
	(Note: Formaldehyde slope factor = 3.96E-02mg/(kg*d) per IRIS inhalation unit risk of 1.3 E-05)											
Acetaldehyde	8.52E+00	3.62E+00	8.37E-01	2.38E+00	2.51E-01	1.50E-02	1.01E+00	1.77E-01	4.48E-03	6.23E-01	3.49E-02	1.50E-03
*Lifetime Residential Composite Dose (ug/(kg*d)*						5.10E-03			1.52E-03			5.10E-04
ACETALDEHYDE RESIDENTIAL LCR						**3.42E-08**			**1.17E-08**			**3.93E-09**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						6.94E-02			6.66E-02			6.59E-02
ACETALDEHYDE WORKER + RESID'L LCR						**4.65E-07**			**5.13E-07**			**5.07E-07**
	(Note:Acetaldehyde slope factor = 6.7E-03mg/(kg*d) per IRIS inhalation unit risk of 2.2 E-06))											
Benzene	8.03E-01	3.41E-01	7.89E-02	2.25E-01	2.37E-02	1.41E-03	9.51E-02	1.67E-02	4.22E-04	5.87E-02	3.29E-03	1.41E-04
*Lifetime Residential Composite Dose (ug/(kg*d)*			2.68E-02			4.81E-04			1.43E-04			4.81E-05
BENZENE RESID'L LIFETIME CANCER RISK						**1.39E-08**			**4.16E-09**			**1.39E-09**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						6.54E-03			6.28E-03			6.21E-03
BENZENE WORKER + RESID'L LCR						**1.90E-07**			**1.82E-07**			**1.80E-07**
	(Note: Benzene slope factor = 2.9E-02mg/(kg*d) per TPHCWG, 1997)											
CARCINOGENIC PAHs (GROUPED, BaP-TEFs)												
Benz(a)anthracene * (.1)	2.15E-04	9.11E-05	2.11E-05	6.00E-05	6.33E-06	3.78E-07	2.54E-05	4.46E-06	1.13E-07	1.57E-05	8.78E-07	3.78E-08
Chrysene*(.01)	5.90E-04	2.51E-04	5.79E-05	1.65E-04	1.74E-05	1.04E-06	6.98E-05	1.23E-05	3.10E-07	4.31E-05	2.41E-06	1.04E-07
Benzo(b)fluoranthene*(.1)	7.04E-04	2.99E-04	6.91E-05	1.97E-04	2.08E-05	1.24E-06	8.34E-05	1.46E-05	3.70E-07	5.15E-05	2.88E-06	1.24E-07
Benzo(k)fluoranthene*(.1)	7.99E-05	3.40E-05	7.85E-06	2.23E-05	2.36E-06	1.41E-07	9.46E-06	1.66E-06	4.20E-08	5.84E-06	3.27E-07	1.41E-08
Benzo(a)pyrene*(1.0)	8.38E-05	3.56E-05	8.23E-06	2.34E-05	2.47E-06	1.48E-07	9.92E-06	1.74E-06	4.40E-08	6.12E-06	3.43E-07	1.48E-08
Indeno(1,2,3-W)pyrene*(.01)	1.33E-04	5.66E-05	1.31E-05	3.73E-05	3.93E-06	2.35E-07	1.58E-05	2.77E-06	7.00E-08	9.74E-06	5.46E-07	2.35E-08
Dibenz(a,h)anthracene*(1.0)	2.20E-04	9.35E-05	2.16E-05	6.15E-05	6.49E-06	3.87E-07	2.60E-05	4.57E-06	1.16E-07	1.61E-05	9.01E-07	3.87E-08
SUMCANCER CONCs as BAP TEQs	4.11E-04	1.75E-04	**4.03E-05**	1.15E-04	1.21E-05	**7.24E-07**	4.86E-05	8.54E-06	**2.16E-07**	3.00E-05	1.68E-06	**7.24E-08**
*Lifetime Residential Composite Dose (ug/(kg*d)*						2.46E-07			7.34E-08			2.46E-08
PAH RESID'L LIFETIME CANCER RISK						**1.80E-09**			**5.36E-10**			**1.80E-10**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						3.35E-06			3.21E-06			3.18E-06
PAH WORKER + RESID'L LCR						**2.44E-08**			**2.35E-08**			**2.32E-08**
	(Note: Benzo(a)pyrene slope factor = 7.3mg/(kg*d), per TPHCWG, 1997)											
TOTAL PAH RESIDENTIAL LCR						**6.84E-07**			**2.06E-07**			**6.89E-08**
TOTAL PAH WORKER + RESID'L LCR						**9.31E-06**			**9.00E-06**			**8.90E-06**

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual

Source: Mine Surface Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	2.71E+02	1.15E+02	2.62E+01	7.55E+01	7.93E+00	4.77E-01	3.19E+01	5.60E+00	1.41E-01	1.97E+01	1.10E+00	4.61E-02
i-BUTANE	6.26E+00	2.65E+00	6.05E-01	1.74E+00	1.83E-01	1.10E-02	7.35E-01	1.29E-01	3.26E-03	4.54E-01	2.53E-02	1.06E-03
n-BUTANE	1.09E+01	4.64E+00	1.06E+00	3.05E+00	3.20E-01	1.92E-02	1.29E+00	2.26E-01	5.71E-03	7.95E-01	4.42E-02	1.86E-03
i-PENTANE	4.69E+00	1.99E+00	4.54E-01	1.31E+00	1.37E-01	8.25E-03	5.52E-01	9.69E-02	2.45E-03	3.41E-01	1.90E-02	7.97E-04
CYCLOPENTANE	9.38E+00	3.98E+00	9.08E-01	2.61E+00	2.74E-01	1.65E-02	1.10E+00	1.94E-01	4.89E-03	6.82E-01	3.79E-02	1.59E-03
3-ME-PENTANE	3.13E+00	1.33E+00	3.03E-01	8.71E-01	9.14E-02	5.50E-03	3.68E-01	6.46E-02	1.63E-03	2.27E-01	1.26E-02	5.31E-04
METHYLCYCLOPENTANE	3.13E+00	1.33E+00	3.03E-01	8.71E-01	9.14E-02	5.50E-03	3.68E-01	6.46E-02	1.63E-03	2.27E-01	1.26E-02	5.31E-04
CYCLOHEXANE	3.13E+00	1.33E+00	3.03E-01	8.71E-01	9.14E-02	5.50E-03	3.68E-01	6.46E-02	1.63E-03	2.27E-01	1.26E-02	5.31E-04
2,3-DIMETHYLPENTANE	3.13E+00	1.33E+00	3.03E-01	8.71E-01	9.14E-02	5.50E-03	3.68E-01	6.46E-02	1.63E-03	2.27E-01	1.26E-02	5.31E-04
3-METHYLHEXANE	7.82E+00	3.32E+00	7.56E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
N-HEPTANE	1.56E+00	6.64E-01	1.51E-01	4.35E-01	4.57E-02	2.75E-03	1.84E-01	3.23E-02	8.15E-04	1.14E-01	6.32E-03	2.66E-04
ME-CYCLOHEXANE	6.26E+00	2.65E+00	6.05E-01	1.74E+00	1.83E-01	1.10E-02	7.35E-01	1.29E-01	3.26E-03	4.54E-01	2.53E-02	1.06E-03
3-METHYLHEPTANE	1.02E+01	4.31E+00	9.83E-01	2.83E+00	2.97E-01	1.79E-02	1.20E+00	2.10E-01	5.30E-03	7.38E-01	4.11E-02	1.73E-03
2,3,4-TRIMETHYLHEXANE	2.35E+00	9.95E-01	2.27E-01	6.53E-01	6.86E-02	4.12E-03	2.76E-01	4.84E-02	1.22E-03	1.70E-01	9.48E-03	3.98E-04
N-OCTANE	8.60E+00	3.65E+00	8.32E-01	2.39E+00	2.51E-01	1.51E-02	1.01E+00	1.78E-01	4.48E-03	6.25E-01	3.48E-02	1.46E-03
BRANCHED NONANE	7.82E+00	3.32E+00	7.56E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
n-NONANE	1.17E+01	4.98E+00	1.13E+00	3.26E+00	3.43E-01	2.06E-02	1.38E+00	2.42E-01	6.12E-03	8.52E-01	4.74E-02	1.99E-03
n-DECANE	1.25E+01	5.31E+00	1.21E+00	3.48E+00	3.66E-01	2.20E-02	1.47E+00	2.58E-01	6.52E-03	9.09E-01	5.06E-02	2.12E-03
(ALIPHATICS TOTAL C5-C10)	1.76E+02	7.46E+01	1.70E+01	4.90E+01	5.14E+00	3.09E-01	2.07E+01	3.63E+00	9.17E-02	1.28E+01	7.11E-01	2.99E-02
ALIPHATICS TOTAL C1-C10	4.65E+02	1.97E+02	**4.50E+01**	1.30E+02	1.36E+01	**8.18E-01**	5.47E+01	9.61E+00	**2.43E-01**	3.38E+01	1.88E+00	**7.90E-02**
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				5.70E+01	5.98E+00	3.60E-01	2.41E+01	4.23E+00	1.07E-01	1.49E+01	8.27E-01	3.48E-02
ALIPHATICS ER CHILD (using RfC)				5.70E-01	5.98E-02	**8.18E-04**	2.41E-01	4.23E-02	**2.43E-04**	1.49E-01	8.27E-03	**7.90E-05**
ADULT INHALED DOSE ug/(kg*d)						4.97E+00			4.85E+00			4.82E+00
ALIPHATICS ER ADULT (RfD fromTPHCWG, 1997)						**1.55E-02**			**1.52E-02**			**1.51E-02**
AROMATICS												
Carbon Range C5-C8												
TOLUENE	3.91E+00	1.66E+00	3.78E-01	1.09E+00	1.14E-01	6.87E-03	4.60E-01	8.07E-02	2.04E-03	2.84E-01	1.58E-02	6.64E-04
ET-BENZENE	3.13E+00	1.33E+00	3.03E-01	8.71E-01	9.14E-02	5.50E-03	3.68E-01	6.46E-02	1.63E-03	2.27E-01	1.26E-02	5.31E-04
M,P-XYLENE	1.56E+00	6.64E-01	1.51E-01	4.35E-01	4.57E-02	2.75E-03	1.84E-01	3.23E-02	8.15E-04	1.14E-01	6.32E-03	2.66E-04
O-XYLENE	7.82E+00	3.32E+00	7.56E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
TOTAL AROMATICS C5-C8 CONC.	1.64E+01	6.97E+00	**1.59E+00**	4.57E+00	4.80E-01	**2.89E-02**	1.93E+00	3.39E-01	**8.56E-03**	1.19E+00	6.64E-02	**2.79E-03**
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				2.01E+00	2.11E-01	1.27E-02	8.49E-01	1.49E-01	3.77E-03	5.25E-01	2.92E-02	1.23E-03
AROMATICS ER CHILD (RfD fromTPHCWG, 1997)				1.01E-02	1.06E-03	**7.22E-05**	4.25E-03	7.46E-04	**2.14E-05**	2.62E-03	1.46E-04	**6.97E-06**
*ADULT INHALED DOSE ug/(kg*d)*						1.76E-01			1.71E-01			1.70E-01
AROMATICS ER ADULT (using RfC)						**1.37E-03**			**1.34E-03**			**1.33E-03**
Carbon Range C9-C18												
Cumene	7.82E+00	3.32E+00	7.56E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
TOTAL AROMATICS C9-C18 CONC.	7.82E+00	3.32E+00	7.56E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				9.58E-01	1.01E-01	6.05E-03	4.04E-01	7.10E-02	1.79E-03	2.50E-01	1.39E-02	5.84E-04
AROMATICS (C9-C18) ER CHILD (using RfC)				2.39E-02	2.51E-03	**6.87E-05**	1.01E-02	1.78E-03	**2.04E-05**	6.25E-03	3.48E-04	**6.64E-06**
*ADULT INHAL DOSE (ug/kg*day)*						8.36E-02			8.15E-02			8.10E-02
AROMATICS (C9-C18) ER ADULT (using RfC)						**1.31E-03**			**1.27E-03**			**1.26E-03**
AROMATICS ER CHILD (using RfC)						**1.41E-04**			**4.18E-05**			**1.36E-05**
AROMATICS ER ADULT (RfD fromTPHCWG, 1997)						**2.68E-03**			**2.61E-03**			**2.59E-03**

Source: Tailings Pond

SUBSTANCE	Overall On Site Max.			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	3.36E+02	1.88E+02	7.04E+01	4.94E+01	7.53E+00	8.94E-01	1.61E+01	2.93E+00	7.60E-02	8.91E+00	4.39E-01	1.86E-02
Isobutane	6.18E+00	3.45E+00	1.30E+00	9.09E-01	1.39E-01	1.65E-02	2.96E-01	5.40E-02	1.40E-03	1.64E-01	8.07E-03	3.42E-04
Isopentane	1.55E+00	8.63E-01	3.24E-01	2.27E-01	3.47E-02	4.11E-03	7.40E-02	1.35E-02	3.50E-04	4.10E-02	2.02E-03	8.55E-05
n-Pentane	2.32E+00	1.29E+00	4.86E-01	3.41E-01	5.20E-02	6.17E-03	1.11E-01	2.03E-02	5.25E-04	6.15E-02	3.03E-03	1.28E-04
Cyclopentane	3.86E-01	2.16E-01	8.10E-02	5.68E-02	8.67E-03	1.03E-03	1.85E-02	3.38E-03	8.75E-05	1.03E-02	5.05E-04	2.14E-05
2,3-Dimethylbutane	1.31E+01	7.34E+00	2.75E+00	1.93E+00	2.95E-01	3.50E-02	6.29E-01	1.15E-01	2.97E-03	3.49E-01	1.72E-02	7.27E-04
n-Hexane	1.08E+01	6.04E+00	2.27E+00	1.59E+00	2.43E-01	2.88E-02	5.18E-01	9.45E-02	2.45E-03	2.87E-01	1.41E-02	5.98E-04
2,4-Dimethylpentane	2.16E+01	1.21E+01	4.54E+00	3.18E+00	4.85E-01	5.76E-02	1.04E+00	1.89E-01	4.90E-03	5.74E-01	2.83E-02	1.20E-03
Cyclohexane	3.94E+01	2.20E+01	8.26E+00	5.80E+00	8.84E-01	1.05E-01	1.89E+00	3.44E-01	8.92E-03	1.05E+00	5.15E-02	2.18E-03
2,3-Dimethylpentane	5.02E+00	2.81E+00	1.05E+00	7.39E-01	1.13E-01	1.34E-02	2.40E-01	4.39E-02	1.14E-03	1.33E-01	6.56E-03	2.78E-04
3-Methylhexane	1.62E+01	9.06E+00	3.40E+00	2.39E+00	3.64E-01	4.32E-02	7.76E-01	1.42E-01	3.67E-03	4.31E-01	2.12E-02	8.97E-04
2,2,4-Trimethylpentane	3.63E+01	2.03E+01	7.61E+00	5.34E+00	8.15E-01	9.67E-02	1.74E+00	3.17E-01	8.22E-03	9.64E-01	4.74E-02	2.01E-03
n-Heptane	2.01E+01	1.12E+01	4.21E+00	2.95E+00	4.51E-01	5.35E-02	9.61E-01	1.76E-01	4.55E-03	5.33E-01	2.62E-02	1.11E-03
3-Methylheptane	1.31E+01	7.34E+00	2.75E+00	1.93E+00	2.95E-01	3.50E-02	6.29E-01	1.15E-01	2.97E-03	3.49E-01	1.72E-02	7.27E-04
2,2,5-Trimethylhexane	3.90E+01	2.18E+01	8.18E+00	5.74E+00	8.76E-01	1.04E-01	1.87E+00	3.41E-01	8.84E-03	1.04E+00	5.10E-02	2.16E-03
n-Octane	3.82E+01	2.14E+01	8.02E+00	5.63E+00	8.58E-01	1.02E-01	1.83E+00	3.34E-01	8.66E-03	1.02E+00	5.00E-02	2.12E-03
n-Nonane	2.09E+01	1.17E+01	4.37E+00	3.07E+00	4.68E-01	5.55E-02	9.98E-01	1.82E-01	4.72E-03	5.54E-01	2.73E-02	1.15E-03
ALIPHATICS TOTAL C5-C10	8.67E+02	4.84E+02	1.82E+02	1.28E+02	1.95E+01	2.31E+00	4.15E+01	7.58E+00	1.96E-01	2.30E+01	1.13E+00	4.80E-02
ALIPHATICS TOTAL C1-C10	1.21E+03	6.76E+02	**2.54E+02**	1.78E+02	2.71E+01	**3.22E+00**	5.79E+01	1.06E+01	**2.74E-01**	3.21E+01	1.58E+00	**6.69E-02**
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				7.83E+01	1.19E+01	1.42E+00	2.55E+01	4.65E+00	1.21E-01	1.41E+01	6.95E-01	2.94E-02
ALIPHATICS ER CHILD (using RfC)				7.83E-01	1.19E-01	**3.22E-03**	2.55E-01	4.65E-02	**2.74E-04**	1.41E-01	6.95E-03	**6.69E-05**
ADULT INHALED DOSE ug/(kg*d)						2.77E+01			2.71E+01			2.71E+01
ALIPHATICS ER ADULT (using RfC)						**8.67E-02**			**8.47E-02**			**8.46E-02**
AROMATICS												
Carbon Range C5-C8												
Toluene	3.32E+01	1.86E+01	6.97E+00	4.89E+00	7.46E-01	8.85E-02	1.59E+00	2.90E-01	7.52E-03	8.82E-01	4.34E-02	1.84E-03
Ethylbenzene	9.12E+01	5.09E+01	1.91E+01	1.34E+01	2.05E+00	2.43E-01	4.36E+00	7.97E-01	2.06E-02	2.42E+00	1.19E-01	5.04E-03
(p+m)-Xylene	9.12E+01	5.09E+01	1.91E+01	1.34E+01	2.05E+00	2.43E-01	4.36E+00	7.97E-01	2.06E-02	2.42E+00	1.19E-01	5.04E-03
o-Xylene	2.86E+01	1.60E+01	5.99E+00	4.20E+00	6.41E-01	7.61E-02	1.37E+00	2.50E-01	6.47E-03	7.59E-01	3.73E-02	1.58E-03
TOTAL AROMATICS C5-C8 CONC.	2.44E+02	1.36E+02	5.12E+01	3.59E+01	5.48E+00	6.50E-01	1.17E+01	2.13E+00	5.53E-02	6.48E+00	3.19E-01	1.35E-02
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				2.75E-01	4.20E-02	4.98E-03	8.95E-02	1.63E-02	4.23E-04	4.96E-02	2.44E-03	1.03E-04
AROMATICS (C5-C6) ER CHILD (using RfC)				1.38E-03	2.10E-04	**1.63E-03**	4.47E-04	8.17E-05	**1.38E-04**	2.48E-04	1.22E-05	**3.38E-05**
*ADULT INHAL DOSE (ug/kg*day)*						5.60E+00			5.47E+00			5.46E+00
AROMATICS (C5-C6) ER ADULT (using RfC)						**4.37E-02**			**4.28E-02**			**4.27E-02**
Carbon Range C9-C18												

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
1,2,3-TMB+p-Cymene	3.09E+01	1.73E+01	6.48E+00	4.55E+00	6.94E-01	8.23E-02	1.48E+00	2.70E-01	7.00E-03	8.21E-01	4.04E-02	1.71E-03
1,2,4-TMB+n-Decane	2.16E+01	1.21E+01	4.54E+00	3.18E+00	4.85E-01	5.76E-02	1.04E+00	1.89E-01	4.90E-03	5.74E-01	2.83E-02	1.20E-03
1,3,5-Trimethylbenzene	4.25E+00	2.37E+00	8.91E-01	6.25E-01	9.54E-02	1.13E-02	2.03E-01	3.71E-02	9.62E-04	1.13E-01	5.55E-03	2.35E-04
Cumene	1.47E+01	8.20E+00	3.08E+00	2.16E+00	3.29E-01	3.91E-02	7.03E-01	1.28E-01	3.32E-03	3.90E-01	1.92E-02	8.12E-04
TOTAL AROMATICS C9-C18 CONC.	7.15E+01	3.99E+01	1.50E+01	1.05E+01	1.60E+00	1.90E-01	3.42E+00	6.25E-01	1.62E-02	1.90E+00	9.34E-02	3.95E-03
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				4.63E+00	7.06E-01	8.37E-02	1.50E+00	2.75E-01	7.12E-03	8.35E-01	4.11E-02	1.74E-03
AROMATICS (C9-C18) ER CHILD (using RfC)				1.16E-01	1.76E-02	**9.51E-04**	3.76E-02	6.87E-03	**8.09E-05**	2.09E-02	1.03E-03	**1.98E-05**
*ADULT INHAL DOSE (ug/kg*day)*						1.64E+00			1.60E+00			1.60E+00
AROMATICS (C9-C18) ER ADULT (using RfC)						**2.56E-02**			**2.50E-02**			**2.50E-02**
AROMATICS ER CHILD (using RfC)				1.17E-01	1.79E-02	**2.58E-03**	3.81E-02	6.95E-03	**2.19E-04**	2.11E-02	1.04E-03	**5.35E-05**
AROMATICS ER ADULT (RfD fromTPHCWG, 1997)						**6.94E-02**			**6.78E-02**			**6.77E-02**

SUMMARY OF RISK ESTIMATES--ALL SOURCES COMBINED

CHEMICAL/RECEPTOR	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALDEHYDES ER-Child (Based on RfC)	not applicable					**1.95E-01**	not apllicable		**5.83E-02**	not apllicable		**1.95E-02**
ALDEHYDES ER-Adult (Based on RfC)	not applicable					**3.63E+00**	not apllicable		**3.63E+00**	not apllicable		**3.63E+00**
KETONES ER-Child (using RfC)	not apllicable					**2.78E-05**	not apllicable		**8.30E-06**	not apllicable		**2.78E-06**
KETONES ER-Adult (using RfC)	not apllicable					**3.90E-04**	not apllicable		**3.80E-04**	not apllicable		**3.78E-04**
ALIPHATICS HI-Child	not apllicable					**4.22E-03**	not apllicable		**5.72E-04**	not apllicable		**1.65E-04**
ALIPHATICS HI-Adult	not apllicable					**1.06E-01**	not apllicable		**1.03E-01**	not apllicable		**1.03E-01**
AROMATICS HI-Child	not apllicable					**2.72E-03**	not apllicable		**2.62E-04**	not apllicable		**6.77E-05**
AROMATICS HI-Adult	not apllicable					**7.21E-02**	not apllicable		**7.05E-02**	not apllicable		**7.04E-02**
PAH-CHILD HAZARD INDEX	not apllicable					**3.30E-06**	not apllicable		**9.86E-07**	not apllicable		**3.30E-07**
PAH-ADULT HAZARD INDEX	not apllicable					**4.63E-05**	not apllicable		**4.51E-05**	not apllicable		**4.48E-05**
TOTAL RESIDENTIAL LCR	not apllicable					**6.84E-07**	not apllicable		**2.06E-07**	not apllicable		**6.89E-08**
TOTAL RESIDENTIAL CARCINOGEN ER	not apllicable					**6.84E-02**	not apllicable		**2.06E-02**	not apllicable		**6.89E-03**
TOTAL WORKER + RESID'L LCR	not apllicable					**9.31E-06**	not apllicable		**9.00E-06**	not apllicable		**8.90E-06**
TOTAL WORKER + RESID'L CARCINOGEN ER	not apllicable					**9.31E-01**	not apllicable		**9.00E-01**	not apllicable		**8.90E-01**

Notes:

1. Exposure concentrations may be slightly higher (I.e., conservative measure) than reported from air dispersion modelling (Section E2) due to rounding.
2. Fluoranthene used as model PAH instead of anthracene.
3. Additional PAHs modelled as pyrene units.
4. Slope factors for formaldehyde and acetaldehyde recalculated from unit risk using 23 m^3/d.
5. Composite receptor inhalation factor averaged over 70 years is 0.34 m^3/kg*d, based on Health Canada (CEPA).
6. Maximum inhalation factor is 0.44 m^3/kg*d, occurs for a child 5-11 years (per Health Canada, CEPA).
7. Adult exposure concentration based on 8 of 24 hrs workplace ambient air and 16 of 24 hrs at residence ambient air.
8. Adult carcinogenic inhalation factor in dose calculations is the time-weighted-average from ages 0 to 20 yrs for residential exposure, and 20 to 70yrs involving both residential and workplace exposure, per Health Canada (CEPA).

Table X-45 Ingestion of Plants (HH-3)

Chemical	Plant Species	Plant Concentrations (mg/kg dry wt)	EDI (mg/kg/day)	ER
Child				
Barium	blue	15.5	0.0048	0.068
	Lab	120	0.0013	0.019
	cattail	47.3	0.00052	0.0074
	TOTAL			**0.094**
Boron	blue	7	0.0022	0.024
	Lab	25	0.00027	0.003
	cattail	29	0.0035	0.0035
	TOTAL			**0.031**
Cadmium	blue	0.09	0.00003	0.027
	Lab	0.09	0.000001	0.001
	cattail	0.17	0.000002	0.002
	TOTAL			**0.03**
Copper	blue	4.6	0.0014	0.0028
	Lab	74	0.00081	0.0016
	cattail	14.4	0.00016	0.00032
	TOTAL			**0.0076**
Lead	blue	0.3	0.000092	0.026
	Lab	2.9	0.00003	0.0089
	cattail	2.5	0.000027	0.0077
	TOTAL			**0.043**
Molybdenum	blue	0.11	0.000034	0.0068
	Lab	0.12	0.0000013	0.00026
	cattail	1.7	0.000019	0.0037
	TOTAL			**0.011**
Nickel	blue	0.99	0.0003	0.015
	Lab	0.15	0.0000016	0.00023
	cattail	10.9	0.00012	0.006
	TOTAL			**0.02**
Vanadium	blue	nd	n/a	n/a
	Lab	0.15	0.0000003	0.000044
	cattail	7.16	0.000078	0.011
	TOTAL			**0.011**
Adult				
Barium	blue	15.5	0.0066	0.094
	Lab	120	0.00024	0.0033
	cattail	47.3	0.000096	0.0014
	TOTAL			**0.099**
Boron	blue	7	0.003	0.033
	Lab	25	0.000051	0.00056
	cattail	29	0.000059	0.00066
	TOTAL			**0.034**
Cadmium	blue	0.09	0.000039	0.039
	Lab	0.09	0.00000018	0.00018
	cattail	0.17	0.00000035	0.00035
	TOTAL			**0.040**
Copper	blue	4.6	0.002	0.0039
	Lab	74	0.00015	0.0003
	cattail	14.4	0.000029	0.000059
	TOTAL			**0.0043**
Lead	blue	0.3	0.00013	0.018
	Lab	2.9	0.0000059	0.00023
	cattail	2.5	0.0000051	0.00071
	TOTAL			**0.019**
Molybdenum	blue	0.11	0.000047	0.0094
	Lab	0.12	0.00000024	0.000049
	cattail	1.7	0.000035	0.00069
	TOTAL			**0.01**

Nickel	blue Lab cattail TOTAL	0.99 0.15 10.9	0.00042 0.000014 0.000022	0.021 0.0007 0.0011 **0.023**
Vanadium	blue Lab cattail TOTAL	not detected 0.15 7.16	n/a 0.0000031 0.000015	n/a 0.000044 0.0021 **0.0021**

blue = blueberries; Lab = Labrador tea leaves; cattail = cattail root

Table X-46 Ingestion of Fish (HH-4)

Chemical	**Fish Tissue Concentrations (mg/kg dry wt)**	**EDI**	**ER**
Child			
Barium	0.5	0.00031	0.0044
Copper	2	0.0012	0.0025
Nickel	2	0.0012	0.062
Adult			
Barium	0.5	0.00015	0.0022
Copper	2	0.0006	0.0012
Nickel	2	0.0006	0.03

Table X-47 Reclaimed Landscape Exposure (HH-7)

Chemical	**Media**	**Exposure Concentrations**	**EDI (mg/kg/day)**	**ER**
Child				
Barium	plants (mg/kg) meat (mg/kg)	19.1 0.4	0.012	0.18
Boron	plants (mg/kg) meat (mg/kg)	35.9 not detected	0.022	0.25
Cadmium	plants (mg/kg) meat (mg/kg)	0.3 0.03	0.0002	0.24
Chromium	plants (mg/kg) meat (mg/kg)	0.9 0.3	0.0011	0.0011
Copper	plants (mg/kg) meat (mg/kg)	3.8 5.4	0.012	0.12
Lead	plants (mg/kg) meat (mg/kg)	0.22 not detected	0.0001	0.038
Molybdenum	plants (mg/kg) meat (mg/kg)	0.65 not detected	0.0004	0.08
Selenium	plants (mg/kg) meat (mg/kg)	0.44 0.2	0.0006	0.12
Vanadium	plants (mg/kg) meat (mg/kg)	0.43 not detected	0.0003	0.038
Adult				
Barium	plants (mg/kg) meat (mg/kg) water (mg/L)	19.1 0.4	0.0039	0.056
Boron	plants (mg/kg) meat (mg/kg) water (mg/L)	35.9 not detected	0.00067	0.075
Cadmium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.3 0.03 0.0002	0.00007	0.075

Chromium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.9 0.3	0.0003	0.0003
Copper	plants (mg/kg) meat (mg/kg) water (mg/L)	3.8 5.4	0.0041	0.041
Lead	plants (mg/kg) meat (mg/kg) water (mg/L)	0.22 not detected	0.00004	0.006
Molybdenum	plants (mg/kg) meat (mg/kg) water (mg/L)	0.65 not detected	0.0001	0.021
Selenium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.44 0.2	0.0002	0.041
Vanadium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.43 not detected	0.00008	0.011
Composite				
Arsenic	plants (mg/kg) meat (mg/kg) water (mg/L)	0.062 not detected	0.00005	8.4
Beryllium	plants (mg/kg) meat (mg/kg) water (mg/L)	0.015 not detected	0.000003	1.3
Benzo(a)pyrene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.002 not detected	0.0000004	0.29
Benzo(a) anthracene	plants (mg/kg) meat (mg/kg) water (mg/L)	0.00975 not detected	0.000002	0.14

X.7 VEGETATION FIELD STUDY

X.7 Vegetation Field Study

X.7.1 Field Methods

A vegetation sampling program was conducted specifically for the purpose of addressing stakeholder concerns regarding aboriginal consumption of locally harvested berries, leaves and roots for nutritional and medicinal purposes. Samples of three species of locally harvested plants (i.e., blueberries, Labrador tea leaves and cattail roots), along with corresponding soil and/or sphagnum samples at the base of the plants, were collected during August, 1997 in four areas:

- Muskeg River Mine Project area (baseline chemical concentrations)
- Suncor Lease 25 (area impacted by air emissions from oil sands operations and used as a surrogate of potential impacts on Muskeg River Mine Project site)
- Mariana Lakes area, approximately 65 km south of Fort McMurray (control location)
- West of Syncrude, outside the zone of influence of air emissions (control location)

Collection of plant and soil samples on the Muskeg River Mine Project site was conducted by Golder Associates in collaboration with Fort McKay Environmental Services Ltd. Collection at potentially impacted areas and control locations was conducted by Golder Associates. Although an attempt was made to also collect ratroot, no ratroot plants were observed during field investigations and therefore no samples were harvested. In the current assessment, it was assumed that chemical concentrations in ratroot would be equivalent to chemical concentrations in the cattail root samples collected in this field study. All plant species were analysed for metals and PAHs.

Soil or sphagnum samples were collected at the base of each plant that was sampled. Soil samples were collected to assist in determining if there are any significant accumulations of metals or PAH in soils, a condition that may lead to bioaccumulation into vegetation.

Detailed Methods

Five suitable test locations within the Muskeg River Mine Project site for blueberries, labrador tea and cattail were chosen, where possible. For each sample, only the relevant parts (i.e., fruit (blueberries), leaves (labrador tea) and roots (cattail)) from three different plants of the same species were placed into one sample container. The material was thoroughly mixed and divided into two sample Whirlpak® bags, one each for metals and PAH analyses. Gloves were used at all times when handling samples. All plant samples were stored in a cooler while in the field and were placed in a freezer until shipment to the laboratory.

The rooting media of the plants (i.e., soil, sediment or sphagnum) was also sampled. Sphagnum samples were collected and treated according to the methods described for plant samples above. Soil samples were collected using a stainless steel scoop from the surface layer (top 2-3 cm) at the base of each of the three plants sampled in each location.

The scoop was wiped with a clean cloth, rinsed with distilled water and then alcohol. Gloves were used at all times when handling samples. Sediment samples at the base of cattails were collected using an Ekman grab sampler, which was cleaned between samples according to the method described for the soil scoop above. Soil and sediment samples were placed in glass jars, stored in a cooler while in the field and were placed in a freezer until shipment to the laboratory.

X.7.2 Analytical Results

Analytical results of the vegetation study are summarized in Table X-48.

TABLE X-48

CHEMICAL CONCENTRATIONS IN PLANT TISSUE SAMPLES

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Chemical	Blueberries			Labrador Tea Leaves			Cattail Root		
	Control Areas	Shell Lease 13 West	Potentially Impacted Areas	Control Areas	Shell Lease 13 West	Potentially Impacted Areas	Control Areas	Shell Lease 13 West	Potentially Impacted Areas
PAHs AND SUBSTITUTED PAHs (maximum detected concentrations)									
Naphthalene/Methyl Naphthalene	<0.02	<0.02	<0.02	0.1	0.2	0.25	<0.02	<0.02	<0.02
Phenanthrene/Anthracene	<0.01	<0.01	<0.01	0.21	0.04	<0.01	<0.01	<0.01	<0.01
INORGANICS (mean concentrations)									
Aluminum	49	0	28	29.00	5.60	26.4	91	315.375	295.4
Antimony	<0.04	<0.04	<0.04	0.37	<0.04	0.498	<0.04	<0.04	<0.04
Arsenic	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.9	0.62	0.95
Barium	16	9.72	6.4	68.05	89.76	87.76	12.7	25.68	19.96
Beryllium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	6	4.8	5	18.08	16.8	20.4	9.6	11	10.8
Cadmium	<0.08	0.09	<0.08	<0.08	0.08	0.09	<0.08	0.13	0.09
Calcium	1037.67	944.4	760.5	5171.67	5147.6	5330	3306	13148	7170
Chromium	<0.2	<0.5	<0.2	<0.2	<0.5	0.4	0.45	0.75	0.93
Cobalt	<0.08	<0.08	<0.08	0.0975	0.2	0.1175	0.54	1.546	0.948
Copper	1.8	3.566	3.3	4.7	18.142	9.78	3.08	2.344	5.225
Iron	17	13.6	12.5	37.5	59	110.2	2063	4178	2521
Lead	<0.1	<0.4	0.3	0.2	1.65	0.53	0.97	1.2	1.04
Magnesium	462	373.2	309	1318.33	1062	1244	1530	1432	1606
Manganese	354.67	330.6	287.5	685.67	702	650.4	290.62	143.56	279.76
Mercury	0.02	0.0175	0.015	0.03	0.026	0.034	0.038	0.032	0.04
Molybdenum	0.31	<0.4	0.105	0.086	<0.4	0.096	0.822	<0.4	0.698
Nickel	0.445	0.564	0.66	2.10	3.732	2.762	30.672	2.902	23.47
Phosphorus	1026	736.6	645.5	1085.17	988.8	934	2348	533	1457.4
Potassium	4550	4162	1473	4526.67	4620.2	4318	17244	6153.6	16620
Selenium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.4	0.2	0.6
Silver	<1	<0.08	<1	<0.08	<0.08	<0.08	<1	<0.08	<1
Sodium	<2	11.5	4	12.8	7.5	15.8	2650	766.4	2622
Strontium	1.17	1.328	1.05	8.52	7.794	9.54	13.5	18.996	25.46
Sulphur	675	570.6	579.5	1143.33	987.4	1054	1050.8	1820.2	1894
Thallium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.12	0.04	<0.04
Tin	0.3	<0.08	<0.1	0.17	0.18	0.16	0.2	<0.08	<0.08
Vanadium	<0.08	<0.08	<0.08	<0.08	<0.08	0.15	0.49	2.934	3.22
Zinc	4.33	1	7	19.2	21.62	23.8	30.4	17.225	22.2

Common Name	***Scientific Name***
VEGETATION	
awned hair cap	*Polytrichum piliferum*
balsam fir	*Abies balsamea*
balsam poplar	*Populus balsamifera*
beaked hazelnut	*Corylus cornuta*
bearberry	*Arctostaphylos uva-ursi*
bishop's cap	*Mitella nuda*
blueberry	*Vaccinium angustifolium var. myrtilloides*
bog cranberry	*Vaccinium vitis-idaea*
bracted honeysuckle	*Lonicera involucrata*
brown moss	*Drepanocladus spp.*
brown-foot cladonia	*Cladonia gracilis*
buck-bean	*Menyanthes trifoliata*
bulrush	*Scirpus spp.*
bunchberry	*Cornus canadensis*
Canada buffalo-berry	*Sheperdia canadensis*
cattail	*Typha latifolia*
choke cherry	*Prunus virginiana*
cloudberry	*Rubus chamaemorus*
common horsetail	*Equisetum arvense*
common pink wintergreen	*Pyrola asarifolia*
cotton grasses	*Eriophorum sp.*
cream-colored vetchling	*Lathyrus ochroleucus*
creeping spike-rush	*Eleocharis palustris*
currant	*Ribes spp.*
dewberry	*Rubus pubescens*
dogwood	*Cornus stolonifera*
dwarf birch	*Betula pumila*
dwarf scouring rush	*Equisetum scirpoides*
feathermoss	*Pleurozium spp.*
fireweed	*Epilobium angustifolium*
golden moss	*Tomenthypnum nitens*
green alder	*Alnus crispa*
hairy wild rye	*Elymus innovatus*
jack pine	*Pinus banksiana*
knight's plume moss	*Ptilium crista-castrensis*
Labrador tea	*Ledum groenlandicum*

Common Name	***Scientific Name***
lichens	*Cladonia sp., and Cladina sp*
low-bush cranberry	*Viburnum edule*
marsh cinquefoil	*Potentilla palustris*
marsh marigold	*Caltha palustris*
marsh reed grass	*Calamagrostis canadensis*
marsh skullcap	*Scutellaria galericulata*
meadow horsetail	*Equisetum pratense*
midway peat moss	*Sphagnum magellanicum*
northern reed grass	*Calamagrostis inexpansa*
northern willowherb	*Epilobium ciliatum*
oak fern	*Gymnocarpium dryopteris*
palmate-leaved coltsfoot	*Petasites palmatus*
peat moss	*Sphagnum spp.*
peat moss	*Sphagnum angustifolium*
peat moss	*Sphagnum fuscam*
pin cherry	*Prunus pensylvanica*
pitcher plants	*Sarracenia purpurea*
prickly rose	*Rosa acicularis*
ragged moss	*Brachythecium spp.*
reed grass	*Phalaris spp./Phragmites spp.*
reindeer lichen	*Cladina spp.*
river alder	*Alnus tenuifolia*
rushes	*Juncus sp., Luzula sp.*
sand heather	*Hudsonia tomentosa*
saskatoon	*Amelanchier alnifolia*
Schreber's moss	*Pleurozium schreberi*
scorpion feathermoss	*Scorpidium scorpioides*
sedges	*Carex spp.*
shield fern	*Dryopteris carthusiana*
shore-growing peat moss	*Sphagnum. riparium*
showy aster	*Aster conspicuus*
slender hair-cap moss	*Polytrichum strictum*
small bog cranberry	*Oxycoccus microcarpus*
snowberry	*Symphoricarpos albus*
stair-step moss	*Hylocomium splendens*
stiff club-moss	*Lycopodium annotinum*
sweet gale	*Myrica gale*

Common Name	*Scientific Name*
sweet-scented bedstraw	*Galium triflorum*
tall lungwort	*Mertensia paniculata*
tamarack	*Larix laricina*
three-leaved Solomon's seal	*Smilacina trifolia*
trembling aspen	*Populus tremuloides*
tufted moss	*Aulacomnium palustre*
twin-flower	*Linnaea borealis*
water smartweed	*Polygonum amphibium*
white birch	*Betula papyrifera*
white spruce	*Picea glauca*
wild lily-of-the-valley	*Maianthemum canadense*
wild mint	*Mentha arvensis*
wild red raspberry	*Rubus idaeus*
wild sarsaparilla	*Aralia nudicaulis*
wild strawberry	*Frageria virginiana*
willow	*Salix spp.*
woodland horsetail	*Equisetum sylvaticum*
algae	*Selenastrum capricornutum*
INVERTEBRATES	
chironomid midge larvae	*Chironomus tentans*
amphipod	*Hyallela azteca*
oligocaete worm	*Lumbriculus*
stoneflies	*Plecoptera*
mayflies	*Ephemeroptera*
dragonflies and daselflies	*Odonata*
caddishflies	*Trichoptera*
water flea	*Daphnia magna*
water flea	*Ceriodaphnia dubia*
luminescent bacteria	*Vibrio fischeri*
FISH	
arctic grayling	*Thymallus arcticus*
brook stickleback	*Culaea inconstans*
bull trout	*Salvelinus Confluentus*
burbot	*Lota Lota*
cisco	*Coregonus artedi*
emerald shiner	*Notropis atherinoides*
Fathead Minnow	*Pimephales promelas*

Common Name	***Scientific Name***
finescale Dace	*Platygobio gracilis*
goldeye	*Hiodon alosoides*
Iowa Darter	*Etheostoma exile*
lake Chub	*Couesius plumbeus*
lake whitefish	*Coregonus clupeaformis*
longnose Dace	*Rhinichthys cataractae*
longnose Sucker	*Catostomus catostomus*
mountain Whitefish	*Prosopium williamsoni*
ninespine Stickleback	*Pungitius pungitius*
northern Pike	*Esox lucius*
northern Redbelly Dace	*Phoxinus eos*
pearl Dace	*Semotilus margarita*
rainbow trout	*Oncorhynchus mykiss*
river Shiner	*Notropis blennius*
shiner Species	*Notropis sp.*
slimy Sculpin	*Cottus cognatus*
spoonhead Sculpin	*Cottus ricei*
spottail Shiner	*Notropis hudsonius*
trout Perch	*Percopsis omiscomaycus*
walleye	*Stizostedion vitreum*
white Sucker	*Catostomus commersoni*
yellow Perch	*Perca flavescens*
REPTILES AND AMPHIBIANS	
Canadian toad	*Bufo hemiophrys*
red-sided garter snake	*Thamnophis sirtalis*
stripped chorus frog	*Pseudacris triseriata*
wood frog	*Rana sylvatica*
BIRDS	
alder flycatcher	*Empidonax alnorum*
American bittern	*Botaurus lentiginosus*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American kestrel	*Falco sparverius*
American pipit	*Anthus rubescens*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*

Common Name	***Scientific Name***
American tree sparrow	*Spizella arborea*
American white pelican	*Pelecanus erythrorhynchos*
American wigeon	*Anas americana*
bald eagle	*Haliaeetus leucocephalus*
bank swallow	*Riparia riparia*
barn swallow	*Hirundo rustica*
bay-breasted warbler	*Dendroica castanea*
belted kingfisher	*Ceryle alcyon*
black tern	*Chlidonias niger*
black-and-white warbler	*Mniotilta varia*
black-backed woodpecker	*Picoides arcticus*
black-billed magpie	*Pica pica*
black-capped chickadee	*Parus atricapillus*
black-throated green warbler	*Dendroica virens*
blackpoll warbler	*Dendroica striata*
blue jay	*Cyanocitta cristata*
blue-winged teal	*Anas discors*
bohemian waxwing	*Bombycilla garrulus*
Bonaparte's gull	*Larus philadelphia*
boreal chickadee	*Parus hudsonicus*
boreal owl	*Aegolius funereus*
Brewer's blackbird	*Euphagus cyanocephalus*
broad-winged hawk	*Buteo platypterus*
brown creeper	*Certhia americana*
brown-headed cowbird	*Molothrus ater*
bufflehead	*Bucephalus albeola*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Canada warbler	*Wilsonia canadensis*
canvasback	*Aythya valisineria*
Cape May warbler	*Dendroica tigrina*
cedar waxwing	*Bombycilla cedrorum*
chipping sparrow	*Spizella passerina*
clay-colored sparrow	*Spizella pallida*
cliff swallow	*Hirundo pyrrhonota*
common goldeneye	*Bucephala clangula*
common grackle	*Quiscalus quiscula*

Common Name	***Scientific Name***
common loon	*Gavia immer*
common merganser	*Mergus merganser*
common nighthawk	*Chordeiles minor*
common raven	*Corvus corax*
common redpoll	*Carduelis flammea*
common snipe	*Gallinago gallinago*
common tern	*Sterna hirundo*
common yellowthroat	*Geothlypis trichas*
Connecticut warbler	*Oporonis agilis*
dark-eyed junco	*Junco hyemalis*
double-crested cormorant	*Phalacrocorax auritus*
downy woodpecker	*Picoides pubescens*
eastern kingbird	*Tyrannus tyrannus*
eastern phoebe	*Sayornis phoebe*
European starling	*Sturnus vulgaris*
evening grosbeak	*Coccothraustes vespertinus*
fox sparrow	*Passerella iliaca*
Franklin's gull	*Larus pipixcan*
gadwall	*Anas strepera*
golden eagle	*Aquila chrysaetos*
golden-crowned kinglet	*Regulus satrapa*
gray jay	*Perisoreus canadensis*
great blue heron	*Ardea herodias*
great gray owl	*Strix nebulosa*
great-crested flycatcher	*Myiarchus crinitus*
great-horned owl	*Bubo virginianus*
greater yellowlegs	*Tringa melanoleuca*
green-winged teal	*Anas crecca*
hairy woodpecker	*Picoides villosus*
hermit thrush	*Catharus guttatus*
herring gull	*Larus argentatus*
hooded merganser	*Lophodytes cucullatus*
horned grebe	*Podiceps auritus*
horned lark	*Eremophila alpestris*
house sparrow	*Passer domesticus*
killdeer	*Charadrius vociferus*
least flycatcher	*Empidonax minimus*

Common Name	***Scientific Name***
least sandpiper	*Calidris minutilla*
LeConte's sparrow	*Ammodramus leconteii*
lesser scaup	*Aythya affinis*
lesser yellowlegs	*Tringa flavipes*
Lincoln's sparrow	*Melospiza lincolnii*
magnolia warbler	*Dendroica magnolia*
mallard	*Anas platyrhynchos*
marbled godwit	*Limosa fedoa*
marsh wren	*Cistothorus palustris*
merlin	*Falco columbarius*
mew gull	*Larus canus*
mountain bluebird	*Sialia currucoides*
mourning warbler	*Oporornis philadelphia*
northern flicker	*Colaptes auratus*
northern goshawk	*Accipiter gentilis*
northern harrier	*Circus cyaneus*
northern hawk owl	*Surnia ulula*
northern pintail	*Anas acuta*
northern shoveler	*Anas clypeata*
northern waterthrush	*Seiurus noveboracensis*
olive-sided flycatcher	*Contopus borealis*
orange-crowned warbler	*Vermivora celeta*
osprey	*Pandion haliaetus*
ovenbird	*Seiurus aurocapillus*
palm warbler	*Dendroica palmarum*
peregrine falcon	*Falco peregrinus*
Philadelphia vireo	*Vireo philadelphicus*
pied-billed grebe	*Podilymbus podiceps*
pileated woodpecker	*Dryocopus pileatus*
pine siskin	*Carduelis pinus*
purple finch	*Carpodacus purpureus*
red crossbill	*Loxia curvivostra*
red-breasted merganser	*Mergus serrator*
red-breasted nuthatch	*Sitta canadensis*
red-eyed vireo	*Vireo olivaceus*
red-necked grebe	*Podiceps grisegena*
red-tailed hawk	*Buteo jamaicensis*

Common Name	***Scientific Name***
red-winged blackbird	*Agelaius phoeniceus*
redhead	*Aythya americana*
ring-billed gull	*Larus delawarensis*
ring-necked duck	*Aythya collaris*
rock dove	*Columba livia*
rose-breasted grosbeak	*Pheucticus ludovicianus*
ruby-crowned kinglet	*Regulus calendula*
ruddy duck	*Oxyura jamaicensis*
ruffed grouse	*Bonasa umbellus*
rusty blackbird	*Euphagus carolinus*
sandhill crane	*Grus canadensis*
savannah sparrow	*Passerculus sandwichensis*
Say's phoebe	*Sayornis saya*
semipalmated plover	*Charadrius semipalmatus*
sharp-shinned hawk	*Accipiter striatus*
sharp-tailed grouse	*Tympanuchus phasianellus*
sharp-tailed sparrow	*Ammodramus caudacutus*
short-billed dowitcher	*Limnodramus griseus*
solitary sandpiper	*Tringa solitaria*
solitary vireo	*Vireo solitarius*
song sparrow	*Melospiza melodia*
sora	*Porzana carolina*
spotted sandpiper	*Actitis macularia*
spruce grouse	*Dendragapus canadensis*
Swainson's thrush	*Catharus ustulatus*
swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
three-toed woodpecker	*Picoides tridactylus*
tree swallow	*Tachycineta bicolor*
vesper sparrow	*Pooecetes grammineus*
warbling vireo	*Vireo gilvus*
western tanager	*Piranga ludoviciana*
western wood-pewee	*Contopus sordidulus*
white-crowned sparrow	*Zonotrichia leucophrys*
white-throated sparrow	*Zonotrichia albicollis*
white-winged crossbill	*Loxia leucoptera*
Wilson's phalarope	*Phalaropus tricolor*

Common Name	***Scientific Name***
Wilson's warbler	*Wilsonia pusilla*
winter wren	*Troglodytes troglodytes*
yellow warbler	*Dendroica petechia*
yellow-bellied flycatcher	*Empidonax flaviventris*
yellow-bellied sapsucker	*Sphyrapicus varius*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
yellow-rumped warbler	*Dendroica coronata*
MAMMALS	
arctic shrew	*Sorex arcticus*
beaver	*Castor canadensis*
big brown bat	*Eptesicus fuscus*
black bear	*Ursus americanus*
Canada lynx	*Lynx canadensis*
caribou	*Rangifer tarandus*
coyote	*Canis latrans*
deer mouse	*Peromyscus maniculatus*
dusky shrew	*Sorex monticolus*
ermine	*Mustela erminea*
fisher	*Martes pennanti*
gray wolf	*Canis lupus*
heather vole	*Phenacomys intermedius*
hoary bat	*Lasiurus cinereus*
least chipmunk	*Tamias minimus*
least weasel	*Mustela nivalis*
little brown bat	*Myotis lucifugus*
marten	*Martes americana*
masked shrew	*Sorex cinereus*
meadow jumping mouse	*Zapus hudsonius*
meadow vole	*Microtus pennsylvanicus*
mink	*Mustela vison*
moose	*Alces alces*
mule deer	*Odocoileus hemionus*
muskrat	*Ondatra zibethicus*
northern bog lemming	*Synaptomys borealis*
northern flying squirrel	*Glaucomys sabrinus*
northern long-eared bat	*Myotis septentrionalis*
porcupine	*Erethizon dorsatum*

Common Name	***Scientific Name***
pygmy shrew	*Sorex hoyi*
red fox	*Vulpes vulpes*
red squirrel	*Tamiasciurus hudsonicus*
river otter	*Lutra canadensis*
silver-haired bat	*Lasionycteris noctivagans*
snowshoe hare	*Lepus americanus*
southern red-backed vole	*Clethrionomys gapperi*
striped skunk	*Mephitis mephitis*
water shrew	*Sorex palustris*
white-tailed deer	*Odocoileus virginianus*
wolverine	*Gulo gulo*
woodchuck	*Marmota monax*

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